SNOW AND ICE DATABOOK 2010

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
AIPCR PIARC

Technical Committee B5
Winter Service

Québec

PIARC Technical Committee
B5 Winter Service

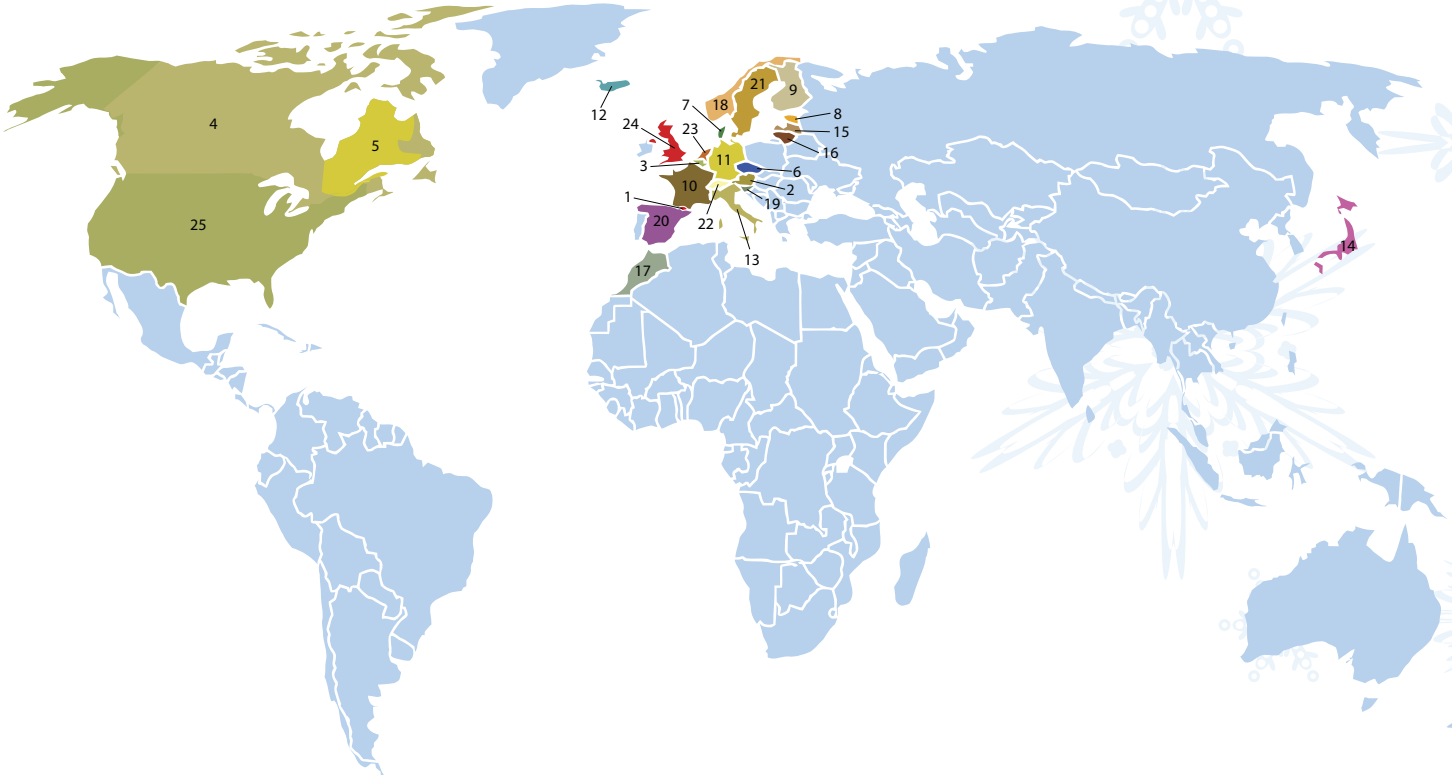
Caring for the environment, the World Road Association and the ministère des Transports du Québec will henceforth produce this document on CD-ROM.

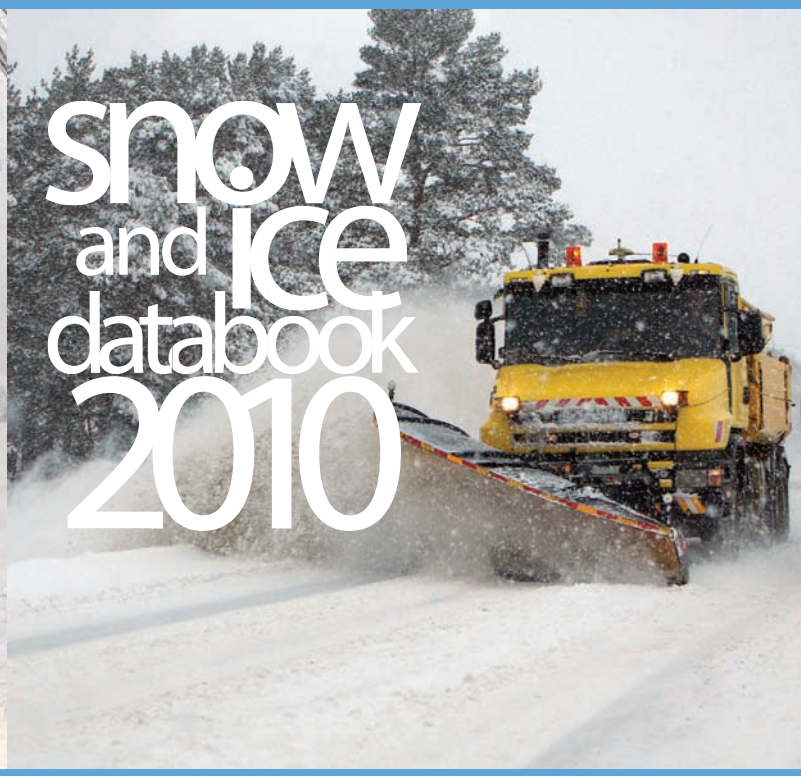
ISBN 978-2-550-57708-9 (CD-ROM)
ISBN 978-2-550-57709-6 (PDF)

Legal deposit – Bibliothèque et Archives nationales du Québec, 2010
Legal deposit – Library and Archives Canada, 2010

snow and ice databook 2010

Table of Contents





Foreword

Varying in intensity and duration, winter remains a season of unpredictability. In the various countries forced to deal with this reality, the unpredictability influences the movements of road users and pedestrians, as well as the flow of goods and services. Adverse winter conditions and resulting counter measures affect an infrastructure's service life and, more importantly, its accessibility and safety.

Within this context, road network managers facing the rigours of winter must ensure the safety of all users while keeping road infrastructures in good condition and making sure to encourage the maintenance and development of economic and social activities across the covered territory. To do this, road administrations must, among other things, allocate major financial, material and human resources while continually searching for ways to improve practices.

Today, road network managers face a number of challenges, such as the increasingly frequent appearance of climate change, increased environmental awareness and growing maintenance costs. That is why the proper planning of winter maintenance strategies and methods is so important.

This document was specifically designed to give managers a quick overview of the climatic and operational realities of various countries contending with winter. Thanks to the exchange of knowledge and success stories between road administrations around the world, the *Snow and Ice Databook 2010* is a very handy reference tool for any stakeholder involved in winter maintenance activities.

The 2010 version is the third edition of this document, which was first published in 2002 at the XI International Winter Road Congress, in Sapporo, Japan. A second edition of this tool was presented in 2006 at the XII International Winter Road Congress in Turin, Italy. The current edition was coordinated by the ministère des Transports du Québec, which also contributed to the organization of the XIII International Winter Road Congress, to be held in Québec in 2010.

I would like to express my gratitude to the members of the B5 Technical Committee who collaborated on updating the content of this document. I also want to point out in particular the involvement of the committee's two secretaries, Didier Giloppé and Paul Pisano, for their support in carrying out this revision mandate.

Finally, I want to say how grateful I am to the ministère des Transports du Québec for seeing the revision and publication of this document through to completion, and particularly to Richard Charpentier, member of the B5 Technical Committee, and Michel Brown, engineer at the ministère des Transports du Québec, for coordinating and performing the work necessary to produce this publication.

The only thing left for me to say is enjoy the document. I hope this tool will help you in the performance of your duties and that it will fuel exchanges with colleagues around the world.

Gudrün Öberg
President of PIARC's B5 Technical Committee on Winter Service

Summary

Framework and objective of the document

The *Snow and Ice Databook*, 2010 edition, contains the contributions of the 25 member countries of the World Road Association's (PIARC) Technical Committee B5 on Winter Service.

This third edition is an update of previous versions. In fact, the first interim edition of the document was released in 2002 under the care of the Japanese Organizing Committee for the XI International Winter Road Congress in Sapporo, Japan. At the time, the objective of this publication was to support and facilitate the exchange of experience between international experts specializing in the field of winter service. It presented the practices of the 15 member countries of the Technical Committee B5 (referred to at the time as Technical Committee 3.4).

Given the favorable reception of this first edition and the added value of this more finely developed tool, the Technical Committee B5 undertook to continue this work by documenting winter service practices more extensively based on well-defined, uniform themes for all member countries interested in contributing to this exercise. The second edition of the *Snow and Ice Databook*, published in 2006 as part of the XII International Winter Road Congress in Turin, Italy, included contributions from the 22 member countries of the International Committee.

This document is an updated version of the information contained in the 2006 edition, as it maintains the structure and themes already established by the Technical Committee B5. It also reflects developments from the past few years in terms of winter service in the various member countries that took part in the previous edition. Three new contributions are added to this revised edition, namely those from the Principality of Andorra, the Czech Republic and the Kingdom of Morocco.

Publication of this document would not have been possible without the invaluable contribution of various experts from the 25 countries included in this document, nor without the commitment of the Francophone and Anglophone members and secretaries of the Technical Committee B5 on Winter Service. It is also important to note the significant contribution of the ministère des Transports du Québec at every stage of the production of this third edition of the Snow and Ice Databook, 2010 edition.

Methodology

Despite the quality of the content presented in previous editions of the *Snow and Ice Databook*, the Technical Committee B5 on Winter Service agreed, in fall 2009, on the importance of updating the content of the already published databook while reducing the workload of the Technical Committee members associated with this demanding exercise.

Summary

Given that Québec is hosting the XIII International Winter Road Congress, the ministère des Transports du Québec readily accepted the responsibility of coordinating the work necessary for the publication of this third edition. To achieve this, the various winter service experts of the B5 member countries were called upon to update the content of the published reports. As part of this update, the themes and directives prescribed for the 2006 edition were fully respected. In this way, in collaboration with the Anglophone and Francophone secretaries of the Technical Committee B5, the ministère des Transports du Québec was able to ensure the consistency of the submitted texts and technical content, thereby ensuring the relevance and comprehension of the data provided.

Moreover, in order to streamline the revision process of the B5 member countries while ensuring the consistency and quality of the translations of the revised reports, the latter were, for the most part, produced in English by the authors. Translations from English to French and from French to English were entirely supervised by the ministère des Transports du Québec.

Structure of country reports

The organization of winter service as a whole, operational management, user needs and safety and a number of other topics are directly dependent on the climatic, organizational, political and social characteristics of the country with which they are associated.

It is with this in mind that Chapters 1 and 2 cover themes of a general nature intended to present elements that are essential to a better understanding of the practices employed in each of the countries covered.

Demographics, political organization, length and classification of the road network, traffic parameters and, of course, statistics regarding temperature, frost and winter precipitation are accordingly presented. Table 1 provides a general description of the content in the 2010 edition of the databook.

Table 1 – Typical structure of the country reports presented in the databook

Chapter and theme	Sub-chapter and sub-theme
1.0 – Demographics and Roads	1.1 – Information about the country 1.2 – Road network and traffic
2.0 – Climate	2.1 – Overview of climatic areas, main winter events to master 2.2 – Meteorological statistics: temperatures, frost, precipitation 2.3 – Winter indices used
3.0 – Winter Road Management	3.1 – Standards and rules 3.2 – Organization and operation of winter maintenance 3.3 – Assessment of the snow and ice control measures 3.4 – Traffic safety and information
4.0 – Ongoing Research and Studies	4.1 – New technologies 4.2 – New management and organization approaches 4.3 – International cooperation
5.0 – References	Internet links or references to information on more complete data.

Summary

The description of winter maintenance practices, presented in Chapter 3, "Winter Road Management," is an important part of each submitted report. In particular, the rules and standards forming the framework of winter maintenance practices are presented, including legal obligations, service levels, quality standards, performance indicators and rules regarding materials and equipment.

Chapter 3 also explains how services are organized and directed as well as the organization of the road administration; where applicable, it presents the public-private partnership, snow and ice control measures, traffic restrictions, meteorological data and forecasts and the road weather information systems. Furthermore, this chapter focuses on the issue of evaluating snow and ice control measures, including cost-benefit analyses, efficiency measurements, regulations regarding payments and rivalry between contractors.

Finally, the last topic addressed in this chapter covers all the methods, systems and equipment set up to guarantee road safety and information for road users.

In closing, for each of the country reports contained in this document, the member countries were invited to briefly describe, in Chapter 4, the innovative technologies and new approaches used in winter service management and organization. Ongoing (or future) research projects and studies that aim to improve winter service management are thus presented.

Summary of the contributions offered by participating countries

As in previous editions, the Snow and Ice Databook, 2010 edition, provides a quick overview of the climatic, social, operational and organizational realities of various countries facing winter conditions. It is a very useful reference for all those involved with winter service activities for whom maintaining service on road networks is a priority.

The organizational and operational facets of winter service are influenced by the characteristics of the countries that accommodate them. Accordingly, the country's demographics, its political organization, the length and characteristics of its road network, the intensity and nature of the traffic and, of course, the climatic characteristics that affect it (temperature, duration of the season, nature and intensity of winter precipitation, etc.) are all elements that must be taken into account when analyzing, comparing and putting the information provided in this compendium into perspective. It is important to remember that the objective of this document is not to classify the maintenance methods and approaches described herein into good and bad practices, but simply to present them.

Summary

1. Demographics and Roads

Roads are a key element for the economic and social health of countries and even entire continents. By ensuring the flow of people and merchandise, they contribute to the maintenance and development of exchanges between the populations they serve. No matter its density, the size of the population served and the extent of the resources available, the road infrastructure must meet the mobility needs of its population.

Table 2 provides a summary overview of the demographics and roads of the various countries that contributed to this compendium. It is always important that these elements be put in perspective when analyzing or comparing the winter maintenance practices listed here.

Table 2 - Population – Land area – Road network

	Population	Land area	Road network (km)	
	Inhabitants	km²	Total (1)	Highways
Andorra	85,000	468	270	N/A
Austria	8,350,000	83,858	106,461	2,029
Belgium	10,670,000	30,528	153,595	1,763
Canada (including Québec)	32,000,000	9,984,670	1,408,800	N/A
Canada-Québec	7,700,000	1,667,441	132,216 (2)	5,775
Czech Republic	10,460,000	78,867	55,583	633
Denmark	5,400,000	43,098	73,200	1,062
Estonia	1,350,000	45,227	58,034	N/A
Finland	5,300,000	338,419	104,000	700
France	64,000,000	551,000	1,000,200	11,200
Germany	82,100,000	356,700	644,300	12,500
Iceland	313,000	103,000	12,867	N/A
Italy	57,000,000	301,302	472,000	N/A
Japan	127,000,000	377,737	1,175,397	N/A
Latvia	2,300,000	64,589	59,193	N/A
Lithuania	3,350,000	65,303	81,010	310
Morocco	30,000,000	710,850	57,347	920
Norway	4,600,000	385,155	92,513	213
Slovenia	2,008,000	20,273	38,762	576
Spain	45,300,000	505,954	166,340	13,873
Sweden	9,300,000	410,929	138,400	1,800
Switzerland	7,600,000	41,285	70,907	1,907
The Netherlands	16,500,000	41,528	136,135	5,050
United Kingdom	61,000,000	243,800	420,041	N/A
United States	304,060,000	9,161,979	6,483,932	262,000

(1) Includes all public networks (highways, national, departmental and communal roads) but excludes private and forest road networks.

(2) Includes the network under the responsibility of the ministère des Transports du Québec and municipal networks.

Summary

Includes all public networks (highways, national, departmental and communal roads) but excludes private and forest road networks.

Includes the network under the responsibility of the ministère des Transports du Québec and municipal networks.

Each country report contains a summary description of the elements that characterize the country with which it is associated, such as its population, economy, parliamentary institutions and geography.

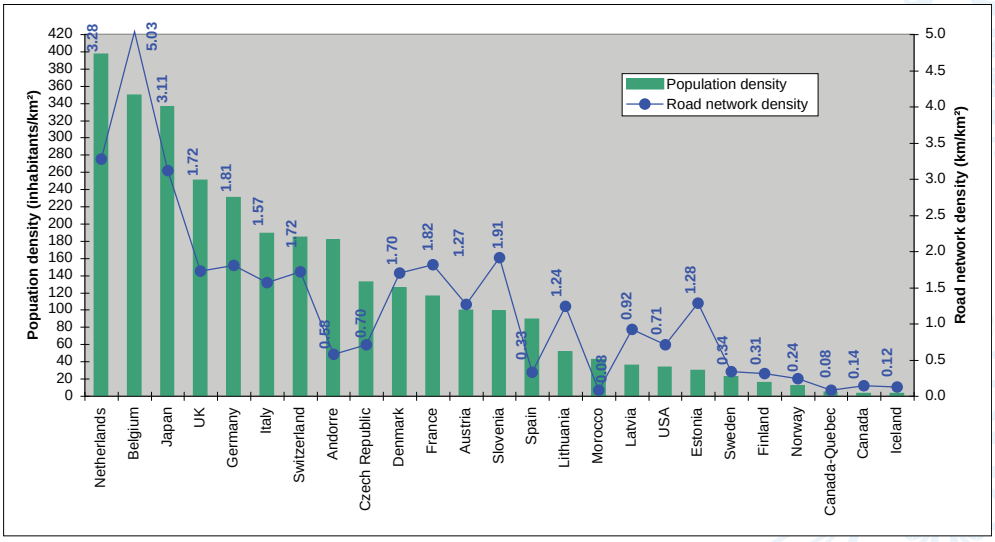
As previously specified, the road network is, first and foremost, a reflection of the mobility needs of the population that uses it. Of course, the density of this network is intimately linked with the land area to be covered, but is also a reflection of the interdependency of networks and, as such, of the need to ensure the maintenance and development of economic activities between countries.

A review of Figure 1 reveals that the countries of the European continent as well as Japan, which all have high population numbers spread out over relatively limited territories, have some of the highest network densities. Conversely, the North American continent in particular, such as in the United States, Canada and Québec (Canada–Québec), has relatively low population numbers compared to the land area available and, consequently, their respective networks show some of the lowest densities.

This information may be considered an important indicator of the dispersion of winter maintenance needs and, indirectly, a parameter influencing the organizational and operational characteristics of winter service, such as the level of decentralization of efforts, public-private partnership, and the extent of operational means. In fact, the need to meet the mobility needs of a population within the context of winter requires, on the part of the various authorities responsible for the network, methods and efforts commensurate with the applicable constraints.

When reading the various country reports, it is important for the reader to remember that the aggregation of information regarding the maintained networks is hindered by the lack of a common terminology to describe in a simple way the various categories and classes of networks discussed in the compendium.

Figure 1 – Population and density of road networks



2. Climate

Climatic areas

The geographic location (proximity to the sea, inland location) and the orographic characteristics (mountain relief, plateau, valley) of the countries mentioned in this publication, affect the different types of winter conditions they face, which are characterized by frequency, duration and intensity.

Each of the following country reports presents the climatic context (temperatures, precipitation) and describes the weather events that can influence the accessibility and safety of the road links available to the populations served.

Since climate varies according to both time and space, it is clearly not limited by a country's borders. Without a common language to present key climate-related data in terms of the use of roads and winter service, presenting an objective summary of this topic was not easily achieved.

Table 3 - Climate of the various countries

Andorra	Temperate – Mediterranean – Mountain
Austria	Temperate – Continental – Mountain
Belgium	Temperate maritime – Continental (in certain limited areas)
Canada	Maritime – Continental – Subarctic – Arctic
Canada-Québec	Maritime (in certain areas) – Continental – Subarctic – Arctic
Czech Republic	Temperate – Continental – Mountain
Denmark	Temperate maritime
Estonia	Temperate – Continental (in certain limited areas)
Finland	Temperate – Continental – Subarctic
France	Temperate maritime – Continental – Mountain – Mediterranean
Germany	Temperate – Continental – Maritime (in certain limited areas)
Iceland	Maritime – Continental – Mountain – Subarctic
Italy	Temperate – Mountain – Mediterranean
Japan	Temperate maritime – Continental – Mountain
Latvia	Temperate maritime – Continental (in certain limited areas)
Lithuania	Temperate – Continental (in certain limited areas)
Morocco	Temperate maritime – Continental – Mountain – Mediterranean – Desert
Norway	Temperate – Continental – Mountain – Subarctic
Slovenia	Temperate – Mountain – Mediterranean
Spain	Temperate maritime – Continental – Mountain – Mediterranean
Sweden	Temperate – Continental – Mountain – Subarctic
Switzerland	Temperate – Continental – Mountain
The Netherlands	Temperate maritime
United Kingdom	Temperate maritime
United States	Temperate maritime – Continental – Mountain – Subarctic

Summary

Table 3 shows the climatic conditions that characterize each country, based on the data provided in the country reports. It shows that the more expansive countries are subject to various types of climatic conditions in winter, even if in some cases, these differences occur in limited areas or sporadically. Briefly, and taking into account the fact that this classification was not established by a team of meteorologists but rather by a community of people specializing in winter service, these climates were characterized based on the following frame of reference:

- A temperate climate is generally characterized by moderate temperatures, mild winters and a limited temperature range, which means that the minimum temperature in winter often hovers around 0 °C;
- A maritime climate is typical of regions close to the sea, which are generally temperate areas with more frequent precipitation and a high level of ambient humidity; in some cases, this may give rise to larger quantities of snow;
- A continental climate presents a greater annual temperature range and relatively stable conditions for extended periods (cold); it is very typical to have long periods of frost and the accumulation of snowbanks in winter;
- A mountain climate is limited to areas located at high altitudes, which means a greater temperature range, low temperatures and heavy snowfalls;
- Subarctic and arctic climates are characteristic of northern regions, with very cold, very snowy days;
- Regions under a Mediterranean influence generally do not have winter problems, given that temperatures normally stay above 0 °C all year long and snow is exceptional;
- Regions under a desert influence have a dry climate characterized by greater evaporation than precipitation and intense aridity.

Winter indices

A number of country reports list various individual initiatives to develop and use winter indices (winter severity index). Some of these indices are composed of strictly climatic or meteorological parameters while others relate climatic (or meteorological) data to operational data for specific purposes. The winter severity index is most often evaluated using a more or less complex function associating various meteorological or road parameters (road surface temperature, dew-point temperature, air temperature, winter precipitation, intensity of snow, thickness of the snow cover, number of days or nights with a sub-zero temperature, etc.). It can be calculated on an annual or monthly basis, usually using data provided by road weather information systems.

The country reports that mention the application or development of such indices include Germany, Belgium, Canada, Denmark, the United States, Finland, France, Iceland, Norway, Canada–Québec, the Czech Republic, Sweden, Switzerland and the United Kingdom.

The targets set by the managers in these countries with respect to the index used are many and varied. Winter performance indices are often used to meet organizational concerns.

Depending on the nature of the elements that make up the index used (or developed), the latter may assist in:

- Qualifying the severity of winters in terms of climate, and thus allow for comparisons between winter periods;
- Determining the performance of the efforts deployed (resources and costs) by an organization to maintain its network and providing justification, during a harsher winter season, for the injection of additional credits into the maintenance program;
- Determining the compensation applicable to the private companies mandated to maintain a network;
- Defining the interventions associated with the spreading of materials to eventually reduce environmental degradations (salt index);
- etc.

It is important to note that as regards winter indices, there is no international classification to objectively and consistently report on climate characteristics important to winter service.

Summary

3. Winter Road Management

Standards and rules

Most of the country reports included in this compendium mention the road legislation (laws, regulations, departmental orders, codes, constitutional rules and others) governing the winter maintenance responsibilities and activities of the various network managers. These responsibilities and activities are often delegated based on the various categories of roads to be maintained, with the ultimate objective of ensuring the free flow of goods and people in the territory where they apply.

Service levels

The country reports show that most network managers use at least three categories of winter service levels. Some administrations have defined more than three. Generally speaking, each service level corresponds to a different maintenance objective, often based on traffic volumes and the classification of the various existing networks (expressways, national roads, departmental roads, etc.).

These objectives are sometimes precisely described (Canada, Denmark, Estonia, Finland, Iceland, Latvia, Norway, Canada–Québec, Sweden), although the parameters used to express these objectives can vary greatly. These include, for example, the characterization of surface conditions resulting from a weather event (clear road, partially clear road, etc.) to which are associated various physical parameters making it possible to judge whether or not the established levels are respected (time or duration of return to reference conditions, maximum thickness of the snow, etc.). Slip resistance criteria are also widely used by some Nordic countries (Finland, Norway, Sweden, and Iceland).

In other reports, for example those from Austria, Belgium, France, Germany, Japan, Slovenia and Switzerland, requirements in terms of road surface conditions are not as defined or are defined with less precision. However, winter maintenance procedures (type and time of action, duration of salting) are also established based on the classification of existing networks (characteristics of the infrastructure, economic significance) as well as on climate and traffic conditions.

The description of final objectives is an important topic for countries that entrust winter road maintenance to private companies. This description makes it possible to assess if they have met established expectations and, consequently, evaluate the services provided to the population.

The variations in winter maintenance service levels ("black roads" vs. "white roads") established by the various road administrations are often intimately linked to the expectations and the density of the population served rather than to the severity of winters. In cases where the harshness of the winter is significant, the means implemented to respect the service levels offered to the population remain just as important.

Product and equipment standards

Precise specifications regarding the physical characteristics of materials and their use are described in some of the country reports (chloride types and concentrations, particle size, water content, packaging, quantity spread). There is also data regarding the supply of sodium chloride as well as the required characteristics for abrasives (sand, gravel, crushed stone aggregate).

Road managers also focus on technical requirements for spreaders (attachment, signage, drive and feed systems, capacity, spreading of wet salt). Some managers use specifications for the supply, installation and maintenance of equipment assigned to the maintenance of networks in winter.

Labor standard

Rules regarding hours of operation, work and rest are highlighted in a number of country reports. It is the case with Switzerland, Norway, France, Belgium, and Canada–Québec. By establishing a maximum number of hours of operation for snow removal vehicles and rest thresholds to be respected by the operators of these vehicles, these measures work together to limit fatigue experienced by these heavy vehicle operators, which can only have a positive impact on the road safety record.

Environment

Given increasing environmental and ecological constraints, the country reports indicate that several road administrations are implementing measures to optimize the use of the salt spread on their networks. The key to achieving this is not only to have cutting-edge snow removal and de-icing equipment, but also to know and, above all, master the effects of the meteorological and road parameters affecting the network (road weather information systems). In addition to these measures, a number of reports discuss the importance of ensuring adequate and regular training for all persons involved in winter maintenance operations.

Summary

Restrictions on the use of sodium chloride are indicated in some reports (Austria, Sweden). In fact, the use of melters is forbidden on certain networks, particularly due to the sensitivity of some environments. As for Canada, a code of practice was published in 2004 regarding the environmental management of road salts. Québec (Canada–Québec) not only reported having specific regulations governing the disposal of waste snow but talked about its steps to adopt an environmental management strategy for road salts.

Organization and operation of winter maintenance

The organization and operation of winter maintenance vary greatly from country to country. Examining the reports contained in this compilation, readers will note:

- The various organizational levels (centralized, regional and local) of the countries listed, despite a shared objective of ensuring the sustainability of the road network;
- The various forms of work planning and organization;
- The various management approaches used (use of internal resources vs. subcontracting to the private sector);
- The various maintenance methods used on the network (preventive spreading, curative spreading) depending on the severity of weather phenomena encountered and, on occasion, environmental concerns.

Despite these differences, all network managers share a common responsibility: to maintain, despite the vagaries of the weather, the sustainability of the road network for which they are responsible. Moreover, the decisions made by these managers and their staff must be as accurate as possible so as to guarantee effective winter service and safe roads while making the most judicious use of the resources at their disposal. A number of decision aids are listed in the various country reports. These include, in particular:

- Road weather systems, which measure and track the meteorological and road parameters that influence the road surface conditions for users. These systems are largely described in numerous country reports;
- Meteorological forecasts, which, through agreements with government or private organizations, make it possible to anticipate meteorological phenomena and better plan the operations to be carried out.

Dry and wet salt and brine are generally spread on roads that must be fully cleared of snow and ice due to a high volume of traffic. Managers faced with major snowfalls or long cold periods also use abrasives (sand or a mix of sand and salt) on mountain and rural roads. Sodium chloride (NaCl - rock salt, sea salt, evaporated salt, and brine) remains the basic de-icing product, probably due to its high level of cost effectiveness. Calcium chloride (solid or brine) and magnesium chloride are used less, usually to dampen the sodium chloride, among other things.

Public-private partnership

Although fundamentally winter maintenance remains a public service, use of the private sector to perform this activity seems to be a well-established practice for a number of countries.

The level of privatization varies, however, in terms of the responsibilities entrusted to the private sector. In fact, responsibilities range from privatization of the execution (supply of trucks with operators and sometimes also the spreader) to winter maintenance on most maintenance routes (Switzerland, Netherlands, Austria, Canada-Québec, Belgium, Denmark, Italy), to the complete delegation of road maintenance (including winter maintenance of the network) to private companies (Estonia, Finland, Latvia, Norway, Sweden and Spain).

Contractual agreements are established for terms varying from to 3–to–5 years (and up to 7 years in some cases) and are awarded following a public tender process. Companies are often fully responsible for the work performed and the evaluation of their performance frequently rests on the results obtained (Nordic countries). Depending on the type of contract, various specific requirements apply with regard to snow removal, de-icing and, sometimes, to network patrols.

Evaluation of winter maintenance measures

The evaluation of winter maintenance measures observed in various country reports takes various forms depending on the objectives sought and the concerns of the various road administrations. Accordingly, it can take the form of:

- A performance indicator or performance standard making it possible to respectively control the quality of the winter service provided to the population and evaluate the maintenance activities implemented;

Summary

- The recording and analysis of costs associated with winter activities. This approach makes it possible to accurately measure network operation requirements and realign actions aimed at the reform, improvement, and cost-effectiveness of maintenance activities. The entry, analysis and processing of data for this purpose are specifically covered in the country reports;
- Organized management systems making it possible, in particular, to document all actions taken and to estimate the resources put in place (material and human) to perform the various winter activities. The introduction of various on-board sensors in maintenance vehicles is one element that largely contributes to this analytical approach in terms of data;
- Inspection and monitoring guides for the work performed. Some countries perform random daily inspections on portions of the road network;
- Compliance measurements of the service delivery offered as part of a public-private partnership to guarantee the quality of the service offered;
- A census and analysis of network user complaints in view of revising and updating the maintenance strategy;
- Efforts deployed by the various organizations in the establishment of training sessions for staff or the implementation of decision aids;
- Devices to prevent certain winter phenomena associated with user safety or mobility (avalanche prevention, snow fences, waste snow disposal, road heating). The use of road weather information systems plays an important part in the management of winter maintenance operations; details on recent innovations are provided.

Environmental issues are also widely addressed in numerous reports, including, in particular, how to achieve the shared objectives of reducing costs and environmental impacts while maintaining a certain level of service to users.

Road safety and information

Most of the country reports discuss the importance granted to informing road users of conditions likely to affect, delay or compromise circulation. This sharing of information helps users better understand the efforts and means deployed by the various road administrations to maintain and preserve the network's sustainability in difficult weather conditions. These exchanges also contribute to user safety in the course of their travels.

Although the posted information varies in nature depending on the country, it can be divided into the following categories:

- Weather and road conditions;
- Traffic conditions (traffic flow and density);
- Traffic hindrances (roadwork, accidents);
- Disruption and reactivation of road service (closing and reopening of the network);
- Travel times.

This information is collected from various sources and in various ways. Potential sources include:

- Meteorological forecasts;
- Data from road weather information systems (air T°, road surface T°, wind speed and direction, humidity and dew point, etc.);
- Cameras placed at strategic points along the network;
- Automatic incident detection;
- The government departments or agencies responsible for the network (roadwork);
- Police forces;
- Dedicated telephone lines allowing users to report an incident or delay on the network;
- Detection via counting loops.

Road information and traffic management centers are in operation in a number of countries. These centers operate 24/7 and are permanently in contact with road managers, meteorological forecasting centers, police forces and emergency services. They broadcast information in real-time using various media such as variable message signs (VMS), radio, television, telephone, websites and newspapers. Some broadcast meteorological and road conditions beyond the country's borders. In fact, a transnational road information service is provided with the collaboration of the Finnish, Estonian, Latvian and Lithuanian road administrations (http://www.balticroads.net) to inform users of these networks of weather conditions in the area of the Baltic Sea.

Summary

To facilitate and standardize the transmission of information to users, some countries (Spain, Andorra and Canada-Québec) have developed specific terminology or codes to inform users of the conditions or situations they may encounter when traveling. Readers will also note the implementation on the North American continent of an abbreviated 511 telephone number providing quick access to information on transportation (winter road conditions, roadwork, major incidents, etc.) and thus allowing users to better plan their trips.

In terms of road safety, the use of variable message signs (VMS) makes it possible to not only inform users of weather and road conditions (T°, condition of the roadway, slipperiness) but also to convey different preventative messages. For example, informing users of speed limitations or of the need to resort to devices designed specifically for winter use (chains or snow tires).

Changing the mentality of road users is also a very important factor, and information campaigns are increasingly being organized to raise their awareness and give them a sense of responsibility with respect to winter road safety. Some countries have tried to draw attention to the importance of slowing down when driving on snow or ice. By using an informative approach, these campaigns seek to encourage users to be careful by increasing their awareness of the risks inherent to winter driving and by explaining how they should change their habits.

4. Ongoing research and studies

Today, technology offers a wide range of ways to obtain accurate, concrete information from the road network in real time. Many network managers are examining the possibilities offered by these new tools through technological projects. The reports describe some of these projects that aim to optimize maintenance operations. These include the use of various technologies and on-board systems in winter maintenance vehicles to collect various types of data (geopositioning, spreading data, grip measurements, operations performed, etc.). Similarly, the development of integration systems for meteorological data, including data obtained from vehicles used by the users themselves, is currently being assessed (United States).

The testing of new spreading methods, the use of brine and automatic spreading systems, the qualification of spreaders, the various modeling tools being developed (salt distribution on the roadway, road surface temperature and frost depth forecasting), the approach using the thermal mapping of networks, and snow disposal systems are all elements currently under examination mentioned in the country reports.

As regards network organization and management, some managers have undertaken to redefine their role in winter service. In this case, (extended) public-private partnerships are considered a potential option. Other countries that have already tasked private contractors with the maintenance of their roads are developing supervision and evaluation methods. The evaluation of snow and ice control measures remains an important topic (winter severity index, salt use index, institution of a customer satisfaction bonus), as are cost-benefit considerations regarding the timeliness and speed of winter services. Here, again, environmental protection remains a prime concern.

In a number of countries, working groups organize training sessions and establish instructions and directives to help road managers and operators ensure the maintenance of roads in difficult climatic conditions (legal aspects, products, equipment, weather reports, and establishment of road weather stations).

Accordingly, for many countries, research, the evaluation of new approaches and new techniques, the development of new tools and the ongoing re-examination of practices constitute a dynamic answer to the challenges of maintaining network sustainability in winter. In fact, by focusing on these elements, each country intends to improve the performance and service offer of transportation systems.

Summary

Conclusion

Since winter varies in intensity and duration, it is always an unpredictable season that not only affects the movements and safety of road users and pedestrians but also hinders the free flow of goods and services on the network. Infrastructures are affected by the impact of the measures implemented to deal with this weather, thereby altering their useful life and, above all, their accessibility and safety.

Within such a context, road network managers all share one responsibility: ensuring the safety of all network users while keeping road infrastructures in good condition, thus fostering the maintenance and development of economic and social activities across their respective territories. To this end, they devote significant financial, material and human resources, while constantly researching for new ways to improve practices, making the appropriate planning of winter maintenance strategies and methods all the more important. Within the context of sustainable development and with the increasing concern to reduce the environmental impacts associated with winter service, this compendium is a one-of-a-kind reference tool for all network operators.

In fact, the themes covered in this document address a number of topics likely to interest any network manager called upon to deal with the rigors of winter. Although there is no right or wrong approach to network maintenance, readers will see that each country uses its own methods in response to its own constraints and objectives.

Michel Brown, Eng.
Ministère des Transports du Québec
Direction du soutien aux opérations

On behalf of PIARC's Technical Committee B5 on Winter Service

Country reports

snow and ice databook 2010

ANDORRA

snow and ice databook 2010

1. Demographic and Roads

1.1 Information about the country

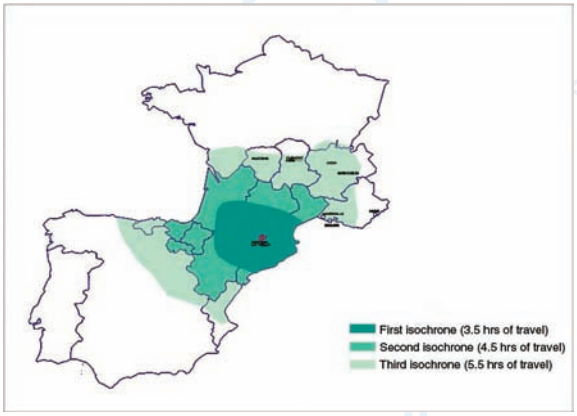
The Principality of Andorra is a microstate (468 km^2) located between Spain and France, in the middle of the Pyrenees mountain range. The current population is over 85,000 inhabitants, with a density of 182 inhabitants/km^2, with the majority of the population concentrated on the valley floors. The key economic sectors are construction and its derivatives, the financial sector, and above all the restaurant industry and trade. Every year more than 11 million tourists visit the country (approximately 80% leave the same day and 20% stay at least one night in the country), attracted mostly by the retail offerings and mountain sports, particularly in winter (the Principality of Andorra has the highest concentration of ski resorts in the Pyrenees, 315 km of trails).

1- Official road map

Administratively, the country is divided into seven parishes: Canillo, Encamp, Ordino, La Massana, Andorra la Vella, Sant Julià de Lòria and Escaldes-Engordany. More than half of the country's population is concentrated in the two major agglomerations of Andorre la Vieille (the country's capital) and Escaldes-Engordany.

1.2 Road network and traffic

Connections to the outside are possible solely by road using either one of the two border-crossing roadways: towards Spain, across the border at the Runer River, at an altitude of approximately 800 meters and 140 km from the city of Lleida or 200 kilometers from Barcelona. The connection to France is more difficult, because the border is at Pas de la Casa, at an altitude of 2,000 meters, making circulation more difficult in the winter months. The closest French cities are Perpignan at 170 km and Toulouse at 190 km.



2- Access isochrones for the Principality

Slightly more than 40 km separate the Spanish border from the French border. This road goes through the capital, where the average traffic is around 100,000 vehicles per day. The other main road is that connecting Andorre la Vieille to the parish of Ordino. The rest of the road system is composed almost entirely of high mountain roads.

ANDORRA

2. Climate

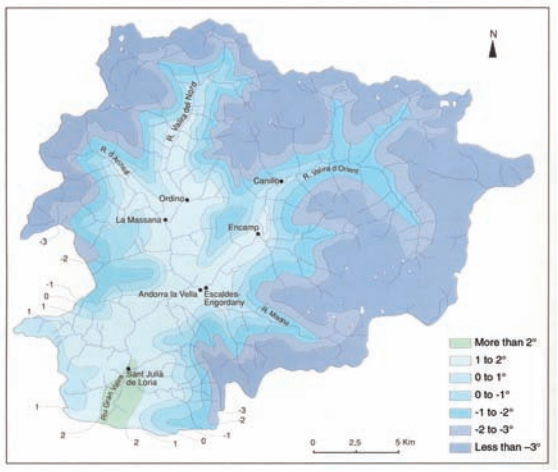
2.1 Overview of climatic areas

From a regional point of view, the Principality of Andorra can be said to fall within the sphere of the Mediterranean climate; however, a set of geographical factors influencing the climatic behavior in particular must be taken into account.

First, the relief and significant altitudinal cline present in the Principality of Andorra. Most of the country is at 2,000 m, and accordingly falls within the realm of mountain climates where precipitations are higher than in the valleys, temperatures lower, the temperature range greater, and the wind more present. From 2,000 – 2,200 m, snow is likely to fall on a regular basis from December to April. The situation changes in the warmest part of the year, especially summer, when the convective activity generates intensive precipitation, often in the form of storms lasting a short time.

The other important geographical factor to be taken into account is Andorra's distance from the sea. Proximity to the Atlantic Ocean fosters the inflow of wet winds from the French side of the Pyrenees. This characteristic leads to major precipitation in the form of snow in the winter season, particularly on the mountains in the mid-north part of the country. Andorra is under the influence of temperate climates (depending on precipitations), particularly in winter. These northern advections arrive with more difficulty in the southern half, which is more under the influence of the inflow of masses of humid air from the Mediterranean, and at a higher continental degree.

Finally, it can be said that the climate in Andorra is defined by the following systems: Mountain – Mediterranean – Temperate.



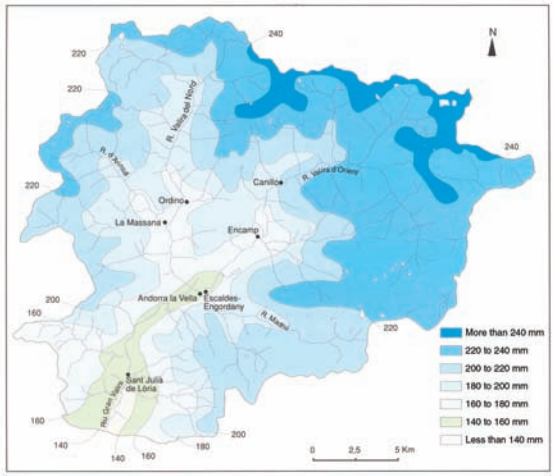
3- Average temperatures in the month of January in Andorra (Raso, 1999)

2.2 Noteworthy climatic data

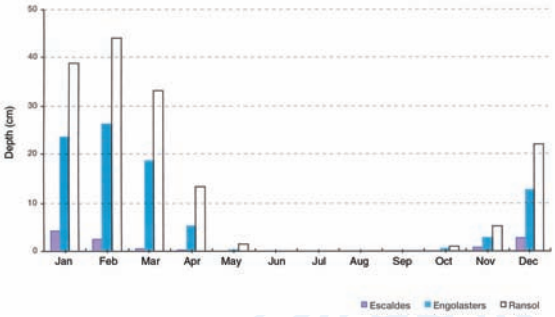
In maps 3 and 4, which show the average figures for precipitations and temperatures during the annual cold period in Andorra, we can see that the northern and eastern sectors of the Principality are the areas where the highest probability of snow on the ground is concentrated.

Graphic 5 provides information on the months when there is more snow on the ground: particularly January, February and March.

In conclusion, note that the maximum amounts of snowfall accumulated in 24 hours in the 1986-2003 period were 85 cm at 2,100 m (Pas de la Casa), 56 cm at 1,600 m (Ransol) and 40 cm at 1,100 m (Escaldes).



4- Average precipitations in the month of January in Andorra (Raso, 1999)

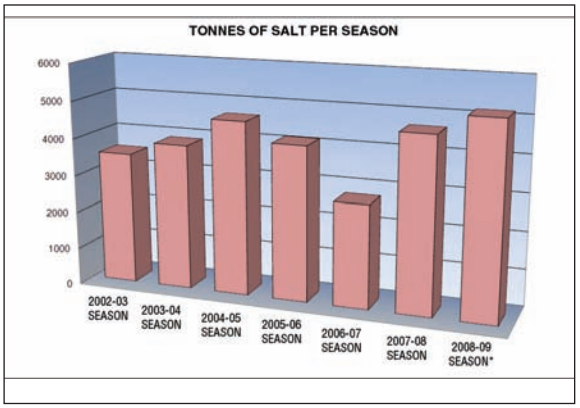


5- Monthly distribution of the average depth of snow in Escaldes (1,100 m), Engolasters (1,600 m / sunny) and Ransol (1,600 m / dark) (Raso, 1999)

ANDORRA

2.3 Winter indices used in the country

The Government, directly through its crews, is responsible for road maintenance and uses indices that are not based solely on weather conditions to indicate the difficulties caused by winter. Snowfalls during the winter in question and the quantities of salt used are the benchmarks for assessing the season's harshness.



6- Graph of tonnes of salt per season

3. Winter Road Management

3.1 Standards and rules

Classification of roads.

Roads are classified into two types:

- General roads, property of the Government;
- Secondary roads, which belong to local corporations, communes.

Legal obligation

As owner, the central government is obligated to oversee the general roads, which ensure circulation at the national level. According to legislation on the delimitation of powers, the government is also responsible for maintaining secondary roads.

Levels of service

In the winter, the Ministry of Land Management, Urbanism and Environment determines the level of service based on two criteria: the functional classification of the road and the daily average traffic intensity (DAI).

Level of service	Classification of roads
Level of service 1: Road always clear	General roads and secondary roads with a high DAI
Level of service 2: Road always clear during the day and partially clear at night	Secondary roads

To talk about "clear roads" in the case of winter maintenance is to talk about a "bare road" strategy. That is, when snow falls, the goal is to successfully remove snow and ice from the road as quickly as possible. New technologies and a larger fleet of vehicles help us to better overcome weather events and shorten response times.

3.2 Organization and operation of winter maintenance

Andorra has a long tradition in the management of winter maintenance and gladly shares its experience in snow removal with neighboring countries by assisting them in extreme situations. This was the case when Catalonia (Spain) saw major snowfalls in 1962 and 2001.

7- Col d'Envalira, 1960

In terms of winter maintenance, all road maintenance is managed by government crews. Communal crews are responsible only for roads within agglomerations. However, the effective collaboration between the seven communes and the central government in this area should be noted.

ANDORRA

Sectoral organization of snow removal

The sectoral division is based on the "Y" shape of the road system, which follows the valley floors. Based on the physical and climatic characteristics, winter maintenance (WM) crews were divided into two sectors:

- The Vallée du Nord sector, with a network of 200 km of road;
- The Vallée d'Orient sector, which only has a network of 70 km, but which must make sure that the Col d'Envalira, at an altitude of 2,408 m, permanently remains open.

Staff labor program

The organization and work of the winter maintenance staff are planned according to the sector:

- In Vallée du Nord, all of the staff works on call. The labor force was increased a few years ago to achieve the levels of service required, because in the case of continuous snowfalls (more than 2 days), we had trouble providing sufficient crews, particularly at night. Remember that these crews are responsible for clearing the only road connecting to Spain;
- In Vallée d'Orient, a sector in which the connection to the French border must be ensured at an altitude of over 2,000 m, a different work method is employed. Near Col d'Envalira and the border, we have a work centre, strategically located, where snow removal staff are present from morning until evening every day of the week. At night, we have on-call staff that can be called depending on weather conditions.

Inspection and winter control

During the Winter Maintenance season, from November 1st to May 30, an inspection service covers all the roads. It focuses in particular on the most problematic areas. The mission of this service is to prevent the risk of morning frost on roads during the rush hour.

In the event of ice or snow, the inspectors notify the salting or snow removal crews. Depending on the weather conditions, these teams monitor road conditions on an ongoing basis.

Snow removal equipment

The total number of snowplows in the Government's possession is 20 units. These are also equipped with salt and brine spreaders.

8- Snowplow

There are also salt/brine spreaders and snowblowers to clear those areas most affected by the snow.

The average is accordingly one snowplow for every 13.5 km of road, in addition to the salt/brine spreader trucks and snowblowers.

9- Snowblower

Avalanche prevention

A technical assistance service with experts in avalanche prevention is on alert for the duration of the winter season. In the Principality, 12 sites where avalanches can reach roads are monitored.

This surveillance is ensured by a third-party company and comprises three types of actions:

1. Monitoring the snow cover and weather forecasts during snowfalls;

ANDORRA

10- Protective barriers, screens, Nicolau Canal, El Serrat.

2. "Expert" estimates of a localized risk when the situation requires it;

3. Avalanche control using avalanche cannons, Catex and Gazex.

11- Gazex at Les Fonts, Arinsal.

3.3 Assessment of snow and ice control measures

Every year, all of the departments that take part in snow operations (government snow removal services, police department, traffic services and communal snow removal services) draw up an account of the season and work to make the necessary improvements in preparation for the next season.

In our country's economy, there is a very strong link between winter maintenance, tourism and mobility, and the GDP. That is why it is important for all officers assigned to these strategic sectors to work together to provide the tools needed to make structural decisions.

3.4 Road safety and information

Information system

The Mobility Agency, the department that oversees the National Traffic Centre (CENATRA) and the snow removal crews of the Road Operation and Conservation Service (COEX), is committed to promoting and disseminating advertising campaigns to raise users' awareness of responsible driving and the use of road vehicles in the event of snow. These initiatives were carried out in the form of the "les couleurs de la neige" [the colors of snow] campaign.

GREEN STARTING TO SNOW	YELLOW SNOW ON THE ROAD	RED ROAD COVERED WITH SNOW	BLACK ROAD IMPASSABLE
			
• Traffic is undisturbed. • Take more care. • Do not exceed a speed of 80 km/h. Stay attentive to weather changes. Drive with care in wet areas and on clear nights because of the possibility of frost.	• Use of chains or special tires at a maximum speed of 60 km/h. • It is recommended that trucks and articulated vehicles not be operated. Slow down, particularly in turns and on banked roads. Avoid all unexpected maneuvers and increase your safety headway. Do not continue travelling if the weather starts to deteriorate and you have no special equipment (chains, warm clothes, etc.).	• Use of chains or special tires at a maximum speed of 30 km/h • Use of chains mandatory on busses. • The use of freight transportation vehicles with an authorized average weight of over 3,500 kg is forbidden. Unless absolutely necessary, it is preferable to postpone the trip. Do not stop the car on a hill or in places where you would be hindering traffic. Do not pass stopped vehicles if you are not sure you will be able to keep going.	• Risk of being immobilized on the road for a long time. In the event of immobilization, conserve fuel and abandon the vehicle only if you are certain of finding shelter. Do not leave the car in places where it might become an obstacle to snowplows.

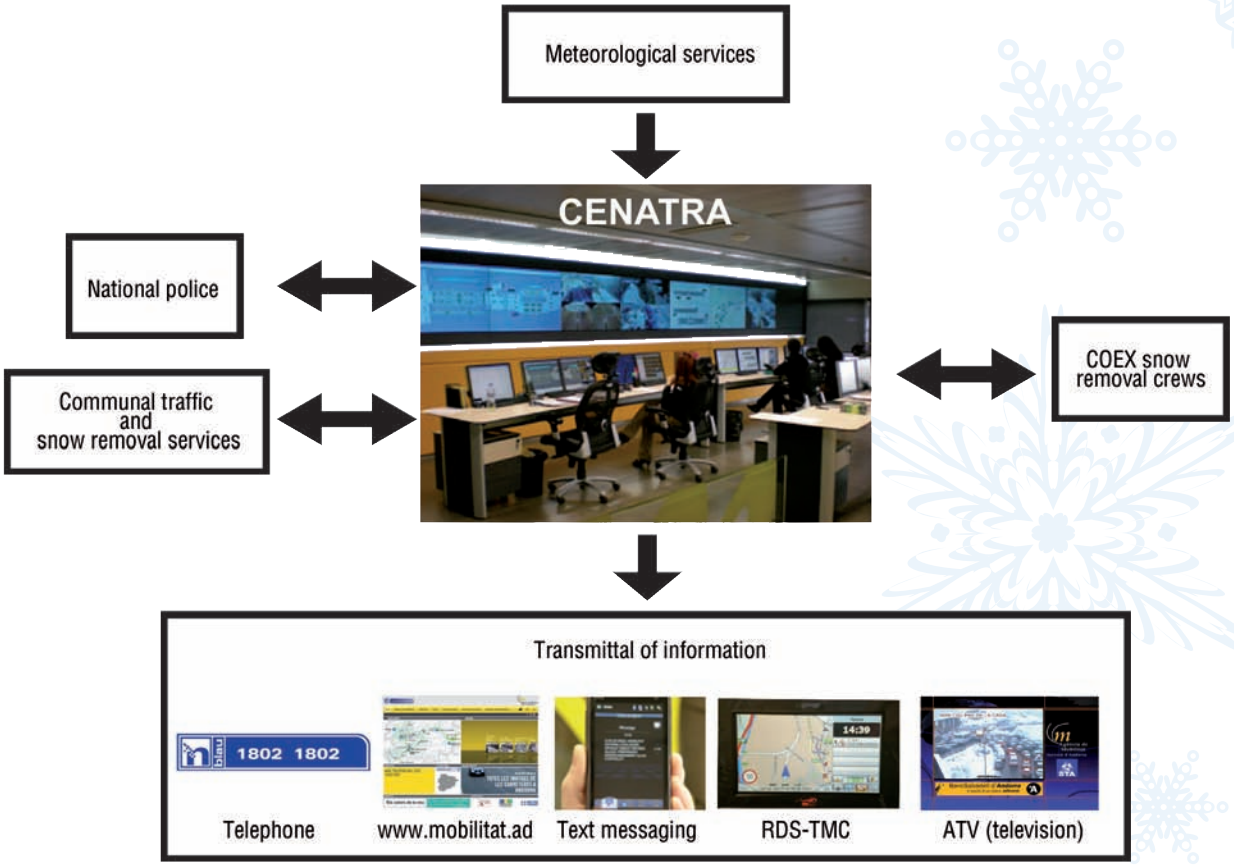
ANDORRA

12- Variable message sign

Information is crucial in winter maintenance management. A communication infrastructure, based in CENATRA, was established.

On the one hand, the road inspection and monitoring crews of the Road Conservation and Operation Service (COEX) notify the National Traffic Centre (CENATRA) of incidents, with constant feedback between the National Police and the communal traffic and snow removal services. On the other hand, using variable message signs and the media (text messaging, web services, RDS-TMC, radio bulletins, etc.), CENATRA provides information regarding road conditions.

13- Variable message sign



ANDORRA

4. Ongoing Research and Studies to Improve Winter Management

4.1 New technologies

Ongoing projects:

- On-board communications equipment (TETRA system) for real-time data on the exact position of all snow removal vehicles and to obtain data from sensors analyzing the working conditions for each vehicle;
- Automatic laser stations on salt-spreading vehicles with relative humidity, surface temperature and air temperature measurement to calculate the exact rate of salt and brine;
- Road frost sensors;
- Generalization of the use of brine.

14- Brine production station

5. References

Principality of Andorra website
www.govern.ad/

Agència de Mobilitat i Explotació de Carreteres
www.mobilitat.ad/

IEA Institut d'Estudis Andorrans
www.iea.ad/

CENMA
Centre d'estudis de la neu i la muntanya d'Andorra
www.cenma.ad/

El Clima d'Andorra
J.M. Raso Nadal, 1999
Ministeri d'Educació, Joventut i Esports
(Government of Andorra)

AUSTRIA

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Austria is situated in the southern part of middle Europe. The neighboring countries are in the north Germany and the Czech Republic, in the east Slovakia and Hungary, in the south Slovenia and Italy and in the west Switzerland and Liechtenstein.

Figure 1 – Republic of Austria

The size of the country is 83,858 km^2, the population 8.35 million. The topography is dominated by the Eastern Alps and the Danube area.

Vienna, the capital of the Republic of Austria, is on the eastern part of the country. The city comprises 414 km^2, population 1.68 million.

Austria is a highly developed industrialized country with an important service portion. The chemical and electrical industries, and agriculture and tourism are important parts of the local economy.

The land has an extensive road and railway system. The Viennese Airport is an important junction for flights between the western and eastern part of Europe.

The country is a democratic federal state, which consists of nine regions:

- Wien (1.68 million people);
- Burgenland (0.283 million people);
- Niederösterreich (1.605 million people);
- Oberösterreich (1.411 million people);
- Salzburg (0.530 million people);
- Steiermark (1.208 million people);
- Kärnten (0.561 million people);
- Tirol (0.705 million people);
- Vorarlberg (0.367 million people).

The motorways are privatized. There is a duty obligation for all vehicles. Owners of passenger cars and motorcycles have to buy a vignette. Buses and trucks must be equipped with a so-called go-box. The other road network system is administered (planning, structural preservation and winter maintenance) by the regions.

AUSTRIA

1.2 Road network and Traffic

Area	83,858 km²	
Population	8.35 million	
Length of roads	Motorway	2,029 km
	Regional main roads	9,960 km
	secondary & country roads	23,472 km
	municipal roads	71,000 km
Latitude (capital)		48° 13' 11" N
Longitude (capital)		16° 22' 12" O

Table 1

The network of the public roads comprises approximately 106,500 km. There are 6 million vehicles with Austrian traffic certification. 4 million are passenger cars. These vehicles drive on the average 13,500 km per year.

2. Climate

2.1 Overview of climatic areas

Austria is a mostly Alpine country, situated in a transition zone between continental and maritime climates. The winter climate is marked by the changing influence between moist, moderate air masses steered towards Austria from the Atlantic Ocean, and cold dry air, related to strong areas of high pressure over Eastern Europe.

Concerning the occurrence of heavy snowfalls Austria can be divided into distinct zones:

- Northern Austria frequently receives great amounts of fresh snow, when moist air is steered with a northwesterly flow towards the Alps. Hitting with the northern rim of this mountain range, the air rises, thus cools and is unable to keep its moisture, which falls as snow to the ground;
- Heavy snowstorms hit Southern Austria in connection with Mediterranean lows centered over Northern Italy;
- In the lowlands of the Eastern and Northern Austria, heavy snowfall is unusually rare and occurs in connection with cold air from Northern Europe or, like in Southern Austria, related to lows over the Mediterranean Sea, if temperatures are low enough for snowfall;
- Freezing rain may affect Austrian roads a couple of times each winter. It sometimes occurs when warm fronts approach the country from Western Europe and the falling rain or drizzle freezes when hitting a thin layer of cold air close to the surface.

Fog or freezing fog may also be a problem for the traffic. This occurs in connection with marked temperature inversions, when cold air from Eastern Europe is topped at altitudes of 600 to 1,200 m by a much warmer layer of air.

Drifting snow can cause catastrophic conditions on the roads in the flat and thus wind-prone parts of Austria if temperatures are sufficiently low.

3. Winter Road Management

3.1 Standards and rules

The traffic regulations are the legal foundation for all winter maintenance activities. In case of snowfall or slipperiness sidewalks must be maintained between 6:00 (6:00 am) and 22:00 (10:00 pm). Responsible are the owners of the neighboring properties.

The winter maintenance procedures on roads are as follows regulated (table 2).

A Motorways and federal highways in direct connection to motorways;

B Country roads or municipal roads with substantial traffic volume (daily traffic >3,000);

C Country roads and municipal roads with substantial traffic volume, scheduled buses, school buses or tourism;

D Country roads and municipal roads with small traffic volume (< 1,000).

3.2 Organization and operation of winter maintenance

The owners of the roads are responsible for the road service and winter maintenance. Motorways and federal highways are administrated by the ASFINAG (**A**utobahn und **S**traßen **Fin**anzierungs **AG**). Roads of the countries or municipalities are administrated by the regions (Lands of the Federal Republic), the cities or municipalities. There is no winter maintenance head office in Austria which is giving instructions to the road masters.

AUSTRIA

3.2.1 Road Master

Austria has 240 service centers led by so-called road masters. They are charged with the organization of a service station during the summer and wintertime. Some of their jobs are planning, executing and monitoring of activities concerning road administration. They have to check the weather reports and make decisions in case of prognosis, which have an effect concerning the road condition.

Road masters are also responsible for the duty organization of the own personnel and the resources of spreading material like grit or salt.

3.2.2 Employment of private companies

Private companies are also involved in winter maintenance activities. The employment with the road administration assumes participation during a tender procedure. The terms of a contract are depending on the requirements of the road administration.

Trucks need a mounting plate to fix the plow to the vehicle and the necessary connections for the hydraulics to lift up and turn the plow. Drivers are employed with the concerned company. The additional equipment, which is necessary to execute the work, like spreaders or plows, is offered by the road administration.

The contracts cover a period of 3 to 5 years. It depends on the requirements of the road administration.

The roads they have to plow/spread are noted on a map. There can be some additional information included (number of the winter maintenance map, area, address/telephone number of stockpile, one-ways).

For the supply of spreading resources (vacuum or stone salt, calcium chloride, grit, potassium carbonate) a European-wide tender is issued. The tender will be carried out by a central unit of the road administration. The contracts are valid for one year. It is usual to include some clauses in the contract. For example, to get an additional delivery after winter maintenance action, there is a clause to deliver new material within 48 hours.

class of road	A	B	C	D
type of road	motorways	regional main roads country roads & municipal roads with substantial traffic volume	secondary roads country & municipal roads with substantial traffic volume, scheduled or school buses or tourism	secondary roads country or municipal roads small traffic volume
vehicles/day		> 3,000	< 3,000	< 1,000
time of circulation	max. 3 hours	max. 5 hours	max. 5 hours	
weather situation 1	road condition	road condition	road condition	road condition
light snowfall, snowy or icy surface, rime, light snow drift	trafficability of all traffic lanes, exit and access roads plowing and spreading with de-icing material 24 hours	trafficability traffic delays possible between 22:00 and 6:00 plowing and spreading basically with de-icing material from 4:00 to 22:00	trafficability Traffic delays possible between 20:00 and 7:00 plowing and spreading with de-icing material or grit from 5:00 to 20:00	trafficability Severe traffic delays possible plowing and spreading with grit once daily
weather situation 2	road condition	road condition	road condition	road condition
snowfall moderate to severe, snow drift, snow depth > 10 cm	trafficability of one lane in each direction, exits and access roads plowing and spreading with de-icing material 24 hours	trafficability severe traffic delays possible plowing and spreading basically with de-icing material from 4:00 to 22:00	trafficability severe traffic delays possible plowing and spreading with de-icing material or grit from 5:00 to 20:00	trafficability severe traffic delays possible plowing and spreading with grit twice daily
weather situation 3	road condition	road condition	road condition	road condition
freezing rain severe snowfall, avalanches	Road safety cannot be guaranteed, during the removal of larger snow quantities (snow drift, avalanches) temporary road blocks are possible			

Categories of winter maintenance

3.2.3 Spreading techniques

There is a statutory duty that winter maintenance must be executed on all public roads in Austria. The kind of spreading material depends on the category of the road (see table 2). On category A roads, the spreading of salt is obligatory, the use of grit is not allowed. On categories B and C, there is a mix of salt spreading routes, routes with a mixture of salt/grit (for example ratio 1:10) or routes where the road administration is using grit only.

The spreading of wet salt (F 30 technology) is usual (fig. 2). If trucks are not equipped with the necessary devices, it is possible to load a mixture dry salt (stone or vacuum salt) and grit.

Figure 2 – Trucks with plow and F 30 equipment

Winter services in alpine regions often require the employment of snow cutter blowers. Due to the avalanche danger in many areas of the Alps, temporary roadblocks are made. The Prealps area 60 km west of Vienna (fig. 3) is concerned with violent snowfall very often. The use of snow cutter blowers is usual in winter service activities in the alpine region.

Figure 3 – Snow cutter blower in the area of Lilienfeld (Lower Austria)

Some high-altitude roads remain closed completely during the winter period. Snow clearing activities start in April. For the Großglockner Hochalpenstraße (fig. 4) 25 working days are necessary to remove 600,000 m^3 to 800,000 m^3 of snow. The snow walls have a height of up to 21 m.

Figure 4 – Snow removal at the Großglockner Hochalpenstraße

3.2.4 Environmental consequences of de-icing agents and grit

The use of de-icing agents can have negative repercussions on the environment. On many roads in Austria the use of chlorides are prohibited due to environmental reasons. Some kinds of trees (for example, chestnut or plane tree) are very sensitive to salt or calcium chloride. To reduce the harmful effects to a minimum, it is necessary to use de-icing agents, which are less harmful. In the Viennese area we also spread potassium carbonate instead of salt. This is necessary on roads where the spreading of grit is not sufficient to keep the roads safe.

AUSTRIA

Figure 5 – Sweeping machine with sodium chloride brine spraying device

On areas where we have to use salt due to a lot of traffic, with trees beside the road surface, it is usual to flush out the green space area in spring to reduce the salt concentration.

There is also a dust when you are using grit during the winter maintenance. Normally the surface temperature has to reach +3 °C or more to use sweeping machines. These machines spread water to prevent a kick up of a lot of dust before the sweep in the grit. The city of Vienna is also using sweeping machines (fig. 5) which also use sodium chloride brine instead of water. Sweeping of the road surface can be accomplished with temperatures below the freezing point during a dry weather period.

3.2.5 Road weather information system

The 9 Lands of the Federal Republic have special contracts with the weather service institutes. There is not only one weather forecast for the whole country, but with consideration of the climate within a small area, a large number of special weather reports are required. Some of the most important weather institutes are:

- The Central Institute of Meteorology;
- Austro Control (flight weather);
- The military weather service;
- Meteomedia and so on.

The following weather values are common for road winter service:

- Air temperature [°C];
- Surface temperature [°C];
- Wind direction and strength (average and peak values);
- Weather condition and tendency;
- Weather effectiveness (e.g., weak, moderate, strong);
- Precipitation (e.g., drizzle, rain, snow rain, snow, ice);
- Type of precipitation (e.g., shower, freezing rain, from time to time);
- Intensity (e.g., easy, moderate, strong);
- Snowfall limit [m];
- Quantity of fresh snow [cm];
- Remarks of the meteorologist.

The responsible persons have to collect this information. With the help of these reports they can make their decisions.

The Austrian roads have 370 ice forecasting systems installed on them. The measured values are transmitted by leased lines to the road administration. In exceptional cases selecting modems are used. Generally the stations are set up at the coldest points of the roads and bridges. The determination of the location of new stations takes place through thermal mapping and the experience of the road master or drivers of snowplows.

Some road administrations have a connection to the weather radar and EUMETSAT system. It is very important additional information allowing the road master to make decisions concerning the start, duration and end of a winter maintenance action.

3.2.6 Traffic safety and road information for drivers

The individual radio and television stations inform about the forecasted and current weather and the road conditions. Weather information is also available on the internet and by teletext. So-called weather cameras are installed on certain points of the whole country. The weather situation can be observed both in the tourist region as well as in the urban areas. A large number of cars are not equipped with winter tires. Most handicaps are caused therefore by insufficiently equipped vehicles.

Information concerning winter road conditions should be given as early as possible. Some road signs indicate a speed limit for the danger of smooth roadways. The police can prescribe the use of winter tires or tire chains on certain roads.

3.2.7 Snow stockpiles for urban areas

Winter maintenance in urban areas has some special emphasis, which does not play a role on highways. Due to a lack of road space large quantities of snow must be removed rapidly. For this reason there are snow stockpiles (fig. 6) in larger cities. The snow can be poured into flowing water. That is problematic due to environmental protection reasons, because a lot of grit and other materials are mixed in the snow.

The storage of snow takes place on so-called snow dumping sites. At these places the snow thaws slowly off and the residual substances can be removed after the winter.

Figure 6 – Snow stockpile

4. On-going Research and Studies to Improve Winter Management

The Austrian Research Council Road and Traffic is responsible for all activities concerning research of all kinds of road construction and maintenance.

Among other things there is a working group, which concerns itself with winter maintenance. Guidelines and instructions are compiled regarding the efficiency in winter maintenance.

At the moment a new recommendation is being prepared. The contents are legal aspects, education, equipment, weather reports and all aspects which are important in winter maintenance. The target group is persons, who are employed in the road service.

5. References

Handbuch für den Winterdienst der MA 48, Wien

Amt der Niederösterreichischen Landesregierung

Anforderungsniveau für den Winterdienst

Der Forschungsgenmeinschaft Straße und Verkehr

www.grossglockner.at/de/grossglockner/

www.asfinag.at

BELGIUM

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Belgian road network (main roads)

Belgium is a country small in size (30,528 km^2) but densely populated (10.67 million), situated at the heart of Europe. The country occupies a privileged position between the Netherlands, France, Germany and Great Britain, and borders on the North Sea, the busiest sea route on the globe. Brussels, the country's capital, is also the capital of the European Union and an international financial centre. The country's flourishing economy is largely built on the export trade (2/3 of the country's production is exported). Belgium's financial health depends to a large extent on its transportation infrastructure. The motorway and railway network is accordingly one of the densest in the world.

The country is a federal state with 3 regions: the Flemish region in the north (6.16 million people), the Brussels-Capital region in the centre (1.05 million), and the Walloon region in the south (3.46 million). These three regions are autonomous in several areas, including the construction, management and maintenance of the motorways and expressways on their territories. Flanders and the Brussels-Capital region are relatively flat regions (0 to 100 m), whereas the Walloon region contains the Ardennes, a group of plateaus 400 to 690 m in altitude and dotted with numerous valleys.

1.2 Road network and traffic

The road network comprises 1,763 km of motorways, 12,613 km of regional (national) roads (both managed by the regional authorities) and 139,219 km of communal and provincial roads.

Area	30,528 km²	
Population	10.67 million	
Length of road	Motorways	1,763 km
	Regional roads	12,613 km
	Provincial roads	1,349 km
	Local roads	137,870 km
Latitude (capital)		50°50'N

2008 statistics on the country and roads (http://www.belgium.be; http://statbel.fgov.be)

Of the 6.48 million vehicles in Belgium, 5.13 million are passenger cars, each travelling an average distance of 15,636 km per year (2007). Traffic is also significant at night, particularly commercial traffic. Road transportation accounts for 73% of the total freight transportation. The average daily traffic (2007; 6 a.m.-10 p.m.) on Belgian motorways is around 51,000 vehicles (with maximums reaching close to 150,000 on certain segments near major cities) and about 10,000 vehicles on regional roads.

Traffic: 98.79 billion veh-km	
On motorways:	35.85 billion veh-km
On regional roads:	40.70 billion veh-km
On communal roads:	22.24 billion veh-km
By passenger cars:	77.02 billion veh-km
By trucks (and commercial vehicles) for freight transportation:	19.71 billion veh-km

2007 traffic statistics (http://statbel.fgov.be)

BELGIUM

The economic importance of roads can therefore not be denied, even in winter. As a result, one of the tasks of the road authorities is to keep the road network serviceable at all times, among other things by setting up a special department for winter maintenance.

2. Climate

2.1 Overview of climatic areas

Due to the geographic location of the country, the climate is largely influenced by the proximity of the sea. Moving towards the interior, behind a coastal plain a few kilometers wide, the terrain rises gradually towards the south and southeast and is characterized by numerous valleys. This diversity leads to significantly different local microclimates that must be considered in the management of winter road maintenance.

2.2 Statistics on temperature, frost days and precipitations

Belgium has a temperate climate with relatively mild and rainy winters. In winter, the weather conditions can be very irregular at around 0 °C. Frequent and abundant precipitations in winter, mostly in the form of rain or winter showers, make the roads wet or damp. The number of days of snow varies considerably depending on where you are within the territory: from around 12 days/year on the coast to 60 days/year on the Ardennes plateaus [3]. The number of frost days in Brussels remains limited, at 52 days per year. It is the number of freeze-thaw cycles that most characterizes the winters in Belgium. In general, the closer you get to the Ardennes plateaus, the more the average temperature drops and the number of frost days increases, up to an average of 115 days per year. Locally the differences in climate conditions between road sections are significant enough to create different types of skidding conditions.

2.3 Winter indices used in the country

No winter indices as such are used in Belgium. "Consumption" indices taking the severity of winter into account are used.

- Balanced scorecard: The Flemish road authority calls on a number of resources (both human and financial) to achieve its strategic and operational objectives. One of these strategic objectives is to minimize the impact on the environment. It is accordingly important to analyze whether any of the measures (excessive interventions, dosing that is too high) taken for winter maintenance were greater than necessary. The ultimate goal is to use as little salt as possible and still achieve the operational objective (avoiding slippery roads). Consequently, an M (= Z/R) index was developed, the latter representing the relation between the quantity of salt spread (Z) and a reference value R defined by the following formula:

$$R = \sum_{i=1}^{9} O_i \times (7\ g/m^2 \times X1_i + 33\ g/m^2 \times X2_i) / 10^6$$

where:

O: is the area of road treated in each of the region's 9 climatic areas.

X1: is the number of nights during which the road surface temperature fell below 0 and where the dew point was greater than the road surface temperature.

X2: is the number of nights during which winter showers or snowfalls on an icy surface were recorded.

The Walloon road administration also develops quality standards and performance indicators associated with the harshness of winter (see § 4.2).

3. Winter Road Management

(on regional roads and motorways)

3.1 Standards and regulations

Legal obligation to perform winter maintenance

The winter maintenance performed by the three regional administrations is a service provided to road users and to the country's economy. Winter service is performed between mid-October and mid-April.

Classification of roads - Levels of service - Route optimization

The level of service allocated to roads aims, insofar as the circumstances allow it, to ensure maintenance or to re-establish normal traffic conditions in all unexceptional winter situations, taking into account the road classification and the volume of traffic. For each level of service required, winter maintenance operations must be completed within 4 hours of the decision to act.

Theoretically, the serviceability of every road is maintained. In the event of extreme winter conditions, and when available resources become insufficient, priority is given to certain roads (motorways, major national roads, roads used by public transportation). The administration must take the actions (spreading, snow removal, signage, etc.) necessary to ensure that ice or snow does not unduly surprise the users.

BELGIUM

Quality standards, performance indicators

Winter maintenance contracts are currently still aimed at securing means rather than achieving actual results or service levels.

Manpower regulations

The organization of local winter maintenance is set out in detail in an organizational plan (internal regulations) specific to each district. This document sets out how each task associated with winter maintenance is organized.

Work is scheduled according to Belgian legislation on work time adopted on 2000-12-14.[3] This legislation stipulates that work time may not exceed an average of 38 hours per week over a reference period of 4 months (without exception).

Regulations regarding the types and characteristics of materials and equipment

Most of the salt used on Belgian roads is sodium chloride (NaCl), either as rock salt, evaporated salt or brine. Supply contracts are established before the winter period (in Walloon: three-year contracts broken down in three annual phases, with a revision in the 2nd and 3rd years of the unit prices initially set); these contracts specify the characteristics that the salt must have (purity, anti-caking agents, grain size) as well as the anticipated quantities and packaging.

Suppliers are required to provide evidence of the existence of appropriate stock levels in Belgium. In particular, the Walloon region requires that salt stocks be transported via inland waterways and ports (to encourage intermodality). Supply contracts allow for three forms of NaCl (brine, evaporated salt and rock salt with a wide range of grain sizes) annually.

Generally speaking, detachable spreaders designed for medium and large road systems (capacity of around 5 m^3) are used; they are wheel driven, driven by an auxiliary engine, by the truck's hydraulics or connected to one of the truck's axles.

Each regional administration has established its own technical requirements regarding spreaders (attachment, signage, drive system and feed system), but in general the spreaders must always be equipped for the spreading of wet salt (brine tanks, feed lines, etc.) as well as with a system to accurately adjust the spread width and rate. The tender specifications refer amongst other things to the CROW 131 publication.[2]

Most of the spreaders operated in Flanders have been equipped with a system that automatically collects and analyses spreading data since 1996.

The trucks used for winter maintenance by the Ministry of the Brussels-Capital Region are equipped with a real-time GPS tracking system. Such a system is also being deployed in Walloon (see § 4.1).

	Motorways	Regional roads
Flemish region		
Districts	93 km/district	275 km/district
Spreaders (≈ 5 m^3) & snowplows	8.1 km/spreader	24 km/spreader
Walloon region		
Districts	87 km/district	212 km/district
Spreaders (≈ 5 m^3) & snowplows	7.5 km/spreader	26.5 km/spreader
Brussels-Capital region		
Districts	11 km/district	320 km/district
Spreaders (≈ 5 m^3) & snowplows	3.7 km/spreader	20 km/spreader
Belgium (average)		
Districts	86 km/district	229 km/district
Spreaders (≈ 5 m^3) & snowplows	7.8 km/spreader	23.9 km/spreader

km of roads include both directions, on-ramps, off-ramps and interchanges

Road management: districts and equipment—in the event of maximum deployment *(this is an average situation and is the result of dividing the number of km by the total number of districts, spreaders and snowplows)*

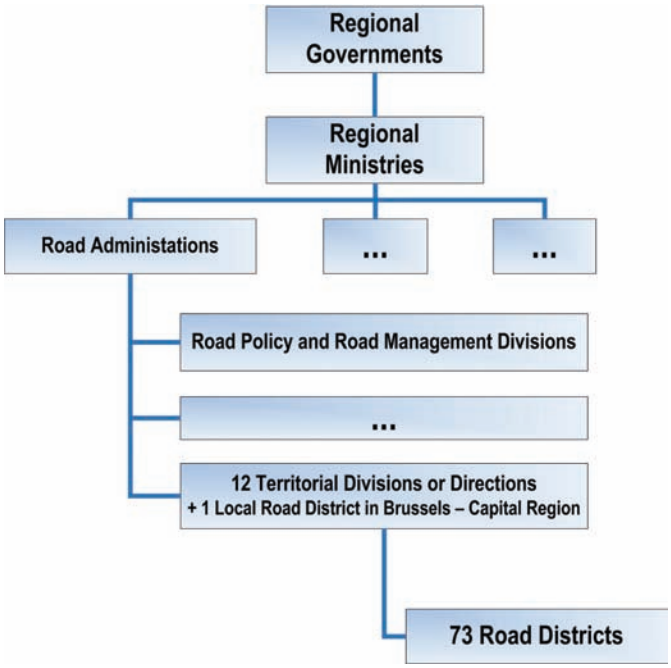
Regional road administrations call on a number of private companies (truck and driver rental, as well as spreader rental in Walloon), whose equipment is tested and eventually calibrated before the start of the winter period. In general, the salting routes, the number of spreaders and their capacity is determined in order to complete each salting route within 4 hours of the decision to respond (response time after the call to start treatment is 1 hour; the treatment time itself is around 2-2.5 hours), considering an average salting rate between 15 and 30 g/m^2.

3.2 Organization and operation of winter maintenance

The organization of winter maintenance along Belgian roads is the responsibility of:

- The three regional authorities for the 14,376 km of regional roads through various central branches and 74 local districts; all winter maintenance operations are carried out or ordered by these local centers;

BELGIUM



Decentralization of the road winter management

- The local authorities (589 communes and 10 provinces) when communal or provincial roads are concerned (these roads were not reviewed in this document).

District tasks

Winter maintenance by the districts comprises the following three main tasks:

- A steering role for the district manager, who is charged with controlling the smooth conduct of winter maintenance and provides the necessary guidance to make sure that instructions are well understood and applied;
- A coordination role for the "winter maintenance coordinator" who ensures the day-to-day running of operations. After taking cognizance of the road weather conditions (observed and forecast) and the results of road inspections, he makes the necessary decisions for interventions, calls up the necessary staff members and private contractors, and determines the type of treatment to be applied and the quantity of salt to be used. Finally, he is responsible for seeing to the encoding or recording of data associated with the delivery of services and management of ice melters (see also § 4.2);
- An implementation role for private contractors (mainly); the logistical support of contractors consists in supplying trucks with drivers as well as, sometimes, spreaders for salt solutions (only in Walloon, since 2000) and snowplows.

These tasks are set out in various internal documents and updated every year (general organization plans, territorial plans, and district level plans).

Public/private partnership for the implementation of winter maintenance

The implementation of winter maintenance on most routes is entrusted to private contractors.

	Level of privatization	% of operations (most recent winters)
Flemish region	Driver & truck	100%
Brussels-Capital region	Driver & truck	≈ 97%
Walloon (240 private contracts)	Driver, truck & spreader	86% (2008-2009 winter)

Interventions carried out by private contractors

Contracts with private contractors are signed before the winter maintenance season; they are based on a standard contract. Depending on the competent authority concerned, various types of contracts describing the winter maintenance operations to be carried out on a well-defined itinerary are used in Belgium:

- Twice-renewable one-year contracts in the Brussels-Capital region;
- Contracts for three winter periods with a formula for the annual revision of unit prices in Walloon (these include rental of the spreader belonging to the private company);
- Three-year contracts (two years for bicycle paths) in Flanders. The spreaders and salt are supplied by the administration.

Salt contracts and directives

Every year, a central branch of each road administration awards contracts to various salt suppliers following an open tendering process, so that the winter stocks can be replenished. These contracts for salt supplies are concluded at the central level in order to derive maximum price benefit from large volumes. The central branch also monitors the implementation of the contracts. Furthermore, it draws up directives for salting under various road conditions (at low temperatures, on ice, on porous asphalt, etc.) and works with industry to further develop winter maintenance material, etc.

BELGIUM

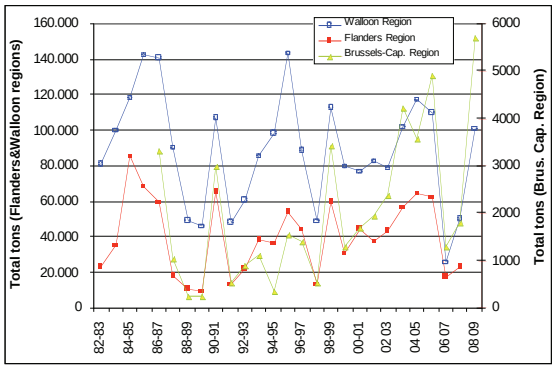
Cooperation with other road management organizations

Agreements are in place between the regional administrations as well as with local authorities to optimize salting routes along the network as well as to organize interventions on a few specific routes.

In addition, the Walloon region makes the information obtained from its road weather system available to Walloon communes to assist them in their decision-making. A replication of the portion of the application relating to meteorological data was developed in 2007 to this end.

Financing winter maintenance

Annual salt consumption is linked to the severity of winter. In the 1982-2009 period, the total annual consumption of road salt (NaCl and $CaCl_2$) along the roads that make up the regional networks was as follows:



Annual consumption of salt on Belgian regional roads

To date, the spreading of $CaCl_2$ along the regional networks represents less than 1% of the total salt consumption.

	Walloon region	Flemish region	Brussels-Cap region
Average for the 2003 to 2008 winters – in tonnes	80,931	44,586	3,154
km²	7,192	7,650	
g/m²/year	11.25	5.83	

Salt use in Belgium: 2003-2008 period

The average annual cost of winter maintenance in Belgium (most recent winters) is about 0.25 Euro/m² (ranging from 0.15 to 0.75 Euro/m² depending on the location of the road).

The total winter maintenance costs (average of most recent winters) can be divided as follows:

	Purchase of de-icing salts	Equipment and personnel	Involvement of private sector
Flemish region	26%	29%	45%
Walloon region	17%	26%	58%**

Breakdown of total winter maintenance costs: 2003 to 2008 period

Operational management of winter maintenance—snow and ice control measures

Interventions are organized as salting routes; the spreader is loaded so as to complete an entire circuit. Circuits are repeated as required. The spreaders are loaded directly from a vertical silo or from a horizontal silo using a loader.

Example of salt silos used in Belgium

There are three types of spreading, depending on the circumstances:

- Localized spreading: to avoid local frost or black ice, or to de-ice locally. The decision to respond and the rate of spreading depend on weather conditions (meteorological analysis of specific critical points in the affected district); the recommended rate varies from 7 to 10 g/m² (anti-icing) and from 20 to 30 g/m² (de-icing);
- Generalized anti-icing (pre-curative) spreading: to avoid general frost or black ice over the entire network, or to prevent precipitations from sticking to the road surface. The recommended rate (pre-wetted salt is very often used) falls between 7 and 15 g/m², depending on road weather conditions and forecasts. These interventions are carried out following a predefined morning and/or evening schedule;
- The generalized curative spreading of ice melters is carried out during or after the precipitations or winter event, and the spreading rates usually vary between 20 and 25 g/m² with a localized maximum of up to 40 g/m².

BELGIUM

Coordinators are instructed to focus on spreading preventively (pre-curative) as often as possible. Pre-salting is done with pre-wetted salt (7 to 15 g/m^2 - i.e., 80% dry salt pre-wetted with 20% of concentrated brine with 22% of NaCl). Spread width and symmetry can be adjusted on all spreaders from the cab, according to road width and number of lanes.

The Flemish road administration fosters the use of evaporated salt for anti-icing with pre-wetted salt and coarse salt for de-icing. There is no spreading of abrasives.

Contracts also include the delivery of generalized or localized snow removal services, combined with a spreading and executed serially (simultaneous snow removal in multiple lanes) as needed.

Wet salt technique

The Flemish road administration has adopted a policy for the complete renovation of its fleet of salt spreaders over a period of twenty years—starting in 1990—by buying only wet salt spreaders.

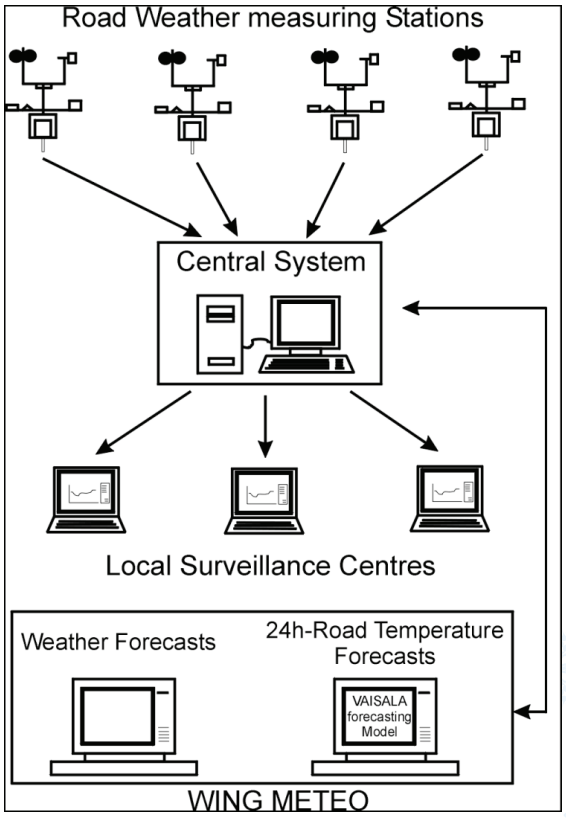
The same progressive spreader renewal is going on in the Brussels-Capital region (in winter 2009-2010, 90% of spreaders will be equipped for spreading wet salt), and since 2000 the Walloon road administration started new contracts with private contractors for winter maintenance operations that also include the rental of wet salt spreaders.

Road weather information system and method

Observations from road network inspections, those made by Road Weather measuring Stations (RWS), the weather forecasts supplied by the Belgian Air Force's weather section (WING) and those regarding road temperature, as well as knowledge of the features of the local road network are the main elements allowing the coordinator to make appropriate decisions in relation to winter maintenance.

The Road Weather Information Systems as a decision support tool

Principle: The RWIS allows for the automatic collection of data related to road surface conditions, as well as local meteorological data, and aims to improve road safety by anticipating the weather conditions likely to result in slippery roads.



Schematic diagram of a road weather information system

Two road weather systems are in operation in Belgium (Flemish and Walloon regions); on the whole, they are composed of the following:

1. 99 Road Weather measuring Stations (RWS) located along the Flemish and Walloon road networks. Each region was divided into relatively homogenous climatic areas and the RWSs were installed in strategic locations for winter maintenance. There are two types of RWSs, which differ in terms of equipment:

   - Primary stations (34): Essentially installed along roads with intense traffic, they are equipped, on the one hand, with atmospheric sensors measuring temperature and air humidity, wind speed and direction, the type, intensity and total precipitate volume, global and atmospheric radiation, and, on the other hand, with road sensors that measure changes in the road temperature on the surface as well as at depths of 5, 10 and 20 cm;

   - Secondary stations (65): Similar but smaller, they do not measure wind characteristics or road temperatures at depths of 10 and 20 cm, nor do they collect any data regarding radiation.

BELGIUM

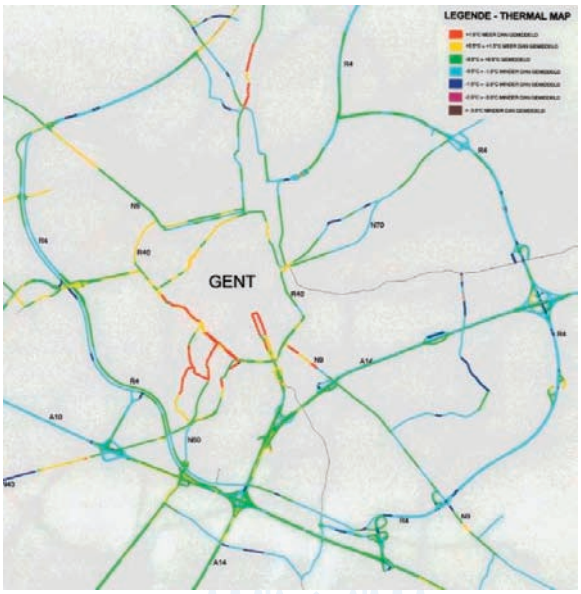
Primary RWS (left) along a Flemish road and secondary RWS (right) along a Walloon road

2. The central system downloads and archives data from each RWS every 6 or 10 minutes;

3. Observations are also transmitted to the WING (meteorological office), which provides weather and change forecasts regarding the road surface temperature. The former are provided at midday and cover a 24-hour period; these are adjusted if a deviation (> 1°C) from subsequent observations of the road surface temperature occurs. All the data observed and forecasts are made available to the districts via the "central system" and can be viewed through various graphs, tables and maps.

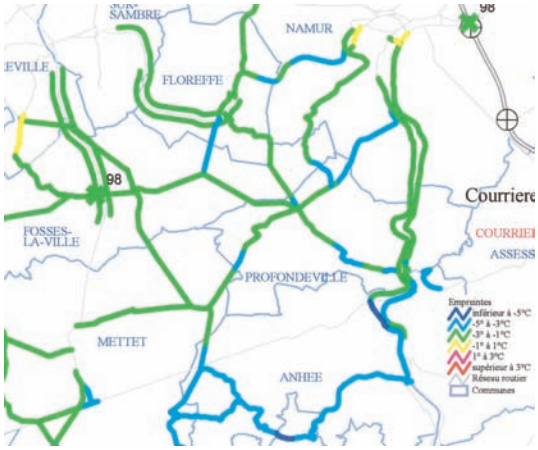
These components are also supplemented by a thermal mapping system to provide a more comprehensive decision support tool to the local manager. The thermal mapping (the thermal impressions were initially made with infrared thermometry using a vehicle operated on the network) makes it possible, within a homogenous climatic area, to determine simultaneously with local observations, under 3 standard sets of circumstances (overcast, clear sky or intermediate), the coldest and hottest areas of the road network.

In the Flemish region, these maps indicate for each weather condition the relative temperature (compared to an average temperature) of the road surface along the network, using a color-coded scale corresponding to increments of 1° Celsius. By combining these relative temperature maps with the forecasts made for each homogenous climatic area represented by an RWS, it's possible to establish a forecast (24 hours) thermal map of road surface temperatures.



Forecast thermal mapping for Flemish roads

In Walloon—where thermal impressions are partially updated every year—relative temperature maps are linked to the data observed by the RWSs to provide a real-time thermal map of the road network. These maps are also used by the traffic management centre to inform road users of the existence of colder areas.



Real-time thermal mapping of Walloon roads

BELGIUM

In the case of the Walloon region, all of these functionalities are grouped together in an application called Météoroutes. A new version of this application was developed (since 2004) using web technology to improve the accessibility and presentation of the data. This evolution made it possible to integrate new sources of forecast data (such as radar images and infrared satellite images, which provide a good view of cloud cover movements) and also a portion related to interventions in the field (organization and execution). Road and motorway districts now have a single, centralized application making it possible to consult real-time meteorological data, short- and medium-term forecasts, and the management of field operations, all at the same time.

3.3 Evaluation of winter maintenance measures

Cost and benefits of winter maintenance activities—measurement of effectiveness

All data regarding winter maintenance activities (forecasts, decisions, actions carried out, human resources and equipment used, work done by private contractors and salt consumption) are recorded daily in the districts. This information is then gathered by territorial or central divisions so as to present, every month for the entire winter period (October to April), all statistics regarding winter maintenance (road network to be maintained, means used, ice melter consumption, cost).

"Consumption" indices are currently used (see § 2.3 and 4.2).

Practices leading to additional cost reductions or to better environmental preservation—Methods to decrease the use of ice melters while maintaining service levels

The logging, analysis and reporting of data regarding the spreading of ice melters (quantities of salt, human and material resources used, costs, etc.) encourage all the players involved to contribute to saving money and the environment.

Yearly debriefings and additional training are also frequently organized between successive winter seasons.

Since 2000, with its new contracting system for winter maintenance with the private sector, the Walloon road administration has updated the fleet of spreaders operated on its roads. Today, the new (wet) spreaders owned by private companies are supposed to allow for more accurate salt spreading adapted to road conditions. However, before a multi-year contract is started, each machine must undergo a technical inspection to evaluate its technical characteristics and performance in terms of spread width and accuracy of dosing.

Overview of the initial technical inspection of spreaders (for wet (left) and dry (right) salt spreading) – Walloon region

Assessment of the maintenance—payment regulations

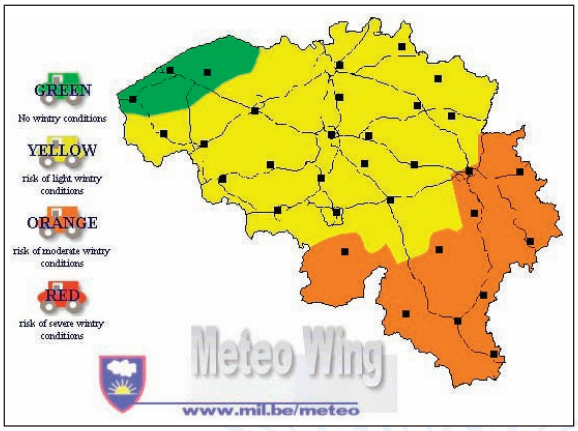
Interventions are mainly assessed as part of network inspections as well as in the analysis of the information collected by each district.

Maintenance work is paid on an hourly basis according to the number of work hours.

3.4 Road safety and information

Information for road users—Use of information technologies

The Belgian Air Force's weather section (WING) publishes bulletins on the Internet with weather forecasts relating to road conditions.



Example of a color-coded WING forecast available online (excerpted from http://www.mil.be/meteo/)

Regional road administrations also provide traffic information from their traffic management centers (three in Belgium). These centers control and manage traffic (sometimes including public transportation) around some cities and along regional road networks.

BELGIUM

Within these centers, data is collected using the following means:

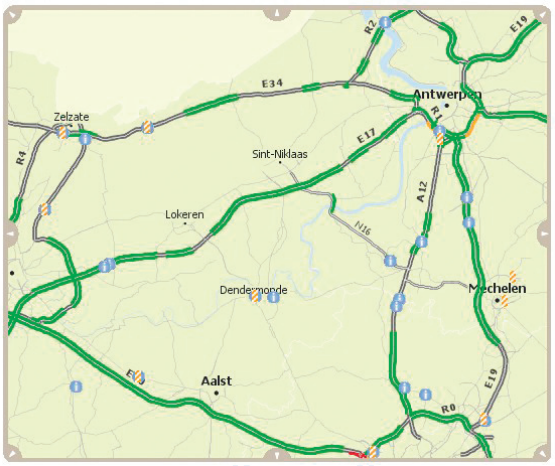
- Visual display of traffic: several hundred cameras placed in strategic locations along the network allow for traffic conditions to be monitored in real time;
- Counting devices: vehicle counting on motorways is usually done with the help of counting loops or specially designed cameras;
- User calls: roadside emergency telephones are placed at 2 km intervals along motorways. As well, call numbers are specifically devoted to calls from users wishing to report an event that may present a hazard or hinder traffic;
- Automatic Incident Detection;
- Information on road works;
- Weather information and winter maintenance: the Road Weather Information Systems of the Walloon and Flemish road administrations collect various types of data from the RWSs and, thanks to forecasts and thermal mapping, provide a valid decision-making tool for managers at the traffic management centre. Information about the spreading actions taken by districts is also sent back to the traffic management centre.

The traffic management centers circulate information to road users through various channels. As the information provided must be adapted to drivers' needs (real-time information, to prepare a journey, etc.) the following means are commonly used:

- Variable message signs (VMS): traffic signs are a useful means of communication between road managers and road users.

Variable message sign

- Radio and RDS-TMC system: radio broadcasters work closely with traffic management centers;
- Websites:
  http://www.bruxellesmobilite.be
  http://www.verkeerscentrum.be/
  http://routes.wallonie.be/trafiroutes



Traffic information concerning motorways in the Flemish region (excerpted from http://www.verkeerscentrum.be)
: congestion;
: dense traffic;
: normal traffic;
: no data; road works.

Locally, in particularly sensitive and dangerous areas, fog detection systems are used along the road, connected to variable message signs or light signals.

International exchange of road information

The automatic exchange of information between adjacent regions regarding traffic management is organized based on a standard European protocol (OTAP system).

4. Ongoing Research and Studies for the Improvement of Winter Management

As each regional administration develops its own winter management policy, the following chapters will present a (non-comprehensive) list of the most interesting studies and projects currently underway in the regions.

BELGIUM

New technologies

The road administration in the Flemish region has already equipped one-third of its spreaders with an automatic control system programmed using geographical coordinates as well as a tool to guide drivers based on features specific to each route. Spreaders with GPS antennae were purchased making automatic spreading with this in mind. This is a further step towards monitoring the environmental and budgetary effects of spreading activities as well as towards increasing road safety.

Furthermore, the first steps have been taken to implement a coordinated winter management system; such a system should be linked to a database connected to geographical interfaces.

The Brussels-Capital region road administration has produced a thermal map of its entire road network and plans to install several Road Weather measuring Stations.

In Walloon, another project is also in the initial stages, this one regarding the real-time positioning (GPS) of spreaders out in the field. In 2005, the Walloon region began a review of a data exchange standard protocol and the design of a common GPS signal transmission box so as to be able to manage data from various models of spreaders, mostly privately owned and accordingly each one operating with its own control box. The deployment of such a system (on a total of 300 machines) will be completed in winter 2009-2010. A visualization and operating system, called IRIS, was developed at the same time. It is composed of a "Map" module (for real-time tracking and route management), a "History" module (route and data associated with the service delivery) and a "Statistics" analytical module.

IRIS – Real-time map module

A subsequent phase is planned to allow for the more automated management of data relating to both the services delivered by private operators and those regarding salt stocks.

4.2 New management approaches

The Flemish administration also plans to establish a new service level plan and include in the maintenance contracts it signs with private contractors an outcome obligation, the latter to be based on user satisfaction.

Since 2005, the Brussels-Capital region also manages the spreading of ice melters on 72 km of off-street bicycle paths. This activity has grown significantly as cyclists expect winter maintenance similar to that practiced on roads. The goal is to make bicycle paths usable within 24 hours of a winter shower. The width of the bicycle paths requires the use of special vehicles. Studies are also underway to provide for snow removal on walkways, diversion parking lots, etc.

The Walloon road administration wants to develop quality standards and performance indicators associated with the harshness of winter. To this end, it uses two major computer programs: Météoroutes and NEVE, as well as a winter harshness road index (WHRI).

Météoroutes is the name given to the Road Weather Information System (see § 3.2). The NEVE computer tool is made available to the winter service coordinator and allows the latter to manage all issues associated with winter service with four categories of information: repositories, services rendered by the private sector and by the road administration, de-icer management, and statistics.

It is crucial for a road manager to quickly analyze whether the means (human and material resources) developed for winter maintenance are adequate in view of the meteorological reality. To this end, a winter harshness road index is calculated via Météoroutes at the end of each month and for each of Walloon's 51 Road Weather measuring Stations (primary and secondary).

The following formula is applied to quantify the harshness of winter:

$$WHRI = 1{,}07\ \mathbf{g} + 2{,}1\ \mathbf{n}$$

where **g** is the number of days of frost on the road surface (= effective days with a road t° $\leq$0°C) and **n** is the number of days of snow with a road t° <0°C. The factor of 1.07 is supposed to take into account the inaccuracy of weather forecasts; the factor of 2.1 is based on the hypothesis that a snow removal operation costs on average twice as much as a simple spreading.

This index is then used to link winter maintenance activities and their cost (NEVE report) to the harshness of winter (Météoroutes report), and then establish a cost-quality ratio.

BELGIUM

5. References

[1]: SNEYERS R., VANDIEPENBEECK M. [1995]. Notice sur le climat de la Belgique. Publication scientifique et technique N°002. Institut Royal Météorologique de Belgique

[2]: C.R.O.W. [1998]. Standaardisatie strooimachines – De juiste apparatuur voor elke specifieke situatie. CROW publicatie 131.

[3]: Moniteur Belge [05.01.2001]. DECEMBER 14, 2000. - Loi fixant certains aspects de l'aménagement du temps de travail dans le secteur public.

Contacts for more information:

x.cocu@brrc.be

thierry.decoux@spw.wallonie.be

planning.coordinatie@mow.vlaanderen.be

meteo.routes@mrbc.irisnet.be

Brussels-Capital region – Snow removal on a bicycle path (January 7, 2009)

CANADA

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Canada is the second largest country in the world and is surrounded by the United States and the Arctic, Pacific and Atlantic Oceans. Ninety percent of the population is located within 160 km of the US. The capital of Canada, Ottawa, is located in southern Ontario. Canada relies heavily on its exports that are responsible for approximately 30% of GDP; therefore, its highway network is important to its viability as a country.

Canada's National Highway

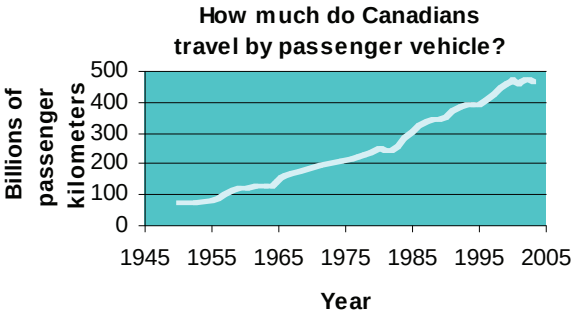
1.2 Road network and traffic

Area		9,093,507 km²
Population		31,946,316
Population Density		3.51 persons/km²
Length of Road (km)	1,408,800	Primary highways 102,700
		Secondary highways 114,600
		Local roads 1,191,600
On Road Vehicles	19,081,478	Passenger cars/light trucks 18,329,066
		Buses 77,447
		Vehicles over 4500 kg 674,964
Cars/trucks per 1000 persons		574
Latitude (capital)		45°25'N

Population & Density

	Sq km 000s	Population 000s	Pop. Density
Canada	9,094	31,946	3.51
Newfoundland and Labrador	374	517	1.38
Prince Edward Is.	6	137	24.36
Nova Scotia	53	937	17.57
New Brunswick	71	751	10.52
Québec	1,667	7,700	4.62
Ontario	918	12,393	13.50
Manitoba	554	1,170	2.11
Saskatchewan	592	995	1.68
Alberta	642	3,202	4.98
British Columbia	925	4,196	4.54
Yukon	474	31	0.07
Northwest Territories	1,183	43	0.04
Nunavut	1,936	30	0.02

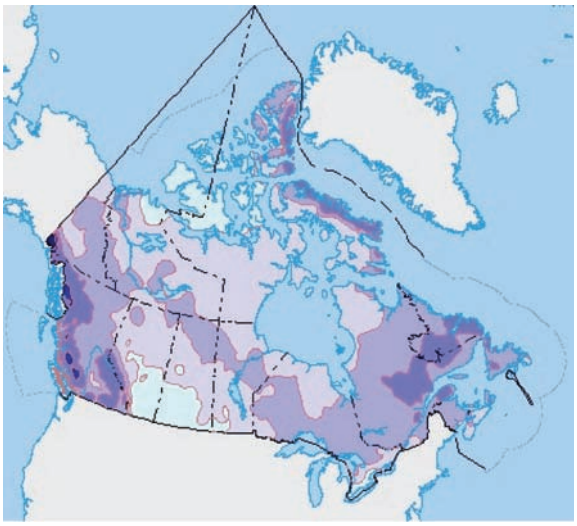
The following graph represents the general increase in passenger-kilometers traveled in passenger vehicles from 1945 to 2003.



CANADA

2. Climate

2.1 Overview of climatic areas



Less than 30 cm
30 to 49 cm
50 to 99 cm
100 to 199 cm
200 to 299 cm
300 cm and greater

This map shows the average maximum snow depth in centimeters computed over 18 winter seasons (1979 to 1997). Over southern Canada this usually occurs in January or February, while the time of maximum accumulation occurs much later in mountain areas and in the Arctic. The main features of the map are the pronounced maximum in snow accumulation over the western Cordillera, where snow depths can exceed several meters, with a secondary maximum over Québec and Labrador. These maxima are related to their proximity to oceans, which act as sources of moisture and winter storms, and to the orographic effect of the mountains in the case of western Canada. The two maxima are linked by a band of higher snow accumulation that follows the boreal forest zone; this is a preferred track for winter storms. To the north of this zone is the relatively shallow snow cover of the Arctic (low snowfall with extensive wind packing). To the south, the depth of snow is limited by the shorter accumulation season and the substantial sublimation of snow over the Canadian Prairies.

2.2 Statistics on winter temperature and precipitation

Average Minimum Temperature (°C)

City	Nov	Dec	Jan	Feb	Mar
Whitehorse	-13.0	-19.1	-22.0	-18.7	-12.3
Yellowknife	-17.7	-27.7	-30.9	-28.1	-23.3
Vancouver	3.1	0.8	0.5	1.5	3.1
Kelowna	-2.7	-6.4	-7.4	-5.5	-2.4
Edmonton	-8.2	-13.9	-16.0	-13.1	-7.3
Calgary	-8.9	-13.4	-15.1	-12.0	-7.8
Regina	-10.7	-18.5	-21.6	-17.1	-10.3
Winnipeg	-9.6	-19.1	-22.8	-18.7	-11.0
Toronto	-0.7	-6.7	-10.5	-9.7	-5.0
Ottawa	-2.8	-11.1	-15.3	-13.3	-7.1
Montréal	-2.2	-10.8	-14.9	-13.4	-6.9
Québec City	-4.3	-13.4	-17.6	-16.0	-9.4
Fredericton	-3.5	-11.4	-15.5	-14.1	-7.8
Charlottetown	-1.1	-8.1	-12.6	-12.4	-7.1
Halifax	-0.7	-7.1	-10.7	-10.2	-5.8
St. John's	-0.7	-5.5	-8.6	-9.3	-6.2
Goose Bay	-8.1	-18.3	-23.3	-21.9	-15.4
Iqaluit	-16.7	-26.9	-30.6	-32.2	-28.6

Based upon Canadian Climate Normals 1971-2000

Snowplowing in Canada's Maritime Provinces

CANADA

City	Mean Annual Snowfall (cm)	Mean Annual Days with Freezing Precipitation
Whitehorse	145.0	2
Yellowknife	151.8	11
Vancouver	48.2	1
Kelowna	101.8	2
Edmonton	123.5	8
Calgary	126.7	6
Regina	105.9	14
Winnipeg	110.6	13
Toronto	115.4	10
Ottawa	235.7	17
Montréal	214.2	13
Québec City	315.9	15
Fredericton	276.5	13
Charlottetown	311.9	17
Halifax	230.5	16
St. John's	322.3	38
Goose Bay	458.8	13
Iqaluit	235.8	6

based upon Canadian Climate Normals 1971-2000

2.3 Winter indices

The Transportation Association of Canada (TAC) has recently commissioned a project to develop a Winter Severity Index for Canada, thus enabling jurisdictions to evaluate a particular winter compared to past winters. This tool could also be used to give road maintainers better information to support the need for financial adjustments in their winter road maintenance programs, and to correlate the winter severity with respect to the use of road salts.

3. Winter Road Management

3.1 Standards and rules

The majority of road maintenance jurisdictions in Canada divide their road inventory into three or more winter service level categories. Each service level targets a different performance standard based on traffic volumes and road configuration. End result goals range from a snow-packed surface on minor roads through to a full bare width surface on high volume routes. Many jurisdictions now apply a maximum allowable time to target surface condition to their service goals.

Over the last decade official storm response policies have increasingly adopted anti-icing measures as a tool to reach target service levels using a minimum of deicing chemicals. The spread of Road Weather Information Systems (RWIS) coverage throughout the country has enabled a corresponding inclusion of liquid application techniques to anti-icing procedures.

Jurisdictions with high traffic volumes such as Ontario, have installed fixed anti-icing systems on some bridges and structures to defend against freeze-up.

Snowplowing in Canada © COREL Corporation 1994

Typical Canadian Level of Service Goals

	Expressways	Arterial Highways	Connector Roads	Local Roads
Maintenance Standard				
Surface Condition	Bare Pavement	Bare Pavement	Bare Centre Line	Snow packed with abrasive
Maximum Time to Level of Service	Within 4-12 hours after end of storm	Within 12 hours after end of storm	Within 12 hours after end of storm	Within 12-24 hours after end of storm
Snow Accumulation Trigger for Plowing	≥ 2 cm	≥ 2 cm	≥5 cm	≥8 cm
Material				
Salt	As Required	As Required	As Required	N/A
Sand	Surface Temperature ≤ -10 °C	Surface Temperature ≤ -10 °C	Surface Temperature ≤ -10 ° C	As Required

3.2 Organization and operation of winter maintenance

Typical Canadian RWIS installation

There are currently over 250 RWIS in operation in Canada. A coordinated effort between the provinces and territories, Transport Canada and Environment Canada will result in the installation of several hundred additional ESS over the next few years.

The federal government confirmed the following support for an integrated RWIS network for Canada:

a) Environment Canada is to provide core data services such as real-time data quality control, building a national integrated RWIS database, and providing numerical weather forecasts and other outputs; and

b) Transport Canada is offering up to 50% funding for the purchase and installation of a pro-rated number of RWIS sites installed along the National Highway System (NHS) of Canada.

Most provinces/territories are at some stage in the implementation of their portion of the national network. Some are now negotiating and signing agreements with both federal departments while others have been building for quite some time and still others are running trials or studies.

The provinces/territories have collaborated closely with Environment Canada, and benefited from the support of Transport Canada and Environment Canada on all aspects of the development of the national network: from the development (and acceptance) of common specifications for the RWIS equipment to common protocols for the exchange of data and metadata. Collaboration continues involving the university sector as well as non-government organizations (NGOs) like the Transportation Association of Canada (TAC) for the development of winter severity indices and standardized definitions for pavement surface conditions.

The provinces/territories hope to integrate more components of Intelligent Transportation Systems (ITS) into their winter maintenance with the goal of providing optimal road maintenance to the motoring public while reducing environmental impacts and costs. It is also expected that the national integrated data set will be a boon to the ITS industry in Canada and feed such initiatives as the national (North America-wide) dedicated road and weather information telephone line – 511.

With the implementation of a national RWIS network, Canada will be a world leader in large-scale, integrated road weather technology.

3.3 Assessment of snow and ice control measures

Provinces are moving to improve the management of road salt in their jurisdictions in conjunction with Environment Canada guidelines. Most Canadian transportation departments have turned to enhanced technology to assist in the effort. Material spreaders are almost universally being converted to computerized ground speed control to improve spreading accuracy and material usage recording. The use of automatic vehicle location (AVL) is increasing as agencies seek to pinpoint the location of chemical application and monitor plow routes. The installation of infrared sensors (IRS) on patrol vehicles to verify pavement temperatures and fine-tune chemical application rates is becoming commonplace.

Environmental Management of Road Salts: A Step Towards Sustainable Development

The arrival of cold weather and winter storms means that road authorities must take a variety of measures to maintain streets and roadways. Road salts are among the most commonly used solutions, as they are the primary de-icers used on roads. Indeed, nearly 5 million tonnes of road salts are used in Canada every winter.

In the context of sustainable development and given the need to ensure both the safety of Canadians on the roads and the protection of ecosystems, a better system for managing road salts had to be found. In Canada, the concept of sustainable development has been included in federal legislation, particularly in the *Canadian Environmental Protection Act, 1999*. The challenge is to promote a more effective use of road salts in order to reduce the amounts released into the environment, thereby reducing the contamination of ecosystems, crops and sources of drinking water.

Code of Practice

On April 3, 2004, Environment Canada published the *Code of Practice for the Environmental Management of Road Salts*. This Code, developed with the participation of municipalities and road authorities, recommends that stakeholders compare their current management of road salts with the practices recommended by transportation experts, particularly the *Best Management Practices* produced by the Transportation Association of Canada.

In addition to provinces and territories, the Code of Practice is intended for municipalities and other road authorities that use or are responsible for the use of more than 500 tonnes of road salts per year on public roads in Canada. It is also intended for municipalities and other entities that have vulnerable areas within their boundaries that could be affected by road salts (for example, wetlands along the roadside).

These areas are identified by municipalities and road authorities, possibly with the assistance of local and regional environmental organizations.

Typical examples of vulnerable areas include:

- wells of rural homes located close to highways or sites where salt is stored;
- provincial and national parks and wildlife preserves;
- areas close to waterways and wetlands;
- areas more susceptible to salt; and
- areas where certain farm products are grown; for example, orchards in the Niagara region in Southern Ontario.

However, other jurisdictions for which the Code is not intended are also encouraged to adopt best management practices that apply to their local conditions and to follow the Code.

The Code of Practice, developed in cooperation with municipal and provincial stakeholders, is a voluntary tool that allows the jurisdictions to implement solutions that are appropriate to their circumstances. The rates of compliance with the Code and implementation of the *Best Management Practices* over the next five years will determine whether stricter control measures will be necessary. Environment Canada has also created an environmental follow-up program to assess the progress made through the implementation of the Code.

CANADA

The many advances in winter road maintenance implemented by road administrations, in some instances together with federal government support, across Canada in recent years bode well for a future with increased mobility and winter motoring safety in addition to enhanced environmental performance.

British Columbia anti-icing truck

CANADA-QUÉBEC

snow and ice databook 2010

1. Demographics and Roads

Located in the northeastern portion of North America, Québec opens onto the Atlantic Ocean and extends from the border with the United States to the Arctic.

Geologically speaking, Québec can be divided into three major regions: the Canadian Shield, essentially composed of granite and ancient gneiss; the Lower St. Lawrence clay plain; and the extension of the American Appalachian Range, mostly composed of sedimentary rock. Québec's geography is relatively flat, rarely exceeding 900 meters in altitude. The northern portion of Québec presents tundra vegetation, with soil resting on more or less continuous permafrost. Further south is a taiga zone (299,900 km^2), followed by the boreal forest, home to highly diversified wildlife and vegetation (761,000 km^2).

Québec's river system is extensive and covers a total of over 355,000 km2. It can be divided into two distinct systems: one running east towards the Atlantic Ocean via the St. Lawrence River and its estuary, and one running west and north towards James Bay and the Hudson and Ungava bays.

The St. Lawrence constitutes a veritable route of entry into the North American continent. It is on the shores of this river that most Québecers have chosen to live. Although Québec is a pluralistic society, where various cultures live in close contact, 80% of its population speaks French. The inhabited portion of Québec is less than 1,000 km from the major urban and industrial centers of the northeastern United States, constituting a pool of over 100 million inhabitants.

Figure 1 – Québec road network

CANADA-QUÉBEC

Table 1 – Demographics and roads

Population of Québec	7,828,879 inhabitants (80% live in cities)	
Population of the metropolitan area	Montréal: 3,750,540 inhabitants	
Land area	1,667,441 km²	
Latitude	45° to 60°	Montréal: 45° 28 (80% of the population lives under latitude 47°)

In Québec, jurisdiction over transportation matters is shared by the federal and provincial governments. Accordingly, the road network is under Québec's responsibility, while the marine, air and rail sectors fall mainly under the jurisdiction of the federal government.

The ministère des Transports du Québec has established a road classification system, which serves as the basis for the day-to-day management of the network under its responsibility. This system makes it possible to categorize and group together roads based on their function and importance. This functional classification of the network is in accordance with those in effect in other Canadian provinces and in the United States.

The roads thus classified are used to link together the main concentrations of population, equipment and lands of national and regional importance (Table 2). Except for the local network, for which Québec's municipalities are responsible (106,800 km), these roads (Table 3) all fall within the MTQ's jurisdiction.

Table 2 – ministère des Transports du Québec 's functional classification

Classification	Characteristic
Motorway network	All motorway infrastructures.
National network	Interregional roads and those connecting major agglomerations. (> 25,000 inhabitants)
Regional network	Link between secondary agglomerations (5,000 to 25,000 inhabitants) and major agglomerations.
Collector network	Connects small agglomerations (< 5,000 inhabitants) to larger agglomerations.
Local network	Makes it possible to connect small agglomerations to one another and access private property.
Network for accessing resources	Leads to logging and mining areas, hydroelectricity workings and Crown recreational and conservation areas.

Table 3 – Network maintained by the ministère des Transports du Québec

Network	Length(1)	Mean AADT(2)
Motorway	(5,775 km)	14,424(3)
National	(8,892 km)	4,058
Regional	(5,513 km)	2 ,937
Collector	(7,819 km)	1,438
Access to resources	(1,437 km)	177
Total	(29,416 km)	

(1) **Length:** Weighted kilometer (two lanes).

(2) **AADT:** Average annual daily traffic. These volumes do not take local urban traffic into account.

(3) **Highway:** The result is weighted by dividing the AADT for the total number of lanes and the annual vehicle-kilometers by 2.57.

2. Climate

In terms of climate, Québec can summarily be described by the following elements:

- From the 45th parallel, to the south, to the High Arctic, Québec covers 15 degrees of latitude. Approximately 70% of the land area is located in a Nordic environment;
- Over this massive territory of 1,667,441 km² there are four types of climate: maritime, humid continental, subarctic and arctic. The continental climate characterizes Québec's most populated areas;
- The ground freezes for at least four months to a depth varying from 1.2 m to 3 m. In some areas, the frost period can even last from September to May;
- Daily temperature gaps can reach 25 °C;
- Winter is the longest season. It affects all of Québec's territory. Depending on the region, it can last on average 18 to 25 weeks, and the number of days of snowfall varies from 55 to over 120;
- Québec receives on average 300 cm of snow every year. In some mountain areas, accumulation can even reach up to 6 m.

Table 4 - Temperature and precipitations

	Montréal (alt. 36 m)	Québec (alt. 64 m)	Sept-Îles (alt. 55 m)	Gaspé (alt. 34 m)
Ave. annual T° (°C)	6.1	4.0	0.8	2.9
Ave. T° in January (°C)	-10.4	-12.8	-15.3	-11.9
Ave. T° in July (°C)	20.9	19.2	15.3	16.6
Days without frost (T° > 0°C)	210	189	163	162
Annual rainfall (mm)	760	924	757	752
Annual snowfall (cm)	214	316	412	380
Days with snow (s)	80.6	107	119	106

3. Winter Road Management

3.1 Legislative and normative frameworks

The *Act concerning Roads* provides the framework that guides the ministère des Transports in carrying out its mission. This framework addresses the sharing of the road network's management with the municipalities. In particular, it establishes the MTQ's jurisdiction over roads decreed by the gouvernement du Québec and defines the powers and obligations associated with the management of these roads. The MTQ's responsibilities in terms of winter maintenance are defined in Section 14 of the Act.

Service levels

In winter period, the ministère des Transports du Québec determines the service levels for the road network under its responsibility based on two main criteria: the functional classification of the network and the average winter daily traffic (AWDT) recorded.

Table 5 – Determination of service levels

Functional classification	AWDT	Service level
Motorway	–	Clear road(1)
National road	> 2,500	Clear road(1)
	≤ 2,500	Partly clear road(2)
Regional road	> 2,500	Clear road(1)
	≤ 2,500	Partly clear road(2)
Collector road and access to resources	> 2,500	Clear road(1)
	from 500 to 2,500	Partly clear road(2)
	< 500	Road with a hard snow base(3)

(1) Roadway whose traffic lanes, including shoulders, are free of snow and ice over the entire width.

(2) Roadway whose traffic lanes are free of snow and ice over a width of 3 m in the straight sections and over a width of 5 m in critical areas.

(3) Roadway whose traffic lanes and shoulders are on a hard snow base at most 3 cm thick.

Quality standards and performance indicators

In the past few years, the ministère des Transports du Québec has implemented various measures to improve its winter maintenance performance. Accordingly, in response to the issues dictated by the Public Administration Act in May 2000, the MTQ undertook in 2002 a major process to design and use a winter maintenance performance indicator (ref. 3.3). It is also evaluating a winter severity index allowing it to establish an objective comparison of the severity of winters from one year to the next and their impact on the maintenance efforts deployed.

Materials

The extent of the road network and the need to ensure a safe and effective supply to the many service points found there prompted the MTQ to establish a contractual agreement through which it entrusts a single service provider with the supply of a major portion of the sodium chloride (rock salt) it uses to maintain the network. This agreement namely sets the technical characteristics that this product must meet to comply with MTQ requirements. These characteristics are drawn, among other things, from the standards in effect in North America.

CANADA-QUÉBEC

Table 6 – Requirements for de-icing salt

Grading screen	Minimum (passing %)	Maximum (passing %)
12.5 mm	—	—
10 mm	95	100
5 mm	20	90
2.5 mm	10	60
630 µm		11

Table 7 – Grading range specifications for abrasives

Grading screen	AB–5 (passing %)	AB–10 (passing %)
10 mm	–	100
8 mm	100	–
5 mm	85–99	95–100
2.5 mm	1–15	–
1.25 mm	0–5	0–70
630 µm		0–50
315 µm		0–35
160 µm		0–15
80 µm		0–5

AB–5: *Type well suited to abrasives composed of crushed stone and the grading range.*
AB–10: *Abrasives composed of sifted sand, crushed stone or crushed or uncrushed gravel.*

In terms of regulations, the Government of Canada published on April 3, 2004, under the Canadian Environmental Protection Act, a code of practice inviting road administrations to implement measures to reduce the environmental damage caused by road salt. Québec has its own environmental protection legislation containing in particular regulations governing the elimination of waste snow.

Furthermore, when it adopted its Sustainable Development Act in April 2006, the gouvernement du Québec instituted, within public administrations, a management framework to ensure that powers and responsibilities would be exercised in the pursuit of sustainable development. It is within this framework that the ministère des Transports du Québec tabled, in May 2009, its action plan titled *2009-2013 Sustainable Development Strategy*. With this strategy, the MTQ undertook in particular to coordinate the development of a Québec strategy for the environmental management of road salts, to be accompanied by a plan for the environmental management of road salt implemented within the ministère des Transports as well as by other network managers (cities and municipalities). For the MTQ, this management plan was established in 2008 and specifies the key objectives it adopted for the environmental management of road salt.

Equipment

In Québec, the Highway Safety Code (HSC) governs the use of vehicles on public roads and in particular sets the framework for the use of chains and studs on tires on the road network. Their use is authorized from October 15 to May 1st and is limited to certain vehicle categories. In October 2008, regulations on the use of tires designed specifically for winter driving took effect in Québec. This obligation covers the period of December 15 through March 15 and affects all passenger vehicles registered in Québec, including taxis.

Table 8 – Studs, chains and winter tires – Authorized vehicles

Device	Authorization
Studs	Commercial and passenger vehicles with a gross vehicle weight not exceeding 3,000 kg (1)
Chains	Emergency and snow removal vehicles
Winter tires	Passenger vehicles (1) and taxis registered in Québec, including rental passenger vehicles

(1) Transportation capacity of not more than 9 people.

Equipment assigned to network maintenance

As all motor vehicles in Québec, the equipment assigned to winter road maintenance and its use is subject to the HSC and to various other laws and regulations:

- The Act respecting owners, operators and drivers of heavy vehicles establishes the framework for road transportation by introducing an administrative system for the registration of owners and operators of heavy vehicles, assigning safety ratings as well as imposing penalties in the event of offences;
- The Regulation respecting the hours of driving and rest of heavy vehicle drivers forces the operators of heavy vehicles to submit to a monitoring of the hours of driving and work performed. Accordingly, to ensure public safety and make it possible to clear roads of snow accumulations and spread deicers or abrasives, the driver of a snow removal truck may drive up to a maximum of 15 hours per work shift. However, he or she must comply with certain rules, including the following:

Table 9 – Snow removal – Hours of driving and rest

Obligations	Rules
Stop driving if the number of consecutive hours worked is:	> 16 hours
Number of consecutive hours of rest before starting a new work shift	≥ 8 hours
Number of hours of turn around time during a 3-day period during which 3 work shifts are worked	≥ 30 hours
Number of hours of driving over the 3 work shifts	≤ 39 hours

Hours of driving: Hours during which the driver is in control of a heavy vehicle with the engine on.

Hours of work: Period of time that includes the hours devoted to driving and various duties.

As well, the owners or operators of heavy vehicles must perform a visual and auditory inspection of certain components of their vehicle to prevent accidents that could be caused by the vehicle's poor condition;

- The Regulation Respecting Vehicle Load and Size Limits applies to road vehicles and combinations of road vehicles primarily to ensure the safety of the road's users and protect road infrastructures (bridges and roads). This regulation sets various standards limiting, among other things, the size and load of road vehicles operated on public roadways. In addition, in the spring, to take into account the reduced load-bearing capacity of the road network during the thaw period, it imposes load restrictions in accordance with three defined areas. Depending on changing weather conditions, the start and end of the load restriction period may be moved up or pushed back.

Figure 2 – Load restriction areas

3.2 Organization and operation of winter maintenance

The ministère des Transports' organizational structure is largely decentralized. It includes in particular two operational directorates in charge of 59 service centers geographically distributed across 14 distinct territories throughout Québec. These territorial units benefit from significant autonomy in terms of resource management and they work together with the regional and municipal organizations present in the community.

The responsibility for the network's maintenance falls directly to the service centers, most of which establish contractual agreements either with the private sector (for 68% of the network) or with the interested municipalities (for 13.5%). The MTQ is responsible for maintaining 18.5% of the network. For everyday maintenance work, the MTQ, like the private sector, encourages the use of three-axle trucks.

Table 10 – Snow removal truck

Basic characteristics	Specifications
Rear axle capacity	18,000 kg
Front axle capacity	9,000 kg
Gross vehicle weight	27,000 kg
Motor	Diesel: 223 kW minimum
Rear suspension	Pneumatic
Chassis frame	Single piece
Spreader	9 m^3
Snowplow wing	3,658 mm
One-way snowplow	3,048 mm
Front mount	Yes

This type of vehicle is called "multifunctional" because it makes it possible to (alternately or simultaneously) carry out both snow removal and de-icing operations on the network. This multiple functionality facilitates the synchronization of operations and ensures increased effectiveness. These vehicles are also equipped with a spreading regulator and, since 2009, light signals specific to snow removal operations. The implementation of these new measures, which aim to improve the visibility of this type of equipment, will be completed on all trucks working for the MTQ by 2011.

CANADA-QUÉBEC

Naturally, snow removal contracts are awarded by the ministère des Transports following a regulated process. Such contracts are awarded either through a call for tenders from the private sector or negotiated with municipalities, also network managers (106,800 km).

These contractual agreements, essentially based on a measure of the outcome, are established for one year and include a renewal clause, generally for two additional years. Because the tendered (or negotiated) price is all-inclusive, the efficient contractor (municipality) can keep the contractual agreement with the MTQ in effect for a maximum period of three years. This approach allows the contractor to better distribute the financial risks inherent to the performance of the contract and the severity of the winters. These agreements generally provide for the supply of materials necessary for the maintenance of the network by the contractors (salt and abrasives).

To supplement its maintenance equipment, the MTQ rents snow removal trucks with operators. The latter report directly and only to the MTQ and are integrated in existing maintenance teams.

Operational management

The partnership on which the MTQ relies for the network's maintenance is based on clear expectations regarding the expected results. Accordingly, depending on the type of network maintained, within each contract granted (administrative and technical documents) are specific requirements regarding snow removal, de-icing and network patrols.

The MTQ monitors the entire network for which it is responsible to ensure compliance with the prescribed expectations. To orient this exercise and guarantee consistency in network monitoring practices, the MTQ defined, through its territorial branches, management frameworks for monitoring winter maintenance work. Also, the MTQ is working to deploy, in a limited way, integrated centers of monitoring (ICM) for the network. Using adapted technology, these centers monitor road weather conditions in support of the management of operational activities carried out on the network.

Road closures

The ministère des Transports may decide to temporarily forbid traffic from circulating on a road to ensure motorists' safety. This decision is always taken jointly with emergency preparedness authorities, municipalities and the police forces concerned. The MTQ alone can decide on the right time to restore traffic.

Cooperation between network managers

The diversity of winter issues encountered across Québec and Canada territories and the multiplicity of stakeholders involved in this matter require ongoing coordination efforts. In order to promote the exchange of knowledge and training in this field, the ministère des Transports works closely with other network managers facing similar issues. This collaboration leads to productive discussions within technical committees (Aurora) and transportation associations, such as the Transportation Association of Canada (TAC), the World Road Association (PIARC) Technical Committee on Winter Service and the Association québécoise du transport et des routes (AQTR).

It is in the spirit of pooling knowledge and experience that the ministère des Transports, in partnership with the AQTR, directs the Winter Service Technical Branch. The aim of this group, composed of representatives from Québec's major cities and the snow removal industry, is to share practices in the field and in particular the results of the work of the PIARC Technical Committee B5 on Winter Service. The MTQ also continues its collaboration with the ministère français de l'Écologie, de l'Énergie, du Développement durable et de la Mer (French Department of Ecology, Energy, Sustainable Development and the Sea) through a common process addressing the environment's vulnerability to road de-icers. Through their mutual efforts, these two departments hope to develop and test methodological tools to identify and evaluate areas vulnerable to de-icing salts and reduce the environmental pressure caused by these salts.

CANADA-QUÉBEC

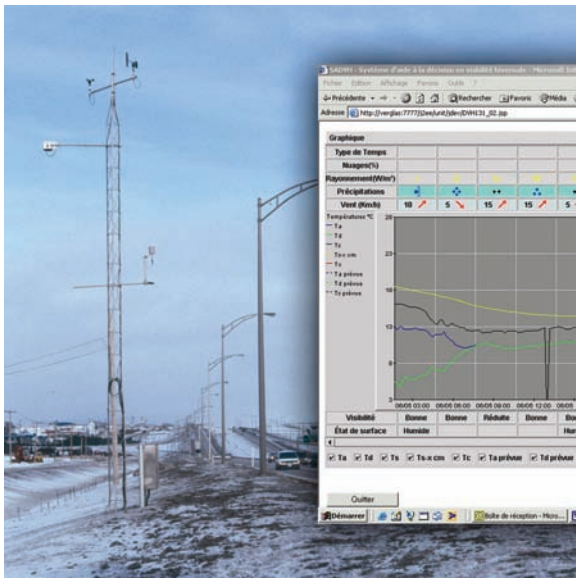


Figure 3 – Road weather station and DVH-6024 system

Road weather and training

• Fixed road weather station

Thanks to its open-architecture design, the station developed entirely by the ministère des Transports offers much flexibility regarding the selection of the various sensors of which it is composed. This station accurately measures the main meteorological and road parameters that have an impact on variations in road conditions. It also provides data for the decision-making process leading to the establishment of the spring load restriction period on Québec's road network. Two types of stations have been developed: one offers a complete range of measurements (see Table 11); the second is a streamlined, less expensive station limited to measuring only certain targeted road and weather parameters. These technologies were implemented following a cautious approach so as to determine the associated benefits and allow for the consolidation of the instrumentation included in these facilities. In the fall of 2008, the MTQ's network of road weather stations included 35 stations. The MTQ intends to enhance its existing network with the addition of 13 new stations by 2011. In order to facilitate the management and interpretation of the data collected, a computer system (DVH-6024) was developed and implemented for the operational staff. The forecast (meteorological and road [Ts]) component is integrated in the DVH-6024 system; the meteorological forecast portion was entrusted to the private sector via a call for tenders.

• Mobile road weather station

Designed by the ministère des Transports du Québec, mobile road weather stations supplement the information collected by the fixed stations. This equipment installed on the MTQ's patrol vehicles provides an accurate portrait of the road surface's behavior along the entire route travelled by the patrol vehicle. The interpretation of the various measured parameters allows the vehicle's operator to anticipate the formation of ice on the road and correct the spreading strategy if required, based on the data collected.

Figure 4 – Mobile road weather station

Table 11 – Functionalities – Fixed and mobile stations

Functionalities available	Fixed station	Mobile station
Wind intensity/ direction	Yes	No
Precipitation intensity/ type	Yes	No
Air temperature (T_a)	Yes	Yes
Relative humidity (U)(1)	Yes	Yes
Atmospheric pressure (P)(1)	Yes	Yes
Dew point calculation (T_d)(1)	Yes	Yes
Surface conditions - freezing point (residual brine)	Yes	No
Road surface temperature (T_s)(1)	Yes	Yes
Residual brine concentration	Yes	No
Frost front propagation in the road foundation(1)	Yes	No
Geographical positioning of data	N/A	Yes
Data display - real time	N/A	Yes
Data retrieval for analysis	N/A	Yes

(1) Streamlined station

To support the implementation of this deployment, a network of winter service instructors was established within the MTQ's territorial branches. Furthermore, in collaboration with the Association québécoise du transport et des routes (AQTR), the MTQ set in motion a winter service training action plan, which includes a section specifically covering road weather. These technical training sessions are accessible to everyone working in the field of winter maintenance in Québec.

3.3 Evaluation of winter maintenance measures

The vastness of the territory and the diversity of Québec's economy have made the province's road network both elaborate and very much in demand. The openness of the economy, the volume of exports to the North American market and the provision of natural resources and manufactured products from outlying areas are all factors that explain the road network's vital role in Québec's economic development.

Table 12 – Québec's economy in numbers

Gross domestic product (2006)	$235 B
Largest trading partner	United States
Proportion of international exports to the United States	90% ($56 B)

Note: According to the grid designed to interpret the results, a rate of between 90% and 95% shows that the contractor effectively met the requirements.

To ensure their sustainability in the 2008-2009 winter season, the ministère des Transports devoted over $248 M ($CAN) to direct operations on the road network under its care. Aware of the economic and social issues associated with snow removal on the network and the challenge presented by its management within the context of the scarcity of resources, the MTQ undertook:

- with the snow removal industry, to reposition and define a better balance with respect to the associated risk. This new sharing led in particular to reduced contract terms and the use of different management approaches in the transition periods between seasons;
- to measure the compliance of the services provided by contractors with the requirements and specifications mentioned in contractual documents. Accordingly, each winter maintenance route maintained by private contractors under contract with the MTQ (≈ 68% of the network) is evaluated according to a grid containing service quality criteria relating to the quality of the snow removal and de-icing service provided, the quality of the communication and collaboration, as well as compliance with the deadlines specified in the contract. This measure is the subject of a target (100% of winter maintenance contractors who meet the prescribed requirements annually) contained in the MTQ's 2008-2012 Strategic Plan. Through this approach and those associated with the surveillance and monitoring of its network, the MTQ ensures that, in the field, the quality of the highway system's maintenance continues to comply with very high quality requirements so as to ensure safe and functional transportation. Accordingly, since 2005, the MTQ has integrated this indicator in its annual management report, a report that is tabled in compliance with the provisions of the Public Administration Act to the President of the Assemblée nationale du Québec.

Table 13 – Indicator – Results achieved

Result	Rate of compliance with winter road maintenance requirements
2005-2006	90%
2006-2007	93%
2007-2008	91%

The ministère des Transports du Québec also intends to revise its policy to adopt a departmental framework for winter service management that sets key objectives for the network's management during the winter season. It also needs to integrate environmental protection issues. By this approach, the MTQ intends to legitimize and consolidate the efforts deployed and the means established to promote the effective management of deicers and, eventually, decide on its orientation in terms of the evolution of practices.

3.4 Road safety and user information

For many years the ministère des Transports has conducted information and advertising campaigns on road safety in winter conditions. Using an informative approach, this campaign aims in general to encourage the road network's users to be cautious by raising their awareness of the risks inherent to winter driving, which requires a change in habits. These campaigns are also an opportunity to inform the population of the limits of winter maintenance operations. The means used for such communications include messages broadcasted on the radio, information capsules integrated in weather and traffic reports, as well as postings on road network panels.

In addition to its communication activities, the ministère des Transports offers the public and users of the road network a greater opportunity to learn about winter road conditions. To facilitate access to this information at any time, both on the Internet and by telephone, the MTQ has made available since 2008 the Québec 511 Info Transports service, which resulted from the enhancement and modernization of the former Inforoutière service.

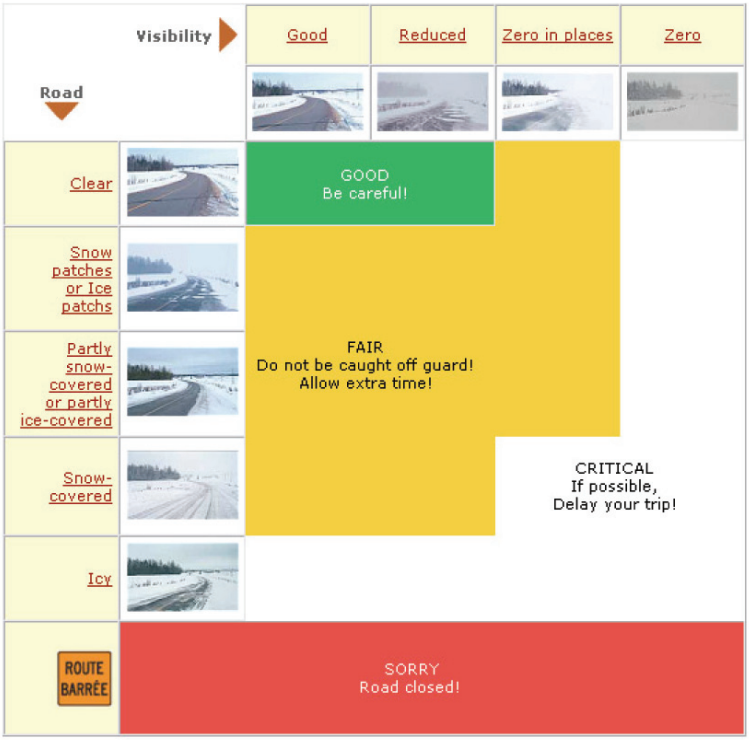


Figure 5 – Road conditions terminology

It also defined specific terminology to inform users of road conditions.

Road conditions are the result of surface conditions and visibility. A four-color code (green, yellow, white and red) is used to provide a visual translation of the road conditions which motorists must take into account in their driving. Key messages are also provided to road users.

Concerned with providing quality information to users of the winter road conditions service, the MTQ implemented a mechanism to verify the information delivered to the population in order to detect potential anomalies in the system and obtain feedback on which it can make corrective actions.

The ministère des Transports du Québec is responsible for the highway system's operation and, as such, must assume a significant share of the responsibilities associated with the assistance to be given to users in trouble and managing the risks associated with these emergency situations. With this in mind, the MTQ published a guide for its staff called upon to help road users in trouble, containing various tips on effective and safe ways to act in such circumstances.

Integrated traffic management centre

Intelligent transportation systems (ITS) are new technologies used to improve the management and operation of transportation systems as well as services to road users. Such systems are used within the MTQ through the integrated traffic management centers (ITMC). Through improved knowledge of the network's usability, these centers increase user safety and the free flow of traffic, in particular during the winter period when conditions can be difficult. Combined with various management tools, the cameras and variable message panels used provide real-time information directly to users on problems arising on the network in winter.

As well, on networks with specific difficulties (e.g., high-volume and high-speed traffic; major wind corridor), a simple preventive approach with the user is possible using pace vehicles or through the establishment of devices forbidding access to portions of the network deemed risky.

4. Ongoing Research and Studies

4.1 New technologies

Today, technology offers a range of means to obtain accurate real-time information from the road network. Like many network managers, the MTQ examines the possibilities offered by this new method by implementing projects of a technological nature. Here are a few examples:

- The deployment and use of on-board equipment for vehicles used in particular for snow removal operations and network surveillance. The purpose of the latter is to record all road and/or operational information (coverage rate, etc.), and transmit the latter in real or non-real time to an integrated network management centre (vehicular data communication [VDC]);
- The utilization of an experimental fixed, open-architecture road weather station to measure the full potential of various sensors and technologies applicable to the field and available on the market;
- The measurement of continuous grip using light-weight equipment;
- The testing of various devices likely to improve visibility and the operation of snow removal equipment.

4.2 New management approaches

The MTQ is in the process of examining the management approaches currently used. To this end, it is trying out new contractual approaches aimed at sharing risks differing from those generally identified for snow removal and de-icing work on its network. In this way, using adapted technology, the MTQ hopes to better control maintenance costs on its network and foster the integration of new contractors on the snow removal market. In the same light, it is pursuing its efforts to design a flexible measuring tool that would make it possible to objectively compare the severity of winters from year to year and their impact on the maintenance efforts needed to keep the road network viable and safe.

4.3 Transcontinental and international cooperation

Given the importance granted by users to information on road conditions in winter, and armed with the expertise developed in this field, the ministère des Transports du Québec, jointly with the Transportation Association of Canada (TAC), wants to define a common terminology for winter road conditions so as to provide consistent and comparable information across Canada to the network's various users.

From a more technical point of view, the MTQ is currently defining a collaborative project on the environmental vulnerability to road de-icers. Accordingly, the ministère des Transports du Québec wants to develop and test, in collaboration with France's ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer responsible for the transportation aspect, methodological tools to identify and evaluate areas vulnerable to road salts.

For the ministère des Transports, imagination and research constitute a dynamic response to the challenges presented by Québec due to its expansive territory and harsh climate. It is by focusing on these elements in particular that the MTQ plans to improve the performance of transportation systems.

5. References

Gouvernement du Québec (www.gouv.qc.ca).

Ministère des Transports du Québec (www.mtq.gouv.qc.ca)

Société de l'assurance automobile du Québec (www.saaq.qc.ca)

Développement durable, Environnement et Parcs (www.mddep.gouv.qc.ca)

Transportation Association of Canada (TAC) (www.tac-atc.ca)

Association québécoise du transport et des routes (AQTR) (www.aqtr.qc.ca)

BOURQUE, A., and G. SIMONET. "Québec," in *Vivre avec les changements climatiques au Canada*, 2007 edition, D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush (eds.), Government of Canada, Ottawa (Ontario), 2008, pp. 171-226.

Management information book - April 2009 - ministère des Transports du Québec.

National Climate Data and Information Archive - Environment Canada (www.ec.gc.ca)

CZECH REPUBLIC

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

The Czech Republic is a medium-sized country (78,867 km^2) but densely populated (10.46 million), situated at the center of Europe. The landlocked country borders Poland to the northeast, Germany to the west, Austria to the south and Slovakia to the east. The capital and largest city is Prague (Praha). The country is composed of the historic regions of Bohemia and Moravia, as well as parts of Silesia. Since 2000, the Czech Republic is divided into thirteen regions and the capital city of Prague. The Czech Republic has been a member of the European Union since 2004.

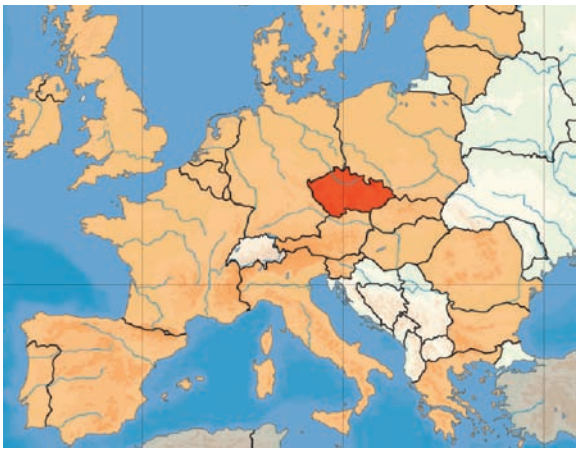


Figure 1 – position of the Czech Republic in Europe

The Czech Republic possesses a developed, high-income economy with a GDP per capita of 84% of the European Union average. The economy prosperity of the Czech Republic relates to the high level and quality of the transport infrastructure. With the density of 0.70 km of roads and motorways per 1 square km the Czech Republic ranks among the leading European countries.

1.2 Road network and traffic

The road network comprises 633 km of motorways, 329 km of expressways and 54,621 km of regional and local roads, amounting to a total of 55,583 km of paved roads. Road transport accounts for 76.04% of total freight transport. The national fleet of 4.9 million vehicles includes 4.1 million passenger cars.

Area	78,867 km²	
Population	10.46 million	
Length of roads	Motorways	633 km
	Expressways	329 km
	Roads class I	5,843 km
	Roads class II	14,660 km
	Roads class III	34,118 km
	Amount in full	55,583 km

Table 1 – Road network

Winter season in the Czech Republic, according to the Road Law is the season between November 1 and March 31 of the following year.

2. Climate

2.1 Overview of climatic areas

The Czech Republic is a landlocked country located in moderate geographical latitudes in the Northern hemisphere. The climate of the Czech Republic is mild but variable locally and throughout the year. The climate differs markedly among the various regions of the Czech Republic, depending on the height above sea level.

CZECH REPUBLIC

2.2 Statistics on temperature

The average air temperature is strongly dependent on the height above sea level. When the temperature on the highest mountain in the Czech Republic (1,602 meters) is only 0.4 °C, the lowlands of southeast Moravia can experience temperatures of almost 10 °C. The annual rainfall is also markedly dependent on the height above sea level. If we want to find the rainiest area in the Czech Republic, we would have to look to the highest mountain range with steep slopes facing northwest. The average total rainfall there is in excess of 1,200 millimeters.

December, January and February are counted as the winter months. The coldest of these is January, when even in the lowlands the average monthly temperature falls below 0 °C. If there is any precipitation in winter, it is usually snowfall in the mountains. In the lowlands it can alternately rain and snow. Snow coverage usually lasts for several months at higher altitudes above sea level. However, during March, April and May, there is a sharp increase in temperatures. Snow coverage usually disappears in the mid-spring, even in the highest mountains of the Czech Republic.

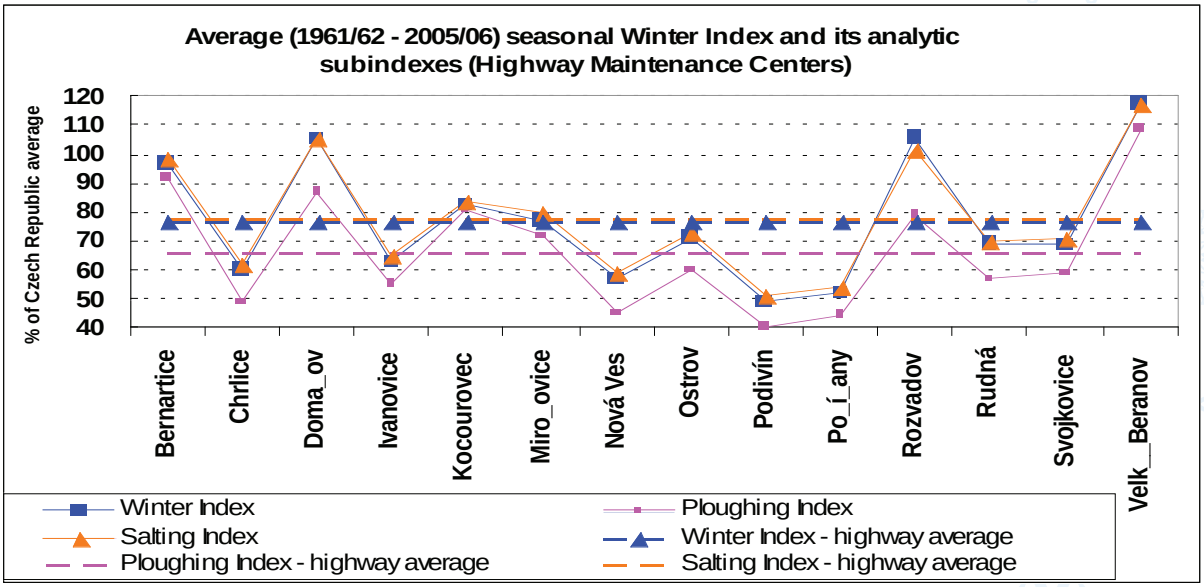


Figure 2 – winter index and its sub-indexes, comparison between different maintenance centers

2.3 Winter indexes

Winter Index (WI) is a unique system of deep analysis and comparison of road winter maintenance performances and costs. The users of this system are mainly administrators responsible for covering the maintenance costs but also contractors of winter road maintenance. WI exactly describes winter conditions on a selected territory in a period of time and compare the real cost of road winter maintenance.

Road and Motorway Directorate of the Czech Republic uses WI for evaluation of winter maintenance effectiveness and performance of particular centers of motorway management and maintenance in cooperation with a company Cross Zlin and the Czech Hydrometeorological Institute.

WI is a system of analysis and comparison of road winter maintenance performances and costs depending on real meteorological conditions at a defined road and highway network. The main activities that are monitored are:

- salting (or gritting) the roads and consumption of salt and other materials;
- snow removal (plowing);
- inspection routes.

There is direct linkage between current weather conditions and extent of above mentioned parameters.

CZECH REPUBLIC

When winter conditions become more severe (snowfall, temperatures around zero, freezing rain, ice on the road, etc.) it is necessary to employ more maintenance vehicles and use larger amounts of salt that represent the major item in winter maintenance expenses. WI is a unique tool that enables retroactive control of road maintenance performances and comparison of maintenance level between different centers of maintenance or contractors. Based on this analysis it is possible to detect divergences from the standard level and separate any isolated or long-time anomalies and unjustified raising of costs.

At figure 2 is presented the usage of the winter index in the form of its graphical output. Performance of particular centers of motorway (highway) management and maintenance is evaluated there.

3. Winter Road Management

3.1 Standards and rules

Winter maintenance in the Czech Republic is regulated by Road Law no. 13/1997 and by Ministry of Transport regulation no. 104/1997, valid for act on Road Law.

The Road and Motorway Directorate of the Czech Republic (RSD) performs the winter management and maintenance for 715 km of motorways and for some expressways. The regional administrators manage the winter maintenance for the other roads. In 2004, the RSD published *"Winter management and maintenance regime"* and in 2007 *"Technological procedure for winter maintenance of motorways and expressways"*.

3.2 Organization and operation of winter maintenance

Winter maintenance reduces climate and winter conditions effects on road serviceability by their importance. In a winter situation the road administrator eliminates or at least reduces problems in road serviceability according to the schedule set in the winter maintenance plan and regulated by the Road Law.

It means that the road administrator removes snow and ice from roads with the help of special machinery. Snow exceeding 3 cm of height is removed by snow plow. Frost, ice and snow up to 3 cm of height is removed with the help of deicing agents. We distinguish just plowing, just chemical materials spreading, and both activities carried out simultaneously. Separately, we consider regular checks of roads serviceability.

Sixteen Centers of motorway management and maintenance (SSUD) and one Center of expressway management and maintenance (SSURS) are managed by RSD and form the basis of the winter maintenance on the motorway. One center SSUD performs the winter maintenance for roughly 50 km motorways, i.e., for roughly 1,000 thousand km^2 pavements.

Each SSUD equipment and facilities for winter maintenance consist of:

- 6-8 fully equipped vehicles with spreader dripping brine and with a snowplow;
- salt storehouse (NaCl) containing up to 2,000 to 3,500 tonnes. The storehouse is usually designed for the whole year consumption;
- brine center which consists of a plant producing brine (aqueous solution of sodium chloride) and two storing tanks and tanks for concentrated solution of calcium chloride (the brine is used for applying on the spread salt);
- loader, a mechanism with about 1.5 m^3 bucket loading salt into spreaders;
- control office in SSUD building with radio connection to working spreading vehicles, telephone and access to meteorological information (cameras monitoring, etc.).

Other facilities and equipment of the centers are shown in "Regime of administration and maintenance". Description of systems related to winter maintenance such as meteorological stations, warning signs and camera systems are shown in *"Regime of road signing and marking and facilities administration and maintenance"*.

Users' requirements are mostly very high. They demand fast and safe use of roads and if possible completely without snow, i.e., "black" throughout their whole length. Demands for maintenance quality, driving comfort, safety and speed are higher and higher.

Road managers try to meet this demand by using high performance equipment, the meteorology agency, installing meteorological sensors, and by performing mutual alerts, etc. Similarly, the use of increasingly better performing spreading materials associated with theses technologies allows the combined use of salt and brine to facilitate the service offering. The ARA also uses inert materials (crushed stone) on a 1.6 km section of Autoroute D2, due to a prohibition against using de-icing chemicals in order to maintain the quality of the water.

CZECH REPUBLIC

Direct winter maintenance operations consist of: road weather situation check-ups, salt spreading, snowplowing (snow removal), snow cutting, and simultaneous spreading and snowplowing. This is the reason for motorway administrator to prepare as best as possible for unpredictable winter conditions.

In respect to winter maintenance, each SSUD design takes into account the length of 50 - 60 km. The spreader vehicle which leaves SSUD (located in the middle) should get to the end and come back and managed with a normal load of ordinary use of salt per 1 square meter. The length is selected so that the drive would not take more than 2 hours.

Winter maintenance is carried out according to SSUD Winter Maintenance Plan. Organizational structure guarantees that personnel have non-stop service and workers (including the controller) take turns in regular shifts. Some workers are on standby duty. The controller (shift supervisor) submits information on roads serviceability to a workstation appointed by Ministry of Transport in set intervals or in necessary situations. The controller cooperates with the Police or other bodies of Road and Motorway Directorate, Integrated Rescue System, provide operation information.

RSD regularly monitor and assess the course of winter maintenance. At the end of the winter season RSD produce evaluation of technical and economical data with comments.

3.3 Assessment of the snow and ice control measures

Basic information concerning winter maintenance in 1999 - 2008 is shown in the table 2. It is especially the total salt consumption, average salt consumption per 1 km of motorway, number of kilometers driven at motorway check-ups, number of kilometers driven at winter maintenance operations.

The winter maintenance costs are above all the costs for salt purchase and operation of individual SSUD.

If the winter conditions cause exceptional number of maintenance operations the financial consequences will reflect to summer maintenance.

Winter maintenance is a specific section, because costs strongly depend on weather influence, which can only hardly be predicted when costs plan is being prepared. It is therefore difficult to predict total amount of costs concerning winter maintenance. However, on the other hand, winter maintenance cannot be restricted because of its importance, because insensitive economizing has an immediate impact on traffic ability of motorways and expressways.

Dependence of winter maintenance costs on weather conditions does not mean that winter maintenance could not be economically effective.

Deicing salt is purchased in a tender. When the preliminary conditions are fulfilled the cost decides. Costs are determined individually for every SSUD and quarter and they include all customs fees and transport. Costs therefore vary for every SSUD and quarter of the year in which salt is purchased. In second and third quarter they are 10% lower than in first and fourth quarter. Therefore, it seems that to purchase salt in summer season is the simplest form of economization. However, limited capacities of warehouses and possibility of unnecessary purchase of supplies which need not used in case of mild winter are factors against this strategy.

Possibility of basic procurement in advance in summer season is used, with the possibility of operative procurement of salt in winter. Contracts concerning supplies are drawn up in a way that the organization can purchase only such amount which corresponds to real needs and financial situation.

seasons	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
consumption salt-t.	18,139	14,076	18,921	17,614	28,339	27,005	34,840	14,472	18,829
tonnes/km	35.6	27.2	34.7	32.3	50.2	46.0	58.0	20.6	26.0
km-check-ups	182,038	131,776	171,531	157,483	166,720	155,042	152,202	83,329	126,503
km-winter operations	327,160	250,770	362,658	276,191	489,984	436,911	583,617	239,283	333,888

Table 2 – Winter maintenance data in 1999-2008

Precise dosage of salt has an important influence on its consumption. It is important to use mechanisms which reliably dose stated amount. It is not only because of economic aspect, but traffic safety as well.

Costs amount for winter maintenance is almost independent on any planning. Because these funds are drawn from the total plan, in case of harsh winters there is shortage of funds for summer maintenance. Therefore planning costs according to the harshest winter seems to be the simplest way. If however funds will be allocated based on some level of maintenance, relative waste of funds could occur. In this case it is ideal to actualize plan after first quarter with regard to past winter. According to long-term planning the optimal amount of financial funds is about 50 millions Czech crowns per year.

3.4 Traffic safety and information

The maintenance itself is above all based on:

a) permanent monitoring of weather conditions and potential development in particular road sections;

b) collecting information from users, the Police, other administrators, etc.;

c) monitoring meteorological stations and sensors data;

d) advice from the specialized Meteo work stations.

The basic impulse for immediate beginning of operations (spreading, plowing, etc.) is precipitation and its intensity. The precipitation may occur in form of rainfall, snowfall, combined, frost formation or glaze ice. Very important is the moment of the beginning of operations, or if possible their start in advance. This is very often based on a supervisor's experience.

The intervention circumstances, levels and situations can be determined by technical (technological) regulations with difficulties.

The intervention levels are set according to public and maintenance personnel general opinion on road surface quality which is not considered to be safe. For winter maintenance, the most difficult are those situations when the change in road serviceability is not apparent (frost, ice) and in addition they occur locally and very fast.

In the table 3 the problems and ultimate situations for interventions to eliminate them are shown.

Problem	Affects	Intervention situation	Return condition
Snow, snowing, snowdrifts	traffic flow consistency and safety	beginning of the situation	original conditions
Frost, ice	traffic flow consistency and safety	prevention, if possible beginning of the situation	original conditions
Drizzling, rain	traffic flow consistency and safety	beginning of the situation	original conditions

Table 3 – Problems ans solutions

Recently, more and more often ecological and technological requirements are applied. Some of the ecological requirements are ground water protection, vegetation at the sides of roads protection, quality of the soil preservation. To guarantee appropriate winter maintenance quality it is necessary to harmonize a number of administrative, social, organizational, distribution and repair operations. It is necessary to consider climatic and geographical standpoints and use experiences from previous seasons. The administrator is always criticized for insufficient emergency service, late operations and also the fact he could use different methods and prevent damage and injuries.

4. On-going Research and Studies to Improve Winter Management

Representatives of the Czech Republic took part on solving of European research projects like:

- COST 343: Reduction in Road Closures by Improved Pavement Maintenance Procedures.
- COST 353: Winter Service Strategies for Increased European Road Safety etc. This way the transfer of the latest knowledge and new technologies concerning the winter maintenance is secured.

4.1 Dispatching module of winter maintenance of communications

This principle of this system is to maximally simplify relevant information concerning probable weather development and pavement condition for the operator. The information is targeted at the area of the operator's responsibility, i.e., it is relevant for a definite area of the road network. Data from road meteorological stations and other sources used up to present are still available and the possibility of detailed analysis and information evaluation is thus maintained.

This new solution moves from a detailed analysis of meteorological data to providing synthesized and clear information in a graphic form about supposed behavior of a road network in next few (about six) hours time frame. Thus is assured that an employee with a lower level of qualification or experience can use this software module without negative impacts on the winter maintenance quality.

The aim of the system is to correctly predict future conditions of the pavement based on predicted meteorological conditions, but not to determine the way and intensity of winter maintenance works.

Pardubice region was the first testing area of this system.

Inputs of this system are:

- meteorological data (CHMI, road meteorological stations);
- thermal mapping;
- knowledge and experience based information;
- geographic data;
- technical data of pavements;
- data about maintenance works.

Outputs of this system are:

- road surface thermal map;
- road surface condition map.

An example of the graphical output from the system is presented at figure 3.

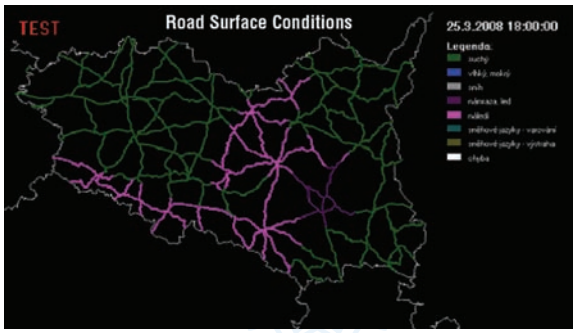


Figure 3 – module output

5. References

Czech Republic - the official website. operator: Ministry of Foreign Affairs

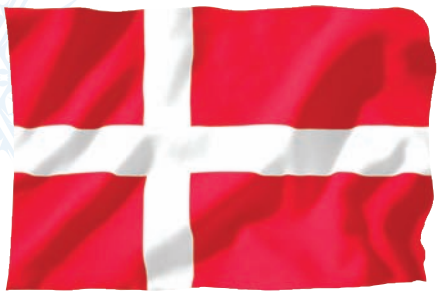
Roads and Motorways in the Czech Republic 2007. Road and motorway directorate of the Czech Republic (RSD), 2007

Motorways Management and Maintenance in the Czech Republic. Winter Management and Maintenance Regime. RSD 2004

Procedure for winter maintenance of motorways and expressways, RSD 2007

Dispatching module of winter management of communications (MDSS). Cross Zlin, 2008

Websites:
www.rsd.cz
www.ceskedalnice.cz



DENMARK

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Denmark consists of the peninsula of Jutland and about 406 islands, of which about 78 are inhabited (2005). Of these, the largest and most densely populated are Zealand on which the capital Copenhagen is situated, Funen and the north Jutland Island.

Denmark has approximately 5.4 million inhabitants - this roughly amounts to 1.4% of the total EU population. In addition to Denmark itself, the kingdom also includes the Faroe Islands and Greenland.

The highest point is 171 m above sea level. No one in Denmark is more than 50 km from the sea. The climate is temperate coastal climate; January and February are the coldest months with an average temperature of 0.0 °C and August the warmest with an average temperature of 15.7 °C. Administratively, the country is divided into 98 municipalities.

Denmark is well provided with traffic systems. The road network is good everywhere in the country; railways and air links provide quick transport, and the islands are connected by ferries and a large number of bridges. Kastrup near Copenhagen is the largest international airport in the country and is at the same time a crossroads for air traffic to and from the other Scandinavian countries.

1.2 Road network and traffic

Towards the end of the 19th century the main network of highroads was established as cobbled roads, which are roads with cobble (stone) material. Together with the secondary roads, the Danish road network had a high density compared with the rest of contemporary Europe.

Particularly during the 1960s and 1970s the network was further consolidated. It was drained and asphalted, supplemented with motorways and new main roads as well as many new local roads to keep pace with demand in the expanding urban areas.

In 2008, Denmark has approximately 73,200 km of road, 1,062 km being motorways. With 1.65 km of public roadways per square kilometer, Denmark, then, has a road density that is among the highest in the world, with a general excess capacity.

The road network incorporates trunk roads (main national roads) and Local Council roads as defined by the road act.

DENMARK

Local Council roads are administrated by the local councils and constitute approximately 69,300 km, about 95% of the public road network. National roads are administrated by the Danish Road Directorate and constitute approximately 3,800 km; the remaining 5% of the public road network, still the public roads cover 45% of all the traffic in km, travelled by vehicles. This means that 45% of all traffic in Denmark travel everyday on 5% (3,800 km) of the public roads.

The Great Belt Bridge, The Øresund Bridge and Øresund motorway are administrated by Sound and Belt Holding A/S and constitute 41 km in total.

The individual roads are classified according to their function.

2. Climate

2.1 Overview of climatic areas

The Danish climate is determined by the country's position on the edge of the continent of Europe close to large sea areas and in the zone of prevailing westerlies. This position results in cool summers with a mean temperature of around 16 °C and winters that are not particularly cold, with mean temperatures of around 0.5 °C. Demark is thus placed in the temperate climate zone.

There is a good deal of wind, strongest in the winter and weakest in the summer. Precipitation falls throughout the year, with the greatest rainfall in September, October and November. The smallest amounts of precipitation occur in February and April. The regular distribution of precipitation throughout the year is due to Denmark's position in the belt of prevailing westerlies, where the predominant wind directions are west and southwest.

Series of low-pressure systems (cyclones) moving north eastwards, often forming over Newfoundland, are the basis of the characteristically changeable weather: within a few days the weather changes typically from steady precipitation preceding a warm front to brighter or slightly misty weather, possibly still with a little drizzle in the following warmer mass of air. Finally, the passage of the cold front will produce precipitation in the form of heavy showers followed by clear weather with few clouds.

Denmark is one of the most exposed countries as regards "slippery road", because of the fact that of the temperature fluctuations around 0 °C during a winter. Until now preventative salting has been the solution to avoid slippery road, which means spreading by salt on roads will occur before it gets slippery. This outcome can be ensured with the help from the Road Weather Information System, today a technology used by Road Directorate and many municipalities to decide whether they start salting or not.

The average temperature for winters is normally 1.5 °C - 2.5 °C. Number of complete days below 0.0 °C is around 5 days in a year. The variation of snow amount during a winter season is between 10-40 cm, and nation-wide snow weather occurs a maximum of 5-10 times during a winter.

2.2 Winter index

The Danish Road Directorate uses a definite winter index to define the severity of a winter related to winter maintenance.

$$Vi = \sum_{1.oktober}^{1.maj} V_{dag}$$

Formula of winter index:

Vday = a • (b + c + d + e) + a

a = days with road temperature below +0.5 °C.

b = the number of times the road temperature is below 0 °C while the road temperature is below the dew-point temperature for a minimum period of 3 hours and with an interval of at least 12 hours.

c = the number of times the road temperature drops below 0 °C of at least 0.5 °C to -0.5 °C.

d = days with snow fall > 1 cm.

e = days with drifting snow.

3. Winter Road Management

3.1 Standards and rules

In agreement with "law about winter maintenance and clearing of roads", the Danish road authorities are charged to: take action for snow clearing and secure against slippery road at the public roads and paths.

For footpaths, the responsibility can be placed on the holder of neighboring properties.

The road authorities determine to what extent and to what sequence snow clearing and fight against slippery road shall be made. Guidelines for workers performance is appointed as directed by the police.

DENMARK

Service objectives for Road:

Class	Type of road
State roads **Priority roads**	• Freeways • Regional Roads • European Freeways • Other priority roads
Other state roads	Other regional roads

Further,

Class	Service objectives
State roads **Priority roads**	Should be passable without major inconveniences 24 hrs. a day Desired road conditions: • Dry • Wet
Other state roads	Should be passable without major inconveniences 24 hrs. a day Desired road conditions: • Dry • Wet

Desired duration of Road Conditions:

Class	Desired duration of Road Conditions below the Service Objectives
State roads	**Slippery roads without snow:** • **Rime frost** **0 hours** • **Ice** **0 hours** **After snowfall:** • **Slush** **2 hours** • **Light snow** **2 hours** • **Compacted snow** **0 hours** **After blown snow:** • **Driven snow** **2 hours** • **Blocked** **0 hours**
Other roads	**Slippery roads without snow:** • **Rime frost** **2 hours** • **Ice** **2 hours** **After snowfall:** • **Slush** **4 hours** • **Light snow** **4 hours** • **Compacted snow** **2 hours** **After blown snow:** • **Driven snow** **4 hours** • **Blocked** **0 hours**

Service objectives for Path and Pavements:

Class	Type of road
Priority paths and pavements	• School paths • Paths in inhabited areas
Other paths and pavements	• Other paths and pavements, except from recreational paths

DENMARK

Further,

Class	Service objectives
Priority paths and pavements	Should be passable without major inconveniences 24 hrs. a day. Desired road conditions: • Dry • Wet
Other paths and pavements	Should be passable without major inconveniences according to the use of the path Desired road conditions: • Dry • Wet • Compacted snow with gravel

Desired duration of Road Conditions:

Class	Desired duration of Road Conditions below the Service Objectives
Priority paths and pavements	**Slippery paths/ pavements without snow:** • Rime frost 0 hours • Ice 0 hours **After snowfall:** • Slush 4 hours • Light snow 4 hours • Compacted snow 0 hours **After blown snow:** • Driven snow 2 hours • Blocked 0 hours
Other paths and pavements	**Slippery paths/ pavements without snow:** • Rime frost 4 hours • Ice 4 hours **After snowfall:** • Slush 6 hours • Light snow 6 hours • Compacted snow 6 hours **After blown snow:** • Driven snow 6 hours • Blocked at night

Threshold limiting value

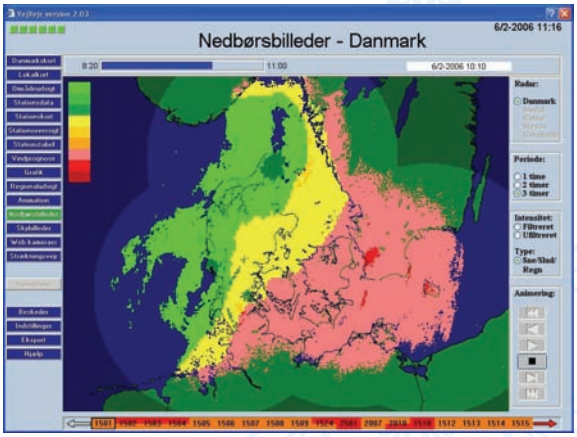
	Call-out [Minutes]	Turnout duration [Minutes]
Roads – salting	45	Max. 180
Roads – snow clearing	60	Max. 120
Paths, pavements and other areas (Salting & Snow clearing)	60	Max. 180

3.2 Organization and operation of winter maintenance

Until the 1st of January 2007, the duties about planning and carrying out winter maintenance of national roads were managed by counties. However, by adoption of new structural reform, the Danish Road Directorate took over the planning of winter maintenance of its own roads. The country is divided in 6 regions (winter centers).

Every winter center typically reflects on approximately 1,000 km road. All convenient jobs (haulage by truck o.l.) are supplied in accordance with EU's service- directive, and are managed by private haulage contractors.

How are roads monitored?



To predict slippery roads:

It is not always easy to predict slippery roads when the weather conditions can change very quickly. Therefore, the unit of winter maintenance cooperates with a number of agencies and uses advanced systems to assist in monitoring.

DENMARK

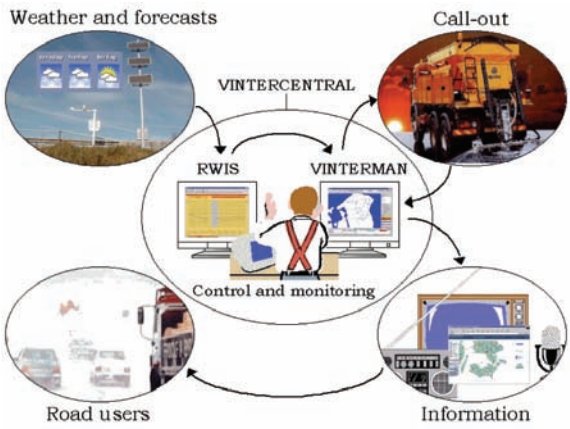
The winter maintenance unit cooperates, in particular, with the Danish Meteorological Institute (DMI), and uses their special forecasts for road and weather purposes, and radar and satellite imagery. Moreover, using the winter maintenance Road Weather Information System VejVejr, which provides comprehensive monitoring and forecasting facilities, winter engineers have the best possible basis for decision making in relation to the chance to call out for road salting.

Information about road and weather situation by monitoring, webcams, police, citizen inquiries and winter monitoring is also used to form the total picture.

Winter Supervision is used in snow situations where they are out driving on the road to examine the need for extra effort, for example, in connection with the operation of formation.

3.2.1 Information dissemination

The general position within the Danish Road Weather Information System is shown below.



The Danish Road Directorate & Danish Meteorological Institute (DMI) have had an arrangement since 1983; the agreement is constructed to exchange information throughout the Road Weather Information System and is mainly about road weather forecast and the objective is to maintain a satisfactory traffic ability and level of traffic safety on the roads during a winter season. Written agreements exist between every member that is connected to Road Weather Information System,

A system that is installed in a series of computers at the 6 winter centers. These receive and present data from the recording stations and the DMI (Danish Meteorological Institute).

This information is communicated by the Road Directorate Traffic Information Center, a central station in the Road Directorate which is open 24 hours a day and which maintains contact with road authorities, Danish Meteorological Institute (DMI), the police, the emergency services etc.

The information is also distributed via radio, telefax, etc., and by direct telephone contact when motorists call.

The Road Weather Information System highlights icy driving situations before they actually arise, enabling preventive salting before it becomes icy. The stations are primarily located at the coldest places along the road network. The system has also affected the importance of control posts and patrols have less significance; however patrolling is still used when necessary (Snowfall, etc.).

The Road Weather Information System is based on a network of approximately 340 recording stations along 4,000 km of Danish national roads and regional ways and a minor portion of 69,000 km of local roads.

Data

The winter patrol's data to decide call outs to salting or snow removal are as based on:

- Online data about slippery road from monitoring stations located throughout the country;
- Projections from each station - to develop the next hours;
- Residual Salt Measurements;
- Regional weather;
- Radar Pictures;
- Patrol - monitor out on the roads;
- Comments from motorists and police;
- Experience - local conditions and vulnerable places.

DENMARK

There are 6 winter centers distributed around the country. Each winter center has manned guards where winter preparedness is affiliated.

In winter inform T.I.C. on slippery roads warnings, and is an integral part of the winter monitoring.

3.2.2 Methods

Winter maintenance usually is provided from 1 Oct. until 30 April throughout Denmark. Before that period, materials and equipment are checked and repaired and staffs are trained in comprehensive programs.

Definite activation depends on the weather forecasts.

Establishment of technological procedures and experiments are normally planned and scheduled before winter seasons. The plan contains all instructions for personnel and their duties. It also includes guidelines for the measurements that have to be done for a given climate situations.

Provision of snow fences has less significance in Denmark, mainly because there are few snowy days (5-10 days in a year) and also because of expenses related small benefit.

Route optimization happens individually for each winter center on its own. The planning is made in each winter center based on requirements and occurs manually for all superior and subordinate road networks.

Based on weather forecasts (whether snowfall appears or has already taken place), the duty engineer must carefully decide when and in which capacity snow clearing should be carried out.

Snow clearing of carriageway should begin, when the snowfall has reached 3-5 cm. and there is a potential for continuous snowfall. Normally, salting is a supplement to snow clearing. However, these procedures are different from urban or rural area.

Snow clearing on paths normally happens during the clearing of carriageway but founded on practical knowledge, the paths should be clear after the adjoining road, otherwise the snow would just fall back again.

3.2.3 Equipment

Denmark has 6 operation winter centers. Each operation center is supplied with Danish Road Weather Information System and all of them are operating with the winter management system VINTERMAN.

The Road Directorate owns approximately 175 spreaders, 50 tractor spreaders and 450 snow plough for securing against slippery roads, mostly pre-wetted salt-spreaders together with a couple of combination spreaders and liquid spreaders. The development in Denmark still goes to use of brine. Driving through of a salt route typically takes 3 hours from call-out to finished task, and the route typically covers an area of at least 400,000 m^2.

Each spreader covers small 40-km. road sections including stand-by spreader. Moreover there is a salt depot for every 400-km. All new vehicles are supplied with stationary GPS equipment. There's only one driver in the truck for salting as well for snow clearing.

To start guiding of mentioned materials the equipment such as de-icer spraying installations, road heating and uses of ice-delaying pavements has been used but none of them are used anymore because of the results and the economic perspectives.

3.2.4 Manpower, training and privatization

Every year there are seminars for engineers and road masters to inform them about the latest knowledge and developments within winter maintenance.

Training and education

The technical development of winter maintenance demands education and in-service training of personnel. For winter maintenance, management and administrative staff exist, an in-service training rise of road region. The classes included winter maintenance in practice and a depth examination of warning-system for slippery roads.

For drivers who participant in the winter maintenance, the Road Directorate has precisely established national classes of 6 modules, extensive haulage with spreaders, snow plough, etc. It is expected that participation in these classes will be required for coming invitation to tenders.

Privatization

Private companies are usually hired to function as drivers on salting or snow clearing occasions. The government is contributing with equipment (spreaders) while private companies are supplying vehicles.

3.2.5 Operational organization of winter maintenance

In a typical winter in Denmark, there are about 100 call-outs for salting due to risk of icy conditions on approximately 4,000 km of national and regional roads. Salting as a result of snowfall, on the other hand, occurs only 5-10 times a year. In Denmark, preventive actions are taken to salt the roads before they get slippery. The decision on whether a call-out is needed is made at a winter operation center, while a local contractor carries out the actual activity. Two computer systems have been developed to support these tasks at the winter center the Road Weather Information System (RWIS) and VINTERMAN.

The decision whether there should be a call-out or not, is a very crucial decision. If many unnecessary callouts are made throughout a winter where icy conditions do not occur, money and resources are wasted.

On the other hand, if the call-out is made too late, or not at all, it can lead to accidents due to slippery roads and, in worst cases, a complete traffic jam. These situations also cost a lot of money for society. This means that each road authority tries to make the optimal decision in each case to ensure a stable traffic flow, but at the same time with a minimum use of resources. In order to reach this optimization the RWIS system is a big factor. If you can predict the timing and type for each slippery road condition then it's possible to correspond in an appropriate way. This doesn't only include finding the optimal timing for the call-out, but also using the right methods and materials. In order to reach this goal the VINTERMAN system was developed.

In this system one can create predefined action plans where the length of routes, methods and amount of salt. etc., are determined. In addition you have a choice between dry salt, pre-wetted salt and brine, depending on the weather situation.

Most salt spreaders are now equipped with GPS data collection. Information regarding speed, dosage, spreading width, etc., is registered. Thus, VINTERMAN is able to provide statistics on the number of activities, consumption of salt, duration and time of callout along with the cost of salt and payments to contractors. This provides the opportunity to monitor and control the work quality, and eventually to re-organize action-plans if needed.

To increase the effect and optimization of actions carried out, the Danish Road Directorate experimented with different types of salt spreading methods and materials. For example the most recent research shows a large potential in salt reduction with use of brine instead of pre-wetted salt in situations of rime (black ice).

3.3 Assessment of the snow and ice control measures

3.3.1 Internal assessment

Winter system

The Danish winter maintenance is mostly applied through EDB-systems and usually inside two main fields:

- Icy road warning. Especially if the needs are possibilities to carry out a preventive contribution, Road Weather Information System has to be established, based on the number of RWS, radar pictures and other meteorological information;
- Winter administration. The winter administration system is applicable as support connected with completion of prevention of icy road and thereby has to insure registration of activities, as necessary.

The systems can be integrated into a large familiar system; however, the interfaces between these two fields are so specific that it's often more practical with smaller systems than an entirely separate system.

Main tasks for a winter administration system:

Winter maintenance is often organized differently from one road authority to another, but regardless of how it is done a winter administration system is always required. The primary structures of organization for completion of winter duty are:

A. Primary applications from own employees. In this case a winter administration system will secure options to document the contribution and estimate a resource allocation for the employees;

B. Their own monitoring stations with decision round contribution, but with contractors to do the performance on the routes. In that situation, the system will secure the data, so that the payment to the contractors proves in order;

C. All jobs are processed through an invitation to submit a tender, which includes a decision about contribution as well as the contribution itself. In this case, it will be with an asset to establish a corporate system that contractors as well as road authorities have facilities to. Typically, the contractor has a need corresponding to model B because the general contractor frequently employs subcontractors.

Information regarding all call-outs can later be obtained along with comprehensive data. Road centers use these data when sending invoicing based on the contractors. The organizations are frequently political to be certain; however, to all three situations an administration and data recording system is required around winter maintenance. The winter administration system must handle subsequent jobs:

- Structure and organize all basics administrative information about winter maintenance;
- Assist to the callout situation and ensure that the required data of a contribution is registered;
- Give alternatives by subsequently documenting the performing contribution;
- Introduce statistical material regarding exported jobs, salt consumption and expenses;
- Handle reports about present road conditions so the knowledge can be continuously shared out to the traffic information centers and various media.

3.3.2 External assessment

All performing spreaders at the Road Directorates roads are equipped with data-collecting equipment, which benefits the VINTERMAN system by viewing every single spreader's contribution. Subsequently, this data can be employed as inspection of the contribution. On the other hand, every driver completes a control scheme that documents contribution of any haulage.

In addition to several road authorities checking is the fact that the amount of residual salt is known by measurement with SOBO20 and road sensors.

The Road Directorate does a national-wide user survey once a year and users' opinions have an importance in the evaluation phase, in order to improve the strategy to obtain a satisfaction among the users.

3.4 Traffic safety and information

Often and accurately, it is possible to inform motorists of icy roads and weather conditions both nationally and locally.

This information is communicated by the Road Directorate's Traffic Information Center, a central station in the Road Directorate which is open 24 hours a day and which maintains contact with road authorities, the Danish Meteorological Institute (DMI), the police, the emergency services, etc.

The information is distributed by radio, telex, etc., and by direct telephone contact when motorists call or Internet website www.vintertrafik.dk.

International exchange of road information

The Danish Traffic Information Center sends traffic information to the previous ERIC3000 system from where it is distributed to many European countries together with traffic information from other countries. Supported by the EASYWAY VIKING EU-project, exchange of traffic information across the boarder is being set up with Sweden, and it is also the plan to exchange traffic information across the border with northern Germany.

4. On-going Research and Studies to Improve Winter Management

The winter maintenance technology improves very fast, and high-speed communication cables and systems make it possible to transfer a large amount of data. With time, it also becomes less expensive. Already it is now possible to see very specific information regarding, e.g., temperatures, winter maintenance activities, road conditions and salt consumption, but there is still a lot that can be improved. All winter maintenance vehicles equipped with GPS and data collection can be monitored in VINTERMAN.

Also, as an on-going project "Modulate of salts decomposition process on road" has as its main objective to find models, which enable road authorities to monitor residual salt amounts after a given time, taking the traffic intensity and precipitation, etc., into consideration. A further goal is to make projections for residual salt for different kinds of road classes, which will be a valuable supplementary tool for decision-makers in surveillance centers.

Research of "Section based (Thermo graphic) forecasts of road surface" is also among on-going projects; the objective is to investigate area prognosis and climate forecasts for the affected stretches, the expectations of analysis are to get an idea for prediction of natural behavior and changes in climatic conditions.

To be able to improve our turnout performance, we have decided to improve our Winter Management System with "Vinterman – voice response system".

Test of salt spreaders in the Research center Bygholm

This project aims to find a method for testing of salt spreaders; the method will set new requirements to spreaders quality and thus ensure a continued development of the winter service.

The project was conducted in close cooperation with the suppliers of salt spreaders. The participating suppliers of salt spreaders were Nido, Kupper Weisser, Falköping and Epoke.

The results of the tests are quite promising, but an adjustment is necessary. The results of tests showed that salt spreading quality could not meet the requirements satisfactorily and that there was no particular difference between spreaders despite the type of spreaders in relation to the quality of the spreading image.

In 2009, work is ongoing to adjust the method and conduct a second test of salt spreaders. It is expected that there are real requirements for salt spreading in late 2009.

Spreader monitoring and control

Today, the changing road geometry needs much attention from the salt spreader driver which is a problem as drivers also need to watch the traffic and road profile.

The objective of the project is to ensure more precise monitoring and control of the salt spreader during action in order to reduce salt consumption and, thereby, the impact on the environment. The monitoring and control will cover spreading width and salt dosage. The spreading width will be controlled by knowledge of the road geometry while the salt dosage will depend on section specific forecasts.

5. References

www.vd.dk

www.vintertrafik.dk

Country report COST 344
"WINTER MAINTENANCE IN DENMARK"
ERIC2000:
http://www.mycontentcompany.com/eric/index.php

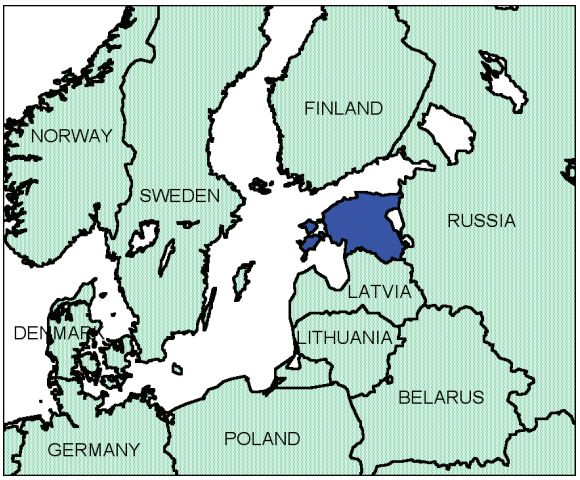
VIKING:
http://www.viking.ten-t.com/VikingExtern/Index.htm

ESTONIA

1. Demographics and Roads

1.1 Information about the country

Estonia is a small northern member-state of the European Union. Its territory can be compared to Denmark, Switzerland or Netherlands.



Area	45,227 km²
Population	1,351,000
Density of population	32 per km²
Capital: Tallinn 400,000 inhabitants	
Latitude (capital)	59⁰ 37′ N
Cars per 1,000 inhabitants	321
Density of national roads	1 283 km per 1,000 km²

General facts about Estonia

Estonia is situated on the shores of the Baltic Sea with access to the Atlantic Ocean, extending its reach to the very centre of Europe.

Most harbors are located on the southern shore of the sea and, therefore, goods and people are used to being transported through Estonia. Nowadays international routes like Via Baltica (from Finland through Baltic States to Centre Europe) and Via Hanseatica (connecting old European Hansa towns with Saint Petersburg, Russia) are developed.

The Republic of Estonia is administratively divided into 15 counties.

1.2 Road network

Total road network km	National roads km					Other roads km
	Total, including :	Main roads	Basic roads	Secondary roads	Ramps	
58,034	16,487	1,602	2,391	12,444	50	41,547

ESTONIA

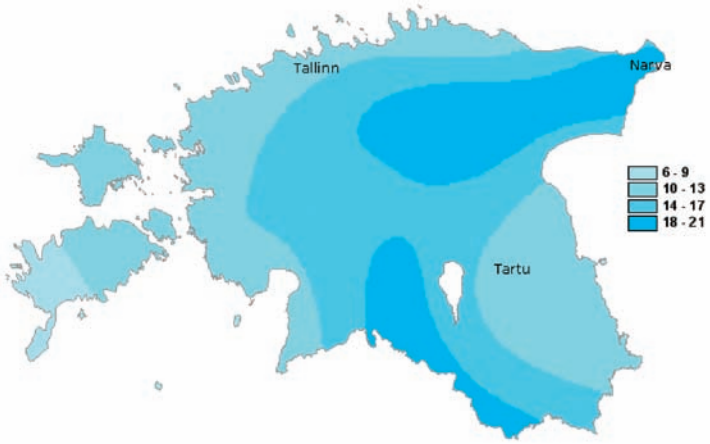
2. Climate

Statistics on temperatures and precipitation

Town	Monthly average Temperature (30-years average)					Snowfall (cm) (30-years max)		Precipitation (30-years average) (cm)				
	Nov	Dec	Jan	Feb	Mar	Daily maximum snowfall	Maximum snow depth	Nov	Dec	Jan	Feb	Mar
Tallinn	1.3	-1.7	-3.4	-4.4	-1.1	25	54	6.9	5.7	5.7	3.6	3.5
Tartu-Tõravere	0.2	-3.0	-4.6	-5.5	-1.2	16	42	5.1	4.6	4.8	3.5	3.6
Narva	0.2	-3.2	-5.2	-6.1	-1.8	15	53	5.5	4.8	4.3	3.3	3.5

30-years average1979-2008

There are 31 days per winter period affected by snow in Tallinn. the Capital of Estonia.



Average snow cover depth (cm) on field. in February

Snowfalls and slippery conditions usually begin in November and winter conditions last for 5 months until April. But we have had snow even in the end of May. The climate varies from the wet maritime on the coasts to the dry continental in the eastern and southern areas. We must be ready to meet quite low temperatures like – 30 °C. Road surface temperature often alters from minus to plus degrees and therefore the skid control is utmost important.

3. Winter Road Management

3.1 Standards and rules

Legal obligation to perform winter maintenance

Estonian Road Administration is responsible for the winter service of 100% of national roads in Estonia. Winter maintenance on all roads is regulated by following acts enacted by Ministry of Transport and Communications:

1.Requirements for the State of the Road;

2. Requirements for Winter Maintenance Technologies.

It is stated by the Traffic Law that winter tires are required to be used by vehicles up to 3.5 tonnes during the period from December 1 until March 1. Driving with studded tires is allowed from October 1 to May 1.

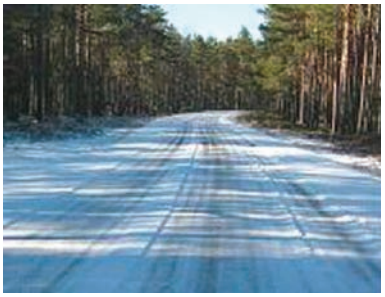
ADT	Required level of service			
	Main road	Basic road	Secondary road	Local road
Motorway	4	-	-	-
> 8,000	3	-	-	-
6,000-8,000	3	3	3	-
3,000-6,000	3	3	3	-
1,000-3,000	3	2	2	2
200-1,000	3	1	1	1
up to 200	-	1	1	1

Classification of the roads - Levels of service

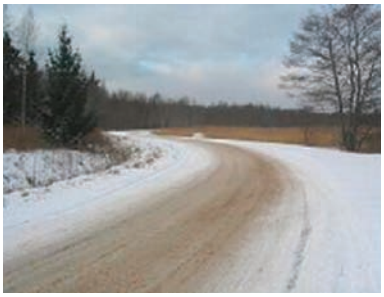
ESTONIA

Requirements for the state of the road

Level 1



Level 2



Level 3

Indicators	Requirements for the state of road by service levels			
	1	2	3	4
State of road surface				
	Packed snow or icy road surface is allowed with anti-skid treatment in unsafe spots.	Packed snow or icy road surface is allowed with entire anti-skid treatment	Wheel tracks free of snow and ice de-icing	Pavement is free of snow and ice entire de-icing
Snow				
Allowed depth of loose snow	< 10 cm	< 5 cm	< 3 cm between wheel tracks	Bare pavement
Allowed depth of slush, mix of salt and snow	< 6 cm	< 3 cm	< 2 cm between wheel tracks	Bare pavement
Width between snow mounds	> 6 m or at least road width	> 8 m or at least road width	Whole driveway and shoulders	Whole driveway and shoulders
Evenness				
Allowed depth of ruts or unevenness in packed snow	< 4 cm	< 3 cm	Packed snow layer <2 cm between wheel tracks	Bare pavement. When T < -12 °C snow layer < 1 cm between wheel tracks

Maximum Service Cycle Time (h)					
Required level of service	Snow and slush removal	De-icing, anti-skid treatment	Salt-snow mix removal	Sidewalks cleaning and skid control	Treatment of other road facilities
4	2	2	4	6	8
3	5	4	8	8	12
2	12	8	-	12	24
1	36	24 (spots)	-	12	36

Required service level	Hours when requirements are applied
Motorway 4	Round the clock
3	6:00 - 22:00 On other time service level 2 is allowed
2	7:00 - 21:00 On other time service level 1 is allowed
1	Determined by the owner of the road

ESTONIA

Rules regarding type and characteristics of materials

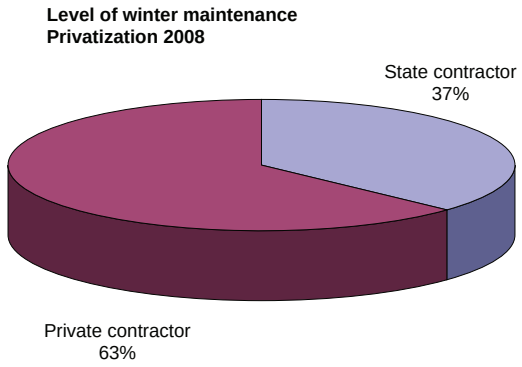
Mainly NaCl is used for de-icing. It is suitable for its price and ease of use. $CaCl_2$ is used for making of moistening brine. According to the Technological Requirements for Road Maintenance amount of salt to be used shall be as follows:

Temp. °C	After snow removal		After wet snow removal		Icy pavement	
	g/m²	kg/km	g/m²	kg/km	g/m²	kg/km
0 ... -2	10-20	75-150	10-20	75-150	2-5	15-40
-2 ... -4	10-20	75-150	20-30	150-225	5-10	40-75
-4 ... -7	20-40	150-300	30-50	225-375	10-20	75-150
-7 ... -10	40-60	300-450	50-70	375-525	20-30	150-225

3.2 Organization and operation of winter maintenance

Organization of winter maintenance

The reorganization of road operations in Estonian Road Administration began in 2000. After 8 years of task-work. we have got through to the final stage of our goal. Road operations are fully entrusted to the contractors and the contracts we have entered into are on a large scale performance-based.



The three principal spheres of work of a maintenance undertaker – routine service. periodic service and retain repairs are all included in a single contract that lasts for 7-8 years. The evaluation of and payment for routine service is fully performance-based. That means there is no counting of amount of work that has to be done; the attainment of the required service level is what counts.

In Estonia, we have 5, 7 or 8-years maintenance contracts. Since the year 2000, 14 countywide performance-based contracts (1000-1200 km) and 3 road-master-area wide (400 km) contracts have been launched. Usually, 4-7 bidders compete. Road maintenance market is progressively developing in Estonia, depending on the location of road construction companies- the most developed is Tallinn area. Tartu follows the next. There is less entrepreneurship on islands and in the Southern Estonia.

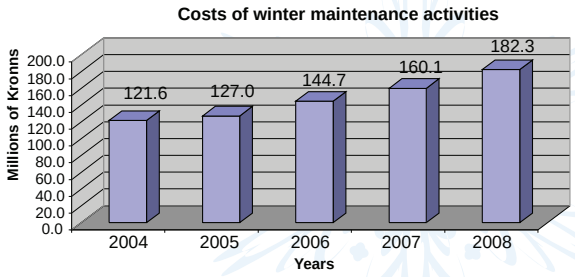
Operational management of winter maintenance

Three-axle SISU- and SCANIA-type trucks are basic trucks for winter road maintenance. UNIMOG- and VOLVO-type trucks are less used. For de-icing treatment mostly NIDO and SALO-type salt spreaders are preferred. For snow removal different types of front. side and under body ploughs are used.

Consumption of de-icing materials

The amount of de-icing materials is constantly decreasing because of the fact that new spreaders and the pre-wetting technology have been taken into use and de-icing is carried out on time.

The amount of salt used depends on winter conditions. especially on how many times temperature varies between plus and minus degrees. In winter 2006/2007 31.0 thousand tonnes and in winter 2007/2008 36.1 thousand tonnes of NaCl was used.



ESTONIA

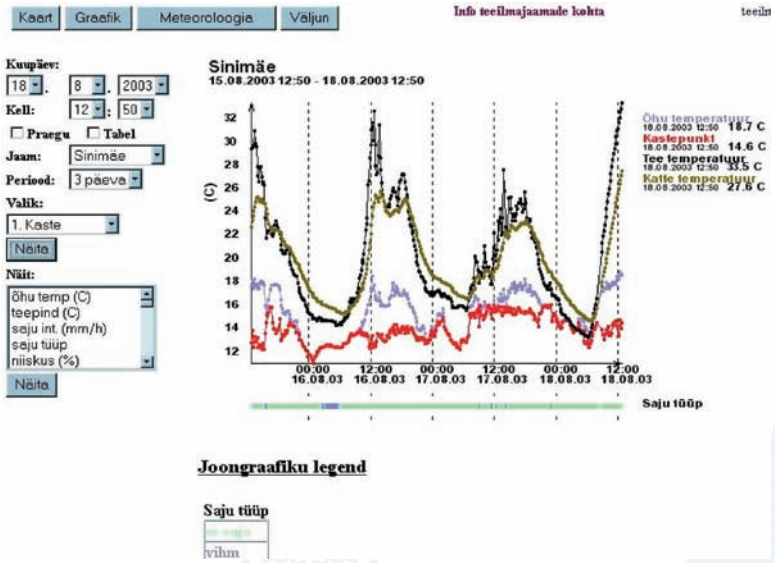
Special requirements for start up. maintenance and using of ice roads are fixed

Signs with the name and telephone number of a contractor are installed on the borders of contract areas to inform road users and to promote competition between neighboring maintainers.

Main characteristics of Estonian Road Weather Stations and Road Weather Forecasts

In Estonia two types of road weather stations are used: 20 ROSA stations made by Vaisala (Finland) and 30 GMS stations made by AerotechTelub (Sweden). The ROSA stations measure the same data as GMS stations measure plus some additional information about road surface. Some of ROSA stations also have more advanced precipitation and visibility sensors called PWD. The ROSA stations measure the following parameters among others:

- air, dew point, surface and pavement temperature;
- air humidity;
- wind speed and direction;
- type and amount of precipitation. also visibility (not in all stations);



- road surface status – dry, wet, snowy, slippery, icy etc.;
- the amount and concentration of salt.

Unfortunately, our road weather stations do not provide any weather forecasts. they only give information about the past and present weather conditions on the road. It is the task of different computer programs to do the forecasts. Estonian Road Administration in developing them in good cooperation with Estonian Meteorological and Hydrological Institute.

Another important part of Estonian RWIS are road cameras. There were 16 road cameras in Estonia at the beginning of year 2009 and the network is growing constantly; each year at least 4-5 new cameras should be installed on major roads to help road masters to have visual information on road and weather conditions after every 10-30 minutes

3.3 Assessment of the snow and ice control measures

The Guide for Inspection of Roads stipulates the road inspection order for supervision.

According to the Guide all inspections are grouped in two groups: one that is done on daily basis and; another that is done monthly.

ESTONIA

The main idea of daily inspection is to check selectively whether the actual road condition complies with the requirements stated by the Requirements for State of Road and whether operations of the maintainer are in accordance with the Technological Requirements for Road Maintenance Works. The route to be inspected is chosen according to the principle of importance by the supervisor doing the inspection. The purpose of monthly inspection is to check the actual road conditions in a wider area. The route to be inspected is chosen on the random basis. A commission comprising a representative of the contractor, representatives of the supervisors and owner do the inspection. During the monthly inspection 20-30% of roads at all service levels have to be checked.

It is allowed to check less than 20% of roads during monthly inspection but then there has to be additional inspection during the next month or two to ensure that the monthly average requirement is fulfilled.

Inspection is mainly done visually. In case of necessity different additional measurements can be done. Some of the measurable parameters are: thickness of snow, width between roadside snowdrifts, and depth of ruts, compliance with timeframes for maintenance cycles, etc.

Noticed shortcomings are written to the Web-based logbook and deadlines for correcting things are given. If the total amount of deficiencies is bigger than allowed, different sanctions against the contractor can be applied.

Teehoolde järelevalve päevik

Päring: Järelvalve insener -Urmas Ilves. Hoolde teostaja -Vooremaa Teed AS. Viimase nädala andmed

Kuupäev	Tee-nr.	Algus TO	Aad-ress	Lõpp TO	Aad-ress	Puudused ja märkused	Foto	Täitja	Täitmise tähtaeg
2005-01-04	3	10	0	14	3407	TO_11-augud kattes (lennuväljal)			14.01.05
2005-01-04	36	1	0	5	5138	korras			00.00.00
2005-01-05	14121	1	0	1	4497	Sadalas lume konarused lubatust suuremad			07.01.05
2005-01-05	14120	1	0	1	7136	vajab sahkamist			07.01.05
2005-01-05	13168	2	0	3	4999	VAJAB SAHKAMIST			07.01.05
2005-01-05	14119	1	0	1	2283	korras			00.00.00
2005-01-05	36	1	0	3	8781	korras			00.00.00
2005-01-05	14135	1	0	1	7691	tase 0 - tagada seisunditase 1			06.01.05
2005-01-05	14136	1	0	1	3575	korras			00.00.00
2005-01-05	14117	1	0	2	6011	korras			00.00.00
2005-01-06	14133	1	0	3	5178	korras			00.00.00
2005-01-06	14109	1	0	1	1981	korras			00.00.00
2005-01-06	14107	1	0	2	1785	korras			00.00.00
2005-01-06	14101	1	0	3	8804	korras			00.00.00
2005-01-06	14241	1	0	1	2155	korras			00.00.00

A sample of a query from an inspection logbook: (in Estonian)

3.4 Traffic safety and information

Information provision to the road user

Road Information Center was established in 1996 to improve the traffic information for road users.

Estonian Road Administration buys the service of collecting and spreading of road information from a private company. A 3-year contract was signed after an open tender held in the end of 2003. In the contract there are certain rules that the private company has to follow in collecting information from road weather stations. meteorological center and road users.

The Road Information Center has to inform radio stations. police and road masters about traffic and road weather conditions at least twice a day and has to renew aforementioned information on Road Administration's web page as well.

So there are several possibilities for road users to gain information about traffic and road weather conditions: calling directly to the road information center. looking at Road Administration's web page or www.balticroads.net web page.

ESTONIA

Balticroads.net – a cross border Road Information project

http://www.balticroads.net/ service is provided in cooperation between the National Road Administrations of Finland. Estonia. Latvia and Lithuania to inform the road users of the current road weather conditions in the Baltic Sea region.

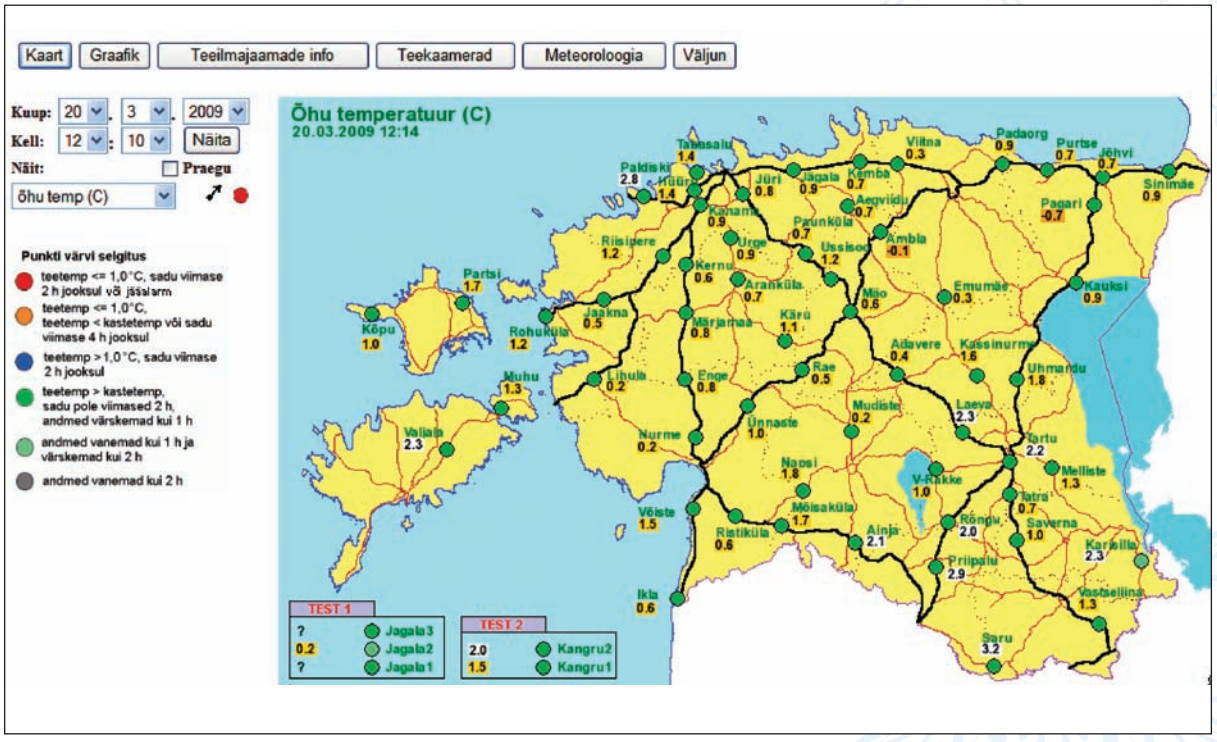
Automated Road Weather Information System (RWIS) is used to continuously record the current and predicted status of driving conditions on the road network. By now there are a total of 149 road weather information stations in the Baltic States:

- Estonia - 58 stations;
- Finland - 23 stations;
- Latvia - 30 stations;
- Lithuania - 38 stations.

The five countries have now joined resources to develop a common Internet interface to share and transfer the existing RWIS data collected around the Baltic Sea Region more effectively to the transport sector and other road users.

The overall goal of the Internet interface is to provide better access to the accurate road weather information for the transport industry and the driving public thus resulting in better service and improved traffic safety. The co-operation between the national road administrations improves the utilization of the information from the existing road weather information stations in road maintenance operations. In addition, the co-operation includes enhanced training for local authorities in RWIS management.

The Baltic RWIS Internet interface provides current data (less than 30 minutes old) on the local road weather displaying data such as: road and air temperature; type of precipitation; road condition; wind speed and direction; as well as dew point and humidity.



A sample of a query from Web site

ESTONIA

Use of weather related road sensors and variable road signs

In Estonia we have three variable road signs. two of them situated on one of our main roads Tallinn – Tartu and one is on Tallinn-Narva road. In a road segment of 7 kilometers many winter accidents happen. The reason for these accidents may be rapidly changing surface conditions caused by the nearby swamp.

A Finnish company, Sabik, manufactured all VMS signs. The contractor responsible for winter road maintenance manually controls the signs. Suggestions about speed and warnings about slipperiness are given to motorists.

An idea for the future is to develop software that could automatically select the important information to be shown on traffic signs. The principle could be that parameters measured by the local road weather stations would directly be shown to road users - road temperature or road surface status for example.

4. On-going Research and Studies to Improve Winter Management

There are 2 different subjects related to winter maintenance that are researched at present.

The first is a friction factor of road pavements and possibilities of implementing its measuring system in Estonia to assess winter road conditions more precisely.

Another topic is the possible use of $CaCl_2$ as a more effective de-icing material on winter roads in Estonia.

5. References

Authors: Kuno Männik ;Tõnu Asandi; Rain Hallimäe
Estonian Road Administration
463a Pärnu Road. 10916 Tallinn. Estonia
Tel. 372 611 9300 / Fax 372 6119360
E-mail: estroad@mnt.ee

FINLAND

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Finland is a country in northern Europe with an area of 338,419 km^2. It is situated between Sweden, Russia and Norway and borders on the Baltic Sea too.

Figure 1 – Finland's location

The country has 5.3 million inhabitants, 15.66 per square kilometer, most of whom (67%) live in towns or urban areas. About one million people live in the metropolitan area of Helsinki.

1.2 Road network and traffic

Roads are especially significant in Finland, because it has a large surface area but is sparsely populated. What's more, from the viewpoint of central Europe, Finland is located on the margins. Most exports to this most important market area are transported by sea. From the standpoint of the competitiveness of industry and commerce, functional logistics are vital, especially the functionality of the internal transportation system. Road transport accounts for 67% of total freight transport.

The road network comprises 78,200 km of public roads, of which 50,800 km has asphalt pavement. 700 km of these are motorways. In addition, there are 26,000 km of streets and planning roads and 280,000 km of private roads.

Passenger cars travel 30,000 million km and buses and trucks 2,800 million km per year on the public road network. Public roads carry about 67% of all traffic.

Traffic volume during the six winter months is around 45% of the year-round volume. In many fields of industry and commerce, the share of transports taking place in the winter months is greater than that in summer. Communities, industry and commerce that depend on transports and road traffic expect transportation to function reliably all year round.

Area	Total snowy regions	338,419 km^2
Population	Total snowy regions	5.3 million
Length of road	Public roads	78,200 km
	Streets and planning roads	26,000 km
	Private roads	280,000 km
Latitude (capital)		60°19'N

2. Climate

2.1 Overview of climatic areas

Finland is situated between the 60th and 70th northern parallels in the Eurasian continent's coastal zone. The mean temperature in Finland is several degrees higher than that of other areas in these latitudes, e.g., Siberia and south Greenland. The temperature is raised by the Baltic Sea, inland waters and, above all, by airflows from the Atlantic, warmed by the Gulf Stream.

Conditions differ in the various different parts of the country. In the coastal areas, where the climate is closer to a marine climate, weather and driving conditions vary greatly and slippery conditions develop easily. In the country's eastern and northern parts, the weather resembles a continental climate and is clearly colder.

FINLAND

2.2 Statistics on temperature and precipitation

In Southern Finland the average winter temperature is about -2 °C and in the North approximately -8 °C (Figure 2). The annual rainfall is less than 600 mm in the North and 600-700 mm in the South.

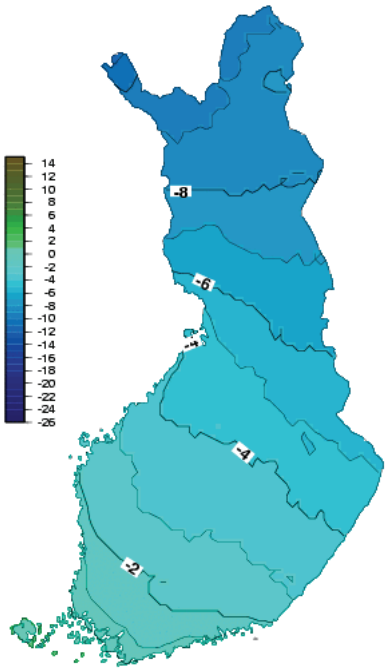


Figure 2 – Mean annual winter temperature (°C) during 1971-2000

Permanent snow falls usually in October or November in the North and in December in the South. The long-term average snowfall converted to millimeters of water varies from 120 to 220 mm in different parts of Finland (Figure 3). This amount of snow accumulates throughout the winter season, mainly as snowfalls under 10 mm.

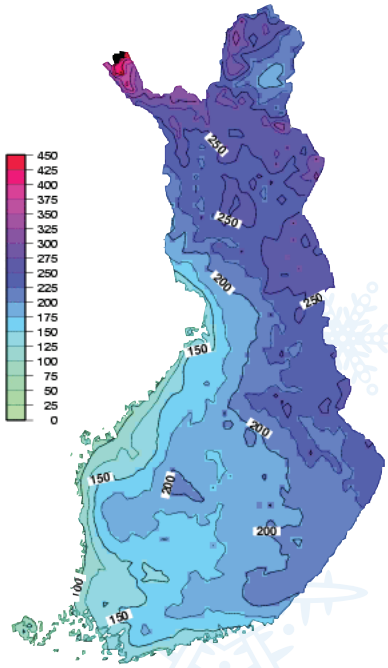


Figure 3 – Mean annual snowfall (mm) during 1971-2000

There is a costal climate on southern and western part of Finland and more a continental climate in eastern and northern part of Finland. The Baltic Sea and especially the Gulf Stream are making the climate warmer. Weather conditions can change quickly in wintertime.

The anti-icing is main concern in coastal area and snow removal more in eastern and northern part of Finland due to the climate differences.

2.3 Winter indexes

Finland does not currently have an index that would describe the severity of winter purely from the perspective of weather conditions. Research has, however, been carried out with the aim of establishing a weather index but a practical one has not yet been found.

The Finnish Road Administration procures road maintenance, and the leveling out of the pricing risk resulting from the level of severity of the winter must still be taken care of between the client and the contractor.

FINLAND

3. Winter Road Management

3.1 Standards and rules

The Finnish Road Administration (Finnra) is a state agency responsible for the management of the countrywide public road network. Streets in cities and municipalities are the responsibility of the municipalities. The private road network is the responsibility of the landowners living along the private roads.

The winter maintenance policy is based on traffic laws concerning winter tires, especially studded tires, and on the possibility of using salt to combat slipperiness. Winter tires have to be used from 1 December to the end of February. Studded tires are allowed to be used from 1 November to 31 March.

Road classification

The road network is divided into five main maintenance classes (Is, I, Ib, II, III). In addition, class Ib has a corresponding maintenance class TIb for built-up areas. Pedestrian and bicycle paths are divided into two maintenance classes (K1, K2).

Each class has a different level of service and quality standards. The level of service is mainly defined according to traffic volume, road functional class and regional climate, but local conditions, nature and composition of traffic, speed limit and qualitative integration with the level of service of municipality's road network are also taken into consideration.

Most of the main road network belongs to categories Is, I and Ib. Categories Is and I are completely free of ice and snow for most of the winter. Salting is the main anti-slipping procedure on these roads. Class Ib is maintained using less salt and the conditions are clearly wintrier than in categories Is and I, but otherwise the level of maintenance is high. Classes II and III are used on quiet roads. Very little salt is used. Instead, sand is used to combat slipperiness.

Quality standards

A friction value is held as an important quality standard in Finland because packed snow and ice is also allowed on the main roads. In many places, the traffic volume on the main roads is so low that a reasonable amount of salt is not able to keep them bare. The friction value is measured by C-Trip which is easy to use and cheap but not very exact. The measuring range is not very large.

Table 1 Correlation between friction values and driving conditions. The friction value is measured by C-Trip.

Friction value	0.00-0.14	0.15-0.19	0.20-0.24
Road surface condition	bad driving conditions, wet ice, very slippery	icy, slippery	tightly packed snow, satisf. winter conditions

0.25-0.29	0.30-0.44	0.45-1.00
rough, packed ice and snow, good winter conditions	bare and wet, not slippery	bare and dry, not slippery

The following tables present the main quality standards and reaction times of winter maintenance.

Table 2 Quality standards of anti-icing

Winter maintenance class	Is	I	Ib
Normal Friction requirement	0.30	0.28	0.25
	road surface below -6 °C 0.25	road surface below -4 °C 0.25	spot sanding 0.25 line treatment 0.22
Cycle time	2 h	2 h	salt 3 h sand 4 h

Winter maintenance class	II	III	K1	K2
Normal Friction requirement	Roughened surface, problem locations are spot sanded	Roughened surface, problem locations are spot sanded	According to traffic needs	
	Line sanding of icy compacted snow	Line sanding of icy compacted snow		
Cycle time	6 h line sanding	8 h line sanding	2 h	

FINLAND

Table 3 Quality standards for snow removal

Winter maintenance class	Is	I	Ib
Maximum snow depth	4 cm	4 cm	4 cm (8 cm, night)
Cycle time	2.5 h (slush 2 h)	3 h (slush 2.5 h)	3 h
If snowing stops after 22 at night	Ploughed clean within cycle time		

II	III	K1	K2
8 cm	10 cm	3 cm	4 cm
4 h	6 h	3 h	4 h
		Ploughed clean before 06	Ploughed clean before 07

Only half as much slush is allowed as snow.

Table 4 Quality standards for surface evenness

Winter maintenance class	Is	I	Ib	II	III	K1 K2
Evenness requirement	-	1 cm	1.5 cm (TIb 3 cm)	2 cm	2cm	2 cm hindering ruts

Tailor-made maintenance

If special traffic needs so require, timing or quality on specific sections on road may be modified locally without changing the maintenance class. The target of tailor-made maintenance is to improve the service provided for road users based on the special needs of the customers.

Rules regarding materials and equipment

Winter maintenance is ordered from contractors based on the principle of quality responsibility. It is thus the contractor's own decision as to which kind of treatments and equipment are used. The only requirement of the owner regarding the equipment is that it is safe, noticeable enough and suitable for the use.

The anti-icing materials intended for use must be accepted by the owner. Only moistened salt and brine are allowed to be used to prevent slipperiness. Calcium chloride is not recommended but allowed to be used in small amounts for moistening or black ice. Also potassium formate is used locally in aquifer areas because it has proven to degrade before it goes to ground water and does not cause more corrosion than sodium chlorite. The size of the de-icing sand grains must be 6-8 mm depending on the road class.

3.2 Organization and operation of winter maintenance

Organization

In 2001 the Finnish National Road Administration was divided into the Finnish Road Administration (Finnra), which orders services from producers, and the Finnish Road Enterprise, which takes care of construction and maintenance among other contractors and also provides consultation services. In the beginning of 2008 Finnish Road Enterprise became known as Destia. The Finnish Road Administration, Railway Administration and Maritime Administration will be united together and a new "Traffic Administration" will be established in the beginning of 2010.

Finnra orders winter maintenance along with summer maintenance as area maintenance contracts from contractors. The contractors for each region are chosen on the grounds of a price and quality competition.

Finland has been divided into nine road districts, which are responsible for the ordering of the maintenance of their own area under guidance of a central unit. There are 82 regional contracts, which means 7-11 regions per road district. Every regional contract includes 500-2000 km of road network and lasts 5-7 years. An option system is used in some contracts too. This means that the contract can be continued if desired by both of the contracting parties. The prices of the option years are the same as those of the last actual contract year.

Determining the level of service of winter maintenance is the responsibility of Finnra. Road users' opinions regarding the maintenance of the previous winter are sought out by a customer satisfaction survey every spring. They are taken into account in the planning work when possible. Direct feedback from the road users is also collected.

Operational management

Each contractor has the overall responsibility for the maintenance of the roads included in the contract area allocated to them, taking care of the supervision of the project, the performance of the maintenance duties, the assurance of quality and the necessary purchases.

FINLAND

The contractor plans and decides on the procedures that are to be carried out in relation to the road network and, by monitoring weather conditions and the conditions of the roads, ensures that the necessary measures are carried out at such a time that allows for the fulfillment of the quality requirements. In addition, the contractor is responsible for acquiring the equipment necessary for carrying out the work, as well as the personnel and materials. Subcontractors are also employed. The contractor must present a plan to the client regarding the execution of the procedures and quality assurance, prior to signing the contract.

The most important measures involved in the maintenance of roads in a condition set out in the quality requirements during winter are the removal of snow, prevention of slipperiness and ensuring a level surface of the road. In addition, the contractor must ensure that traffic symbols are clean and that banks of snow are lowered. The contractor must also keep in contact with the contractors responsible for adjoining areas, in order to ensure consistency in quality across the borders of different contract areas.

Road information provision

In order to ensure the timeliness of winter maintenance, various kinds of information on the current and impending weather conditions are necessary. To this end, the Finnish Road Administration has at its disposal road weather stations and weather camera systems. In addition, the Finnish Road Administration subscribes to various kinds of weather reports as well as satellite and radar images from external organizations. The supplier of weather information is also selected through competitive tendering. The weather information produced and subscribed by the Finnish Road Administration is also available to the regional contractors. Contractors can acquire additional weather information services to those provided by the Finnish Road Administration at their own expense.

The road weather station network of the Finnish Road Administration consists of over 350 road weather stations. The stations gather information on factors affecting the weather and driving conditions, such as the temperature of ambient air and the road surface, wind velocity and the moisture level of the road surface. The road surface information is assessed using a small sensor placed on the road surface. In addition Finnra uses optical remote surface state sensors, which give also the surface friction value (0.0-1.0). These sensors are combined to the 90 normal road weather stations. In the winter, road weather information is updated at least three times an hour. The information is updated more regularly when the temperature approaches zero, as this is when the weather is at its worst from the perspective of drivers and road maintenance staff. During the summer months, the information is updated approximately once an hour. The locations of the road weather stations along the road network are shown in Figure 4.

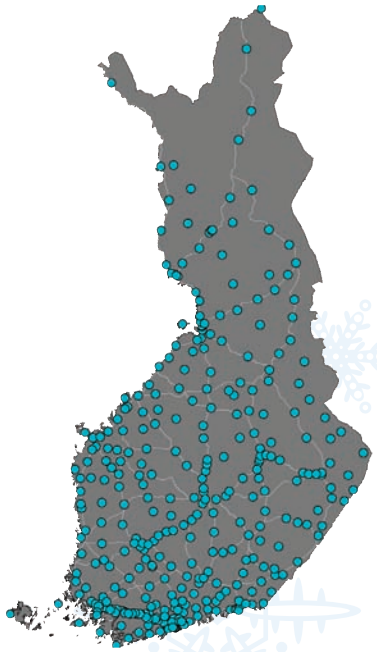


Figure 4 – Locations of the road weather stations

The weather camera network of the Finnish Road Administration comprises approximately 375 weather cameras. The network provides equal coverage of the whole of the Finnish public road network. In the autumn and the winter, all cameras are operational. The weather camera image is updated at an interval of approximately 15-90 minutes; more regularly in bad weather, and less regularly in good weather. The locations of the weather cameras along the road network are shown in Figure 5.

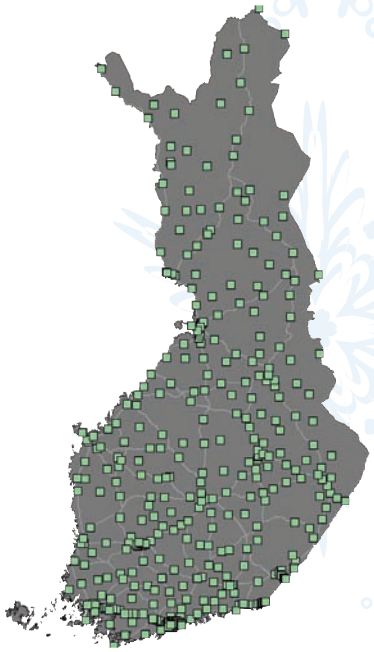


Figure 5 – Locations of the weather cameras

3.3 Assessment of the snow and ice control measures

Costs

The modest average daily traffic and long road network, which is maintained year-round to ensure usability, unavoidably leads to a relatively low level of cost-effectiveness. The annual winter maintenance costs have, however, been in same level as a result of competitive bidding. Winter maintenance costs of public roads maintained by the Finnish Road Administration (78,200 km) are about 98 million euros. This indicates a cost of approximately 1,000 euro/km.

The Finnish Road Administration finds the winter maintenance of lower-level roads (usually with a maintenance class of III) an especially demanding challenge and the users of these roads are unsatisfied with the maintenance. The number of lower-level roads is considerably higher than that of main roads, but only a fraction of the traffic takes place on these roads. The average daily traffic is often only a few hundred cars, whereas main roads usually have thousands if not tens of thousands of cars travelling along them every day. This is why focus on the maintenance of main roads provides higher efficiency in improving safety in traffic, for example. Due to the large number of lower-level roads, even a small increase in the level of quality creates significant additional costs. The division of roads, traffic and winter maintenance costs in relation to different maintenance classes is shown in Figure 6.

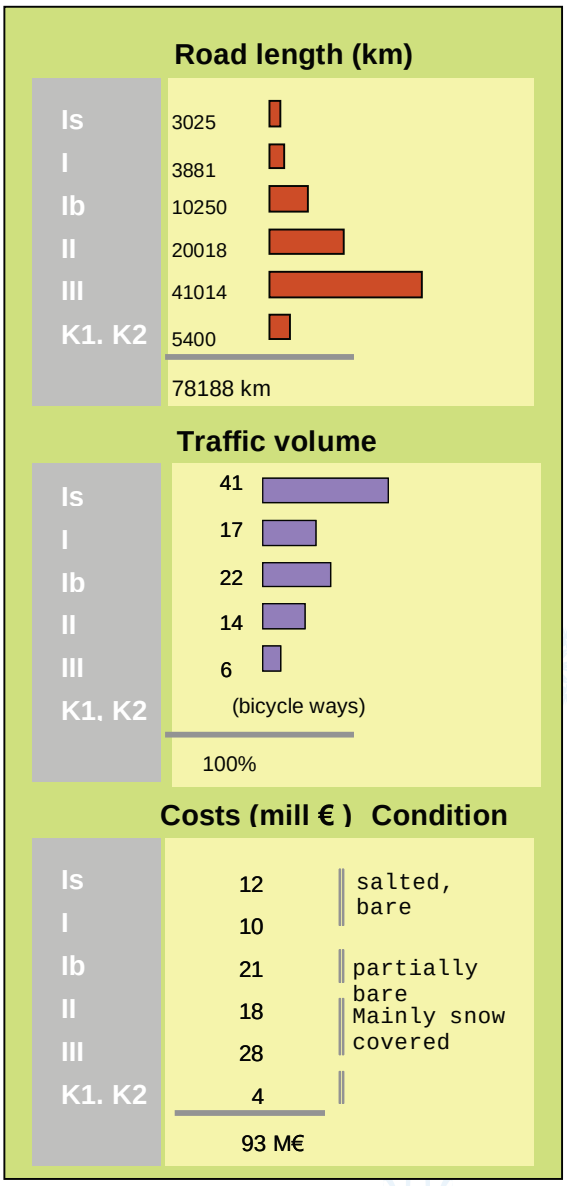


Figure 6 – Road lengths, traffic volumes and costs of winter maintenance in different maintenance classes 2007

Salt consumption

The most significant environmental issue resulting from winter maintenance is the damage suffered by ground water due to the salt used in anti-icing. The use of salt is especially popular in the coastal regions of Southern and Western Finland, where weather conditions often change suddenly and where there are large amounts of traffic. In some areas of Northern Finland, there is no need to use salt at all, as the amount of traffic is low and the weather conditions are colder and more stable.

The reduction of the harmful effects of salt is aspired to in many ways. According to the winter maintenance policy of the Finnish Road Administration, very little salt is used on groundwater areas for anti-icing, or potassium formate is used.

Due to significant wastage, the use of dry salt is forbidden as anti-icing. Salt is applied either as a solution or it is moistened prior to spreading. Roads in classes Is and I are kept unfrozen throughout the winter, as a result of which slipperiness of these roads has been prevented in advance, whereby less salt is required than in situations involving already-formed layers of ice.

In order to restrict the use of salt, the Finnish Road administration also defines on an annual basis the amount of salt to be used in each contract area on the basis of salt amounts used in previous years. In addition, separate, stricter restrictions are set for the use of salt on the groundwater areas. If the contractor uses more salt than has been agreed, fines will be enforced. Correspondingly, if salt is left over, the contractor will receive a bonus. The accepted amount of salt is, however, increased in winters that are considerably warmer than average.

The contractor is also expected to store the salt in covered facilities that have drainage, to ensure that groundwater across the rest of the environment is not at risk.

Assessment of the work

The contractor is responsible for ensuring and demonstrating the achievement of the quality of their work, as agreed in the quality plan. Quality reporting comprises reporting of the procedures that have been carried out and any deviations that have occurred. The reporting of procedures is realized through so-called cross-section monitoring, where the contractor discloses all measures taken in previously agreed reporting points and the times when these measures where performed. The contractor is expected to fill in a separate deviation report whenever the quality requirements are momentarily not met in relation to an individual section of the road network. The client expects the contractor also to keep an event log, where procedures, quality assurance and notes are recorded.

The client monitors the efficiency of the quality assurance measures taken by the contractor, and carries out random checks to ensure that the work is being carried as agreed. If a failure to meet the quality requirements is identified, the contract will receive a warning or a fine.

The contractor will receive payment for the work done on a monthly basis.

3.4 Traffic safety and information

Communicating traffic and road conditions improves safety and smoothness of traffic and reduces damages and harm suffered by the road-users and the environment as a result of traffic. The Finnish Road Administration has a Traffic Information Center that provides road-users with up-to-date information on the traffic and weather conditions as well as disturbances in traffic, such as accidents.

The Traffic Information Center provides information on traffic conditions primarily through the mass media – the radio, television and the Internet. The images from nearly 400 weather cameras of the Finnish Road Administration as well as information gathered by the road weather stations are available on the website of the Finnish Road Administration. Road users can also report any disturbances that they witness on the roads to the line for road users maintained by the Traffic Information Center. In addition, road users are guided with the help of changing road signs and traffic symbols to select their route in such a way as to make travel time as short as possible and the level of service as high as possible throughout the journey.

Variable speed limits exist on some important 2-lane main roads and motorways comprising over 300 kilometers in total. The speed limits are displayed according to the road surface condition and weather monitored in real time. Occasional disturbances for traffic such as road accidents or road maintenance work may be reasons for a lowered speed limit displayed as well. Furthermore, variable message and traffic signs may be used as complementary tools, for example, to inform the drivers of road weather conditions or important traffic incidents. Variable speed limit signs have also been installed at some special sites where accident risk is high, in order to lower the speed limit for a short period of time.

In addition to the road weather stations and the weather cameras, the Traffic Information Center gathers the information it needs for communicating and guiding traffic through an automatic traffic measuring system (LAM). The system comprises 290 traffic-measuring devices with sensors placed on the road as well as the related systems for transferring, storing and printing out the information. The system provides information on the amount of traffic on a stretch of road, the average speeds and the overall time spent on a journey.

The information is used not only for monitoring and communicating traffic issues but also for planning road maintenance. For example, the daily maintenance of a road can be carried out in a more meaningful and economic way through taking advantage of the information on amounts of traffic at different times of the day. The system also provides information for traffic safety studies, indicating the breakdown of a driving experience in terms of speed and distance between cars in different conditions and as a result of different factors. By combining traffic information with the weather information produced by the road weather system, the development of a risk of accident can be studied with regard to different weather and congestion conditions, as can the effect of winter speed limits to the travelling speed of cars, for example.

In addition, the Traffic Information Center receives up-to-date information on the condition of the road network from other authorities, such as the police, the emergency centers, road services and regional contractors, as well as from road users via the telephone line for road users.

4. On-going Research and Studies to Improve Winter Management

Developing a customer satisfaction bonus

The Finnish Road Administration actively aims to find ways to improve the service provided for road users. The Finnish Road Administration has been trying to find ways of improving the service without significantly increasing the costs. The aim has therefore been to improve the operations of both the Finnish Road Administration and, through subscription services, those of the contractors to take heed of the local needs of the road users even better than before.

As one of the ways of encouraging contractors to serve road users better, the Finnish Road Administration has been developed a customer satisfaction bonus to be paid to contractors. In spring 2004, the Finnish Road Administration launched a separate research and development project that aims at developing the customer satisfaction bonus, as well as already piloting the bonus scheme at the same time in relation to five contracts that begin in 2004.

The objective of the study was to improve the service provided to road users by developing a bonus system for contracts that encourages the contractors to take road users and good service actively into account. The study was completed in October 2004.

The bonus, which is based on customer satisfaction, has been used since 2004 in little different forms. Bonus on customer satisfaction is available annually. The extent of the bonus depends on 6 different assessment factors, of which 4 relate to customer satisfaction, one deals with the success of winter maintenance and one relates to the success of summer maintenance on the basis of an assessment carried out by the client. The assessment carried out by the client is based on the reporting of the contractor in relation to measures taken. Customer satisfaction bonus is paid annually and the extent of the bonus varies between 0 and 1.6 percent of the annual costs of the contract.

The bonus system has not proved to be as good as expected. Customer satisfaction is so strongly depending on weather conditions that it effects more than the contractor's actions. The bonus system is, however, an effective way to get contractors to understand that road users are also their customers.

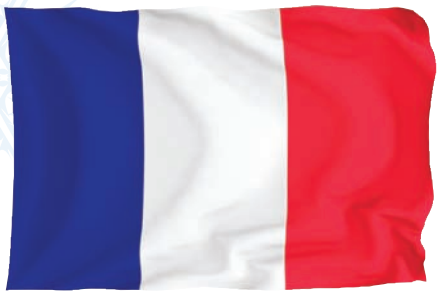
5. References

Information about Finland's geography, population, climate etc.: http://virtual.finland.fi

Finnra : www.tiehallinto.fi/eindex.htm

Travel and traffic information:
www.tiehallinto.fi/alk/english

Traffic Management Center:
www.tiehallinto.fi/alk/english/info/likesk_e.htm



FRANCE

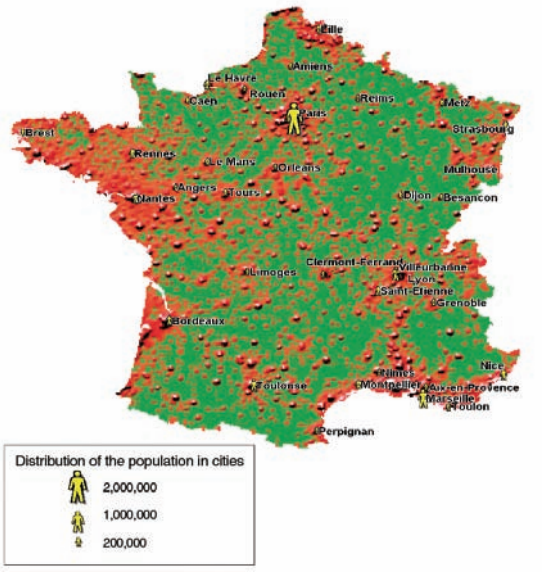
snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

France is a country of average size located on the Atlantic. Its 64 million inhabitants are somewhat unevenly distributed across its territory.

Surface area	551,000 km^2
Population	64 million
Density	116.15 inh./km^2
Capital	Paris
Latitude (capital)	48.8 N



Its geography is very diverse, as is its climate, making France a preferred tourist destination. Aside from the major economic activity generated by tourism, France's industrial and agricultural sectors remain very active. The country's administrative organization and history have given France a very dense network of roads.

1.2 Road network and traffic

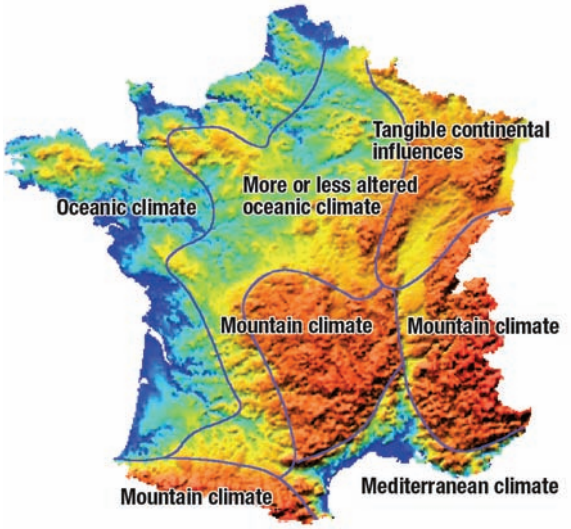
As a whole, the French road network represents about 1 million kilometers. The State operates 2% of the network, i.e., 20,000 km of national roads and conceded motorways. State departments are divided into 11 DIRs (inter-departmental road directorates) managing 9,000 kilometers of national roads and 2,800 kilometers of motorway. Motorway concession holders manage 8,400 kilometers of roads. General councils manage 380,000 kilometers of departmental roads.

Communes manage 600,000 kilometers of communal roadways. There are around 26,800,000 private vehicles and 5,500,000 utility vehicles.

Network of DIRs

FRANCE

Conceded motorway network



2. Climate

2.1 Overview of climatic areas, main winter events to be addressed

France can be divided into five main climatic areas:

Mediterranean climate

Temperatures are mild in winter (7 to 9 °C on average in January), but the windchill can sometimes cause a sharp drop in temperature. There are 20 to 30 days of frost per year and often fewer along the coast. Snowfalls are rare and the population is not accustomed to them; however, between 700 and 800 millimeters of rain falls every year over 70 to 80 days.

Oceanic climate in the west of France

Rain is frequent but of low intensity (between 150 and 180 days per year). Humidity is high and temperatures are mild.

Less oceanic climate

Less precipitation and colder winters. More days of frost.

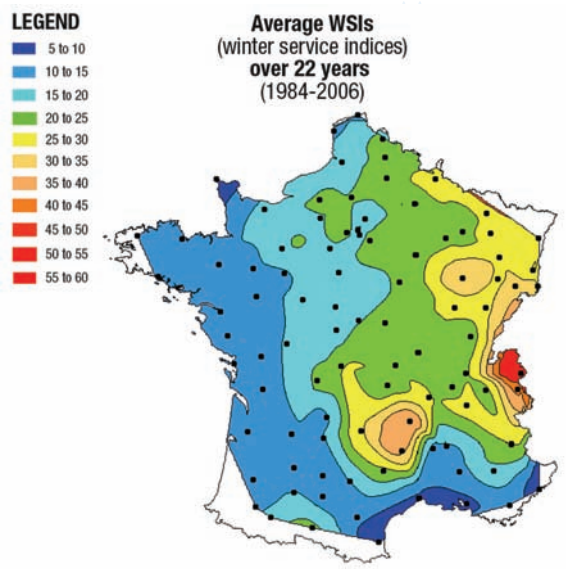
Continental climate: From north to east. Dry, harsh winters with snowfalls.

Mountain climate: (Vosges, Jura, Alps, Pyrenees) Due to altitude: lower temperatures and more frequent precipitation (snow).

	T °C	Precipitation		
Climate	January	Quantity per year in mm	No. of days	Days of Frost
Mediterranean	7 to 9 °C	700 to 800	70 to 80	20 to 30
Oceanic	5 to 7 °C	700 to 900	150 to 180	15 to 45
Less Oceanic	2 to 5 °C	600 to 700	140 to 160	40 to 60
Continental	-1 to 1 °C	700 to 900	150 to 170	70 to 90
Mountain	-1 to 4 °C	1000 to 1500	170 to 180	70 to 90

2.2 Winter index used in the country

A winter index was developed based on meteorological data. It is calculated for an entire winter and characterizes the latter.



FRANCE

3. Winter Road Management

3.1 Standards and regulations

In France there is **no legal obligation** to provide winter maintenance. Documents produced and distributed by the MEEDDAT (French Department of Ecology, Energy, Sustainable Development and Territorial Development) set out general rules. The other Road managers (motorway concession holders, general councils) draw from the regulations established for national roads to define their levels of service or develop their own specifications. There are documents on the organization of winter maintenance (Winter Service Organization File (WSOF) and Winter Service Operating Plan (WSOP)) (SETRA 1994, SETRA 2009 comprehensive approach methodological guide).

Using these documents (circular, departmental WSOF, local WSOP), the levels of service are defined based on the harshness of winter and the type of network. The Winter Service Organization File is a kind of contract between owners of the road and main contractor. It informs the various partners of the objectives, limits and measures taken for winter maintenance. It explains the organization and actions to be taken in each situation. It also aims to ensure some consistency between road managers. Threshold meteorological situations are defined. The WSOF sets out the measures regarding road information.

Winter road conditions that users may encounter due solely to the presence of snow or ice on the road form the basis of a common language. Cis are used to establish levels of service and winter road information.

Winter driving conditions	Depiction	Heading/color code	Perception of danger	Probability of a jam
C1		Normal (green)	N/A	N/A
C2		Tricky (orange)	Low (presence of ice barely perceptible; localized snow)	Low, possible on slopes or inclines greater than 3%
C3		Difficult (red)	Easy for snow Low for ice	High
C4		Impossible (black)	Clear	Traffic fully jammed

	Black Ice	
Road conditions (RC)	Standard 99-320 terminology	Operating terminology
RC1	Dry, Transitory moist, Moist, Wet, Streaming wet	Absence
RC2a	White frozen, Frosted, Icy, Ice	Localized, thin formation of ice (freezing of existing moisture or condensation) or ice patches
RC2b	Localized or thin	
RC3	Frosted, Generally icy due to the freezing of supercooled droplets or freezing of preexisting water	Generalized formation of ice due to the freezing of existing moisture
RC4	Generally icy following precipitations on the road at below-zero temperatures or supercooled precipitations	Generalized formation of ice following freezing rain

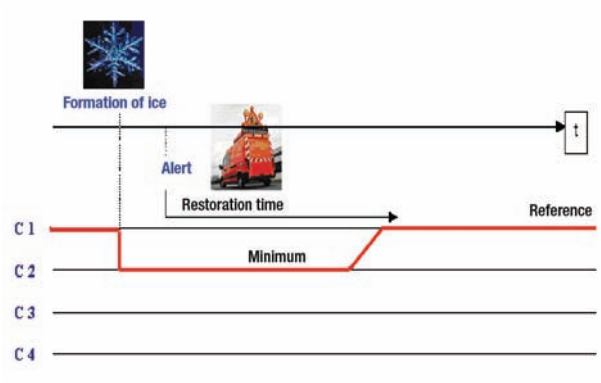
Road conditions, example of ice

Road conditions (illustrative data, to be specified and adapted)			Winter driving conditions	Color code
Black Ice	Snow, no slope or incline	Snow, with slope or incline > 3%		
RC1	RC1	RC1	C1	Green
RC2	RC2a	RC2a	C2	Orange
	RC2b			
RC3	RC3	RC2b	C3	Red
		RC3		
RC4	RC4	RC4	C4	Black

Link between road conditions and winter driving conditions

FRANCE

The principle of levels of service is the following. In winter, a reference condition is allocated to each road based on traffic patterns and geographical location. During a winter event, traffic conditions will fall below the reference conditions. At the end of the weather event, the service must restore the reference conditions within a given amount of time. This response time is a quality indicator. For ice, the clock starts at the time the alert is issued; for snow, it starts at the end of the snowfall.



Evolution of driving conditions in the case of ice

Four restoration times have been defined:

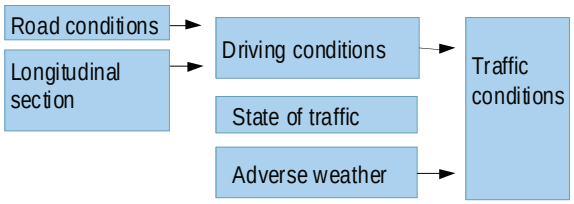
- Short: 1 to 2 hours;
- Average: 3 to 5 hours;
- Long: more than 6 hours;
- Indefinite time.

The quality objectives defined by each service are called **levels of service (LS)**. This choice is defined by the various owners of the road.

Levels			LS	LS	
				Terms 1	Terms 2
Validity periods					
Reference conditions					
Ice situations	Without precipitations	Minimum condition			
		Restoration time			
	With precipitations	Minimum condition			
		Restoration time			
Snow situations		Minimum condition			
		Restoration time			

Standard framework for defining levels of service

Winter driving conditions are but one example of the potential components of traffic conditions.



3.2 Organization and operation of winter maintenance

Personnel standards

The European directive of 1993 is applied to winter maintenance through various texts defining its application. The principle is as follows. For each homogeneous climatic area, a standard situation is defined in the WSOF, taking into account the average response actions for that type of situation. In this case, the European directive applies. In the event of an unusual and unforeseeable situation, the following exemptions apply: the rest period can be more than 9 hours (instead of 11 hours), the work time can be 60 hours (instead of 48 hours) per week, and there may be a weekly consecutive rest period of 24 hours every week (instead of 36 hours). At the end of each exceptional situation, there must be a rest period.

Equipment standards

Standards regarding winter maintenance equipment and materials have been developed.

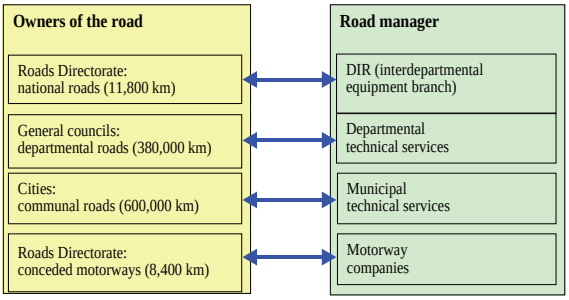
- *NF P 98-180: Use of sodium chloride as an ice melter, specifications*
- *NF P 98-181: The aim of this draft standard is to provide a framework for all melting products likely to be used on roads, whether mineral or organic, by-products or even industrial co-products in liquid or solid form.*
- *NF P 98-790: Winter maintenance materials, baseplate, characteristics*
- *NF P 98-791: Winter maintenance materials, customized hydraulic device on vehicles equipped with salting units and snowplows, characteristics and specifications*
- *NF P 98-792: Winter maintenance materials, position of in-cab controls, characteristics and specifications*
- *NF P 98-793: Winter maintenance materials, terminology*
- *Standard NF P98-795: Winter service and maintenance materials for road appurtenances—signs, markers and lights for winter service responder units—characteristics and specifications*
- *Standard NF P 98-796: Light baseplate, characteristics and specifications*
- *Standard NF P98-797: Road maintenance materials and products—ice melter spreaders for roads—fixed-station testing method for the measurement of flow rates*
- *NF P 95-303: Avalanche protection equipment, avalanche barriers, specifications and design*
- *NF P 95-304: Avalanche protection equipment, avalanche protection net, specifications and design*
- *NF P 95-305: Avalanche protection equipment, avalanche protection net, snow fence, specifications and design*
- *NF P 95-306: Avalanche protection equipment, selective passive anchors in loose ground, wrench-test method—specifications and design*
- *NF P 95-310: Avalanche protection equipment, avalanche release, technical principles*
- *NF P 95-311 Avalanche protection equipment, avalanche release, cable explosives transport system (CATEX)*
- *NF P 95-313: Avalanche protection, gas activation*
- *NF P 95-314: Avalanche protection, electric activation*

FRANCE

Winter maintenance preparation and organization

General

In France, road maintenance operations are organized as follows:



No matter the owners of the road, the organizations established are built following the same pattern, resulting most of the time in the production of a WSOF.

The DIRs comply with government requirements regarding their organization. Motorways are generally granted the highest level of service.

The WSOF informs the various partners of the objectives, limits and measures taken. It sets out all the instructions for various winter situations. It must ensure consistency between the various networks. It is used to structure user information.

A description of road weather phenomena is given, in particular the threshold meteorological situations beyond which it is no longer considered possible to maintain normal service.

Parameters	Criteria and associated values
1 – Intensity of snowfall	Average hourly snowfall (non-melting snow), calculated over a three-hour period, at least equal to N cm/h
2 – Duration of snowfall	Continuous or intermittent snowfall (non-melting snow) at < 6-hour intervals, for a total duration of over N hours
3 – Snowfall and low temperature (during or immediately after, because of the risk of freezing and adhesion to the ground)	Temperature below – 8 °C during the snowfall or immediately after
4 – Freezing rain	Rain causing the formation of ice
5 – Wind and snowdrifts	Snow accumulation at a depth exceeding the capacities of the measures in place, over at least one lane and a significant cumulative distance (e.g., at least 100 m for 10 km of road)

Characterization of threshold meteorological situations

For each winter phenomenon, rules and procedures are defined, setting out the players concerned and the measures to be implemented.

In the WSOP, which is the local version of the WSOF for operational centers, all the procedures are described in detail. This document generally contains the following information:

Various maps

- roads and levels of service;
- patrol routes and control points;
- location of RWISs;
- response centers and materials storehouses;
- map with road conditions.

FRANCE

Guides for:

- the distribution and use of weather reports;
- supporting decision-making;
- organization in exceptional situations.

Other documents:

- Patrol checklist;
- Equipment and materials checklist;
- Checklist describing actions (for decision-making and response purposes);
- Name and contact information of managers;
- Instructions for pre- and post-winter actions.

Before each winter the WSOF should be read and modified as required. The WSOPs are updated within the departments.

A status report must be produced after winter. As well, indicators must be defined and their use generalized to evaluate the quality of the services.

Information used

Meteorological information

Various service providers offer weather reports adapted to the road. Each local administration must purchase its local weather forecasts; there is no national contract and the information is not centralized. Basic weather information is also provided to the CRICR (organization responsible for road information and including peacekeeping forces (police, gendarmerie) and equipment). For the purposes of road safety, the CRICR may retransmit the information to departmental services.

RWISs

There are approximately 800 **R**oad **W**eather **I**nformation **S**ystems (RWISs) along most motorways and major roads.

The information obtained from these stations is not centralized at the national level. For motorways, the information is sometimes centralized in a district and/or region (for one motorway concession holder).

There are four categories of stations.

Road weather information system.

The information can be centralized at the departmental level. The department then retransmits the information to local services or the information stays at the local level (in this case, only information from a single station is available).

Choice of location for a RWIS station:

RWISs are generally implemented in more representative locations, based on a thermohydric profile or the knowledge of the officers who choose the locations.

Vehicle used for the thermohydric survey

Methods

Preparatory program

Winter is generally defined as beginning on November 15 and ending on March 15. Many RWISs are activated only during this period.

FRANCE

Various states of activation

The latter depend on the situation. Two types of situations have been identified: normal and abnormal.

Context	Types of actions		Comments
Normal situation	Performance of winter service in accordance with the levels of service set	With own resources only	Resources (human and physical) available to the road manager on a permanent basis. Their effective mobilization is decided based on the current and foreseeable meteorological situation.
		With own and complementary resources	Resources available to the road manager in addition to his own, either systematically or based on the extent of the adverse weather, following pre-established procedures and provided for in contracts and/or agreements.
	Special traffic management measures		Provisions specific to these measures are defined in the [PGTs] and/or in adverse weather plans. These measures may be preemptively taken in normal situations and/or taken in abnormal situations
Abnormal situation	Performance of winter service with mobilization of support services[2]		Resources that will be mobilized in addition to the organization's own and complementary resources in the event that the threshold meteorological situation is exceeded, following the provisions made in the Winter Service Organization File (lists of resources, mobilizable companies, etc.), aiming for compliance with the levels of service, but without any guarantee regarding the often uncertain mobilization of support services.
	Temporary downward adjustment of service levels on part of the road network[3]		The aim here, if the threshold meteorological situation is exceeded, is to focus response actions (see the three types defined above) on a fraction of the network (linear, number of lanes, etc.) designated by the owners of the road. The terms for the implementation of this type of measure must be defined in the WSOF and/or in the adverse weather plans.

Equipment

Response vehicles

In all of France's departments and services, approximately 9,000 winter service units are available for response actions. The equipment used often varies greatly depending on the region and the type of network.

Response unit

Snow fences

Snow fences are used preventively. Their selection and implementation is governed by a standard (AFNOR 1992). Revegetation is also used. The decision to install a snow fence is made and funded at the local level.

Materials

Salt consumption varies between 0.4 and 1.6 million tonnes per year (average of 1 million tonnes). For a preventive application, 15 g/m^2 are used on average. Curative applications use an average of 25 to 30 g/m^2.

Various pedagogical documents regarding the optimal use of salt have been published at the national level. They contain general information and tips, but no absolute procedures. The quantity of salt depends on the nature of the road weather event to be addressed. For example, the quantity of salt to be spread will differ depending on the nature, quantity of ice, etc.

Personnel training

Between 30,000 and 35,000 officers can be mobilized across all departments responsible for winter maintenance.

Specific tasks

Specific trades are identified for specific tasks.

- *Intervention manager*: responsible for the response equipment and, depending on the organization in place, may decide when to carry out response actions and informs the CRICR;

FRANCE

- *Response authority or weather guard*: centralizes all of the information available: meteorological, RWIS, patrols, truck drivers. Following the organization in place, decides when to carry out response actions and informs the intervention managers;
- *Patrol*: verifies road surface and driving conditions, takes note of road weather parameters and observes the future formation of ice;
- *Response team or response unit driver*: carries out response actions using the response units (spreaders, snowplows).

For main roads, this system works quite well.

For the other networks, there is not enough staff to define specific tasks, and several tasks are sometimes entrusted to a single employee. E.g., the patrol officer may decide that response actions are needed. The duties of an intervention manager may sometimes be combined: decision-maker or weather guard and response unit driver.

Training and education

For the main roads, training is organized internally. Generally speaking, motorway concession holders have a training center and provide specialized training in winter maintenance.

For national roads, the training is organized in professional training centers and provided by the winter maintenance scientific and technical network (approximately 10 people). There is special training for new employees and introductions to specialized topics in more general training.

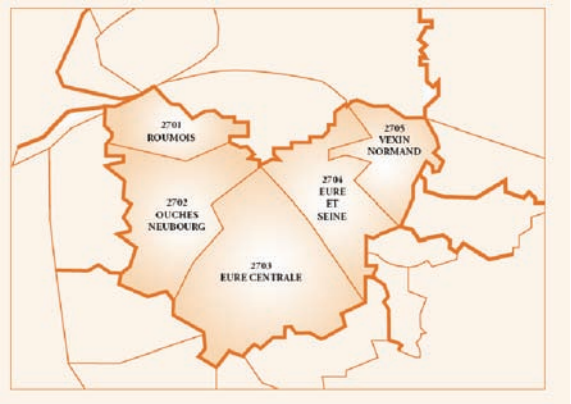
Engineers receive no particular training regarding winter maintenance.

Operational issues

Winter maintenance services respond on average 14 days per year, from 0 to 150 days depending on the year and climatic area. Interventions take place twice as often during the night as in the day.

Weather forecast

Forecasts adapted to road applications are available: air temperature, wind (strength and direction), cloudiness, and meteorological events: precipitations (nature and intensity), storm, and fog, in various forms. Aside from the historic government service provider, private suppliers offer the same kinds of services. The following example is based on the services offered by Météo France.



Winter service bulletin: Expert commentary on forecasts of phenomena likely to affect roads within a department or even a road segment in the next 24 hours. Updating frequency: twice daily.

Weather maps: A department can be divided into 6 to 8 homogeneous sectors. A three-hour forecast of various parameters is given for each sector every three hours. This allows for a visual representation of weather forecasts on a map using specific values or pictograms. At the present time, the atmomap provides forecasts every 3 hours for time + 3 to 36 hours.

Meteorological chart: Table providing for a given point a 36-hour forecast of various meteorological parameters, given every 3 hours.

Weather flash: Alert bulletin on the prediction of so-called "hazardous" weather phenomena (e.g., snowfalls, air temperatures below -10 °C, etc.).

Operators can generally call the weather office for more information.

A surface temperature forecast product is available: hourly predictions of road surface temperatures up to 36 hours in advance across the country over an 8-km grid.

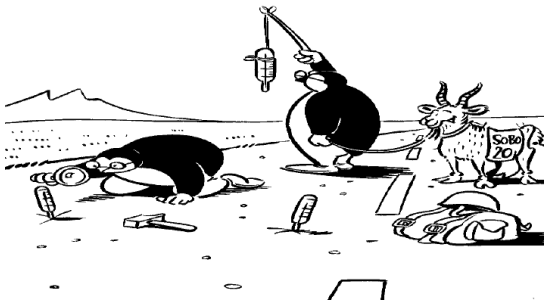
The raw data obtained can be enhanced with statistical adjustments for specific points for which at least two years of observed data regarding the road temperature are available.

Patrols

On motorways and national roads (and normally when the level of service is high), a patrol takes place every three or six hours to monitor roads (accidents, road clearing and winter maintenance). The idea is to quickly remove all disturbing events and to quickly have somebody on site in the event of a problem (accident, traffic jam, etc.).

FRANCE

On networks with a lower level of service, no response actions are carried out between 9:00 p.m. and 6:00 a.m., and often no patrol.But depending on weather forecasts, there may be a patrol around 3:00 or 4:00 a.m. In some cases, patrols are systematic if there is a risk of ice forming, even on smaller roads.



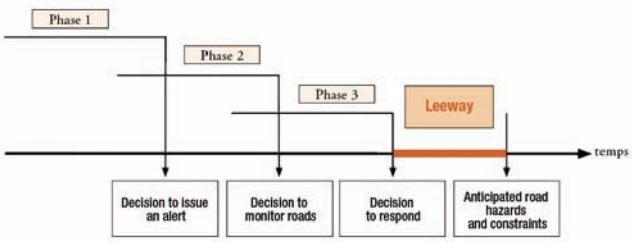
Decisional process

There are three types of activities to be carried out before an actual intervention:

- Taking into account of weather forecasts;
- Collection of information on road networks;
- Selection of the type of intervention.

These activities correspond to three decision levels, spread out over time with increasingly shorter deadlines:

- The decision to issue an alert;
- The decision to monitor roads;
- The decision to respond.

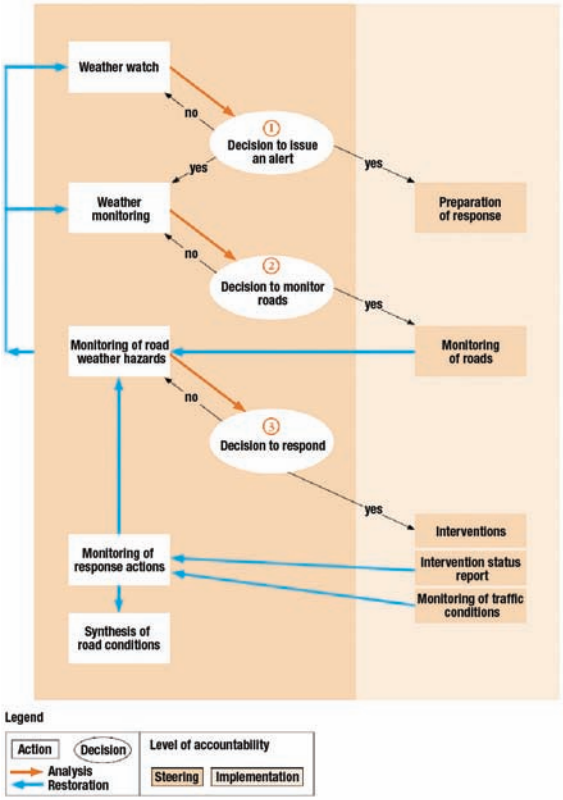


Three phases have been identified:

- A qualified weather watch and the decision to issue an alert;
- Close meteorological monitoring and the decision to monitor roads;
- Accurate analysis of road hazards and the decision to respond.

Meteorological data, the information obtained from RWISs and observations from patrols are used to make decisions regarding whether or not response actions are needed.

Equipment and organization levels can vary widely depending on the network manager. Sometimes, patrol officers can themselves decide to respond if they are alone at the operation centre. Patrols can sometimes be performed directly using response units, which then carry out interventions if necessary.



Methods, equipment and materials

There is no general snow removal policy and practices can differ greatly. For multiple-lane roads, some start on the right and others on the left. There is still also the exit problem.

Roads with a high level of service must, under normal conditions, be cleared to the pavement very quickly. To help prevent wet snow from sticking, a pre-emptive treatment may be useful (15-20 g/m^2). Then, frequent plowing is needed if traffic is heavy. Salting after each plowing (15-20g/m^2) is recommended. If there is less traffic, plowing without salting may suffice.

Salting must not be used to melt snow (because the quantity needed would be too great) but must transform the snow to prevent compacting and facilitate plowing. The treatment depends of the quality of the snow.

FRANCE

A dry, cold snow on a dry, cold road sticks very little and is not tamped down by traffic. Salting in this type of snow would transform the latter into wet snow that would be tamped down by traffic.

When the snow contains a little water and the air temperature is low (< - 3 °C) or the humidity is low (< 75%), it is better to use wet salt.

In the mountains, snowfalls are heavier, the air is drier and the temperature colder. This is why salting is less effective. An increase in the quantity of salt is not recommended. More frequent plowing combined with a wet salt treatment may be useful. But to date, these data constitute expert knowledge and are not often used by operational services.

White roads

On some roads, no winter maintenance is done, and may even be closed in winter.

Abrasives to ensure the usability of white roads are little used. They are used in cities and winter resorts; however, the latter are increasingly resorting to the use of ice melters.

Special rules for lorries

In France, almost all lorries are semi-trailers, which cannot drive on sloped roads (more than 4%, for example) when they become slippery. On heavy-traffic roads, lorries often generate problems (accidents, traffic jams, etc.). The definition of traffic conditions takes into account the specific characteristics associated with the profile of the road and the types of vehicle (trucks, light vehicle (LV)). The dissemination of information has improved with the use of PMVs and radio (CB). Lorries are sometimes invited to stop and wait as part of measures taken in the event of adverse weather.

But on smaller networks, there is no dynamic signage. On some roads, "white convoys" are organized. About 10 lorries follow a winter maintenance vehicle under police control and cars can circulate in the other lanes. But this system does not work very well when lorry traffic is heavy, which requires good coordination between the various services responsible for winter maintenance and the police.

Traffic

Article R414-17 of the *Code de la route* stipulates the following:

When at least one lane is covered with snow or ice on all or part of its surface:

1° Passing and changing lanes are forbidden for all vehicles with a gross vehicle weight rating greater than 3.5 tonnes or combinations of vehicles longer than 7 meters;

2° Passing winter maintenance vehicles in operation on the road is forbidden for all vehicles.

Furthermore, adverse weather plans provide for the management of crisis situations. Each plan sets out:

- The coordinating authority in charge, as well as the CP (command post) on which it can rely to carry out its duties;
- The organization responsible for making decisions and coordinating the authorities involved;
- The operational organization of the services to implement the decisions made;
- The organization responsible for communicating with road users;
- The various coordinated operational measures that can be applied depending on the context at hand.

Their goal is to ensure maximum user safety, particularly in the event of seriously adverse weather, by:

- Providing information to users;
- Managing the road traffic in such a way as to allow for the optimal flow of traffic, even in degraded conditions;
- Providing assistance and help to blocked users.

Methods, equipment and material for ice control

Chemical de-icing

Removable spreaders equipped for wet salt are used most of the time. The wet salt is composed of brine and pellet salt. The brine (water saturated with salt) is usually made at the response center using water and NaCl. Because they are rarely used, calcium- and magnesium-based brines are usually delivered.

In 99% of cases, solid NaCl or NaCl brine is used. In exceptional situations (very cold temperatures, freezing rain), some use solid NaCl and $CaCl_2$ brine.

The proportion of brine and rock salt can be adjusted on the spreaders and is usually set between 15% and 30% brine. In France, almost all the spreading is now done using wet salt. The spread rate depends on the kind of problem. With wet salt, it is possible to achieve rates of up to 5 g/m^2 for preventive treatments. Salt is increasingly being stored under shelter so as to limit losses, environmental impacts and drops in quality.

Automatic brine spraying:

This technique appeared in France some ten years ago but is relatively little used because of its cost. It is used on motorways because of the significant heavy-vehicle traffic and on short 100- to 300-metre segments.

Plowing:

In general, double-blade plows are used across the road network.

Sanding and sand sweeping

Very little sanding and sand sweeping takes place in France.

Porous asphalts

Porous asphalts are generally treated differently. A pedagogical document explains the particular difficulties encountered on these surfaces and proposes methods for monitoring and treatment.

Average spread rates are higher (between 50 and 100%) and there can be up to twice as many interventions. In the event of snow, motorway concession holders provide for plowing every 20 minutes.

Thin bituminous concrete is also sometimes problematic. The only known solution is to plan for more interventions and higher spread rates.

Bridges

There are no regulations with any particular provisions to ensure the wintertime operation of bridges. However, there is a set of measures contained in various documents and standards mainly aimed at the design of structures.

The use of non-corrosive melters to systematically treat all bridges is no longer justified.

Recently built structures, as well as older structures that have recently been upgraded and/or undergone maintenance, benefit from modern construction details and protection techniques. The use of special, non-corrosive melters is not necessary for these structures.

The use of special non-corrosive melters is accordingly reserved for metal bridges that have not been the subject of particular maintenance over the last two decades and those affected by localized corrosion.

Avalanches

There is a special organization for predicting avalanches. Winter avalanche fences can be installed.

High-altitude weather stations (called "NIVOSE") record meteorological data and the characteristics of the snow cover. In ski resorts, qualified staff take snow samples every week to study the evolution of its various layers.

A model called SAFRAN-CROCUS-MEPRA taking into account meteorological forecasts and the physical parameters of the various layers of the snow cover calculates the avalanche risk for a given point. The information is then broadcast to users using various means (TV, radio, etc.). When possible, avalanches can be provoked when there is a hazard.

3.3 Evaluation of the results

Measurement of efficiency

A few years ago, the Roads Directorate performed an assessment using the following parameters: salt consumption, cost per kilometer, number of man-hours for winter maintenance. User satisfaction surveys were conducted.

Inspections are sometimes performed to determine how directives are applied by the services.

Analyses that are now fairly old were performed regarding the application of circulars and the quality of the WSOFs. The DIT (as the Roads Directorate is now called) has undertaken a thought process on the implementation of indicators, in particular user satisfaction indicators.

FRANCE

3.4 Road safety and information

Information for users

Before winter, information is disseminated by road managers through various media (radio, newspapers) or in public places, town halls, etc. Maps showing the levels of service are distributed.

Agreements have been established between road managers and local radio stations for the dissemination of information regarding road weather events. Road services develop texts containing the information to be distributed to the radio stations.

On motorways, a special radio station (107.7) as well as dynamic signage broadcast road information. Users can also contact the CRICR 24 hours a day for specific information (roadwork, traffic jams, usability of the road).

Winter driving conditions	Depiction	Heading/color code	Translation for user communications and information		
			Perception of danger	Probability of a jam	Advice to be disseminated to users
C1		Normal (green)	N/A	N/A	Be careful. "A road can never be considered to be free of hazards."
C2		Tricky (orange)	Low (presence of ice barely perceptible, localized snow)	Low, possible on slopes or inclines greater than 3%	Slow down and drive very carefully. Increase the gap between your car and those around you. Winter tires are recommended
C3		Difficult (red)	Easy for snow Low for ice	High	Install winter equipment adapted to the conditions; otherwise, change your travel plans(1)
C4		Impossible (black)	Clear	Traffic fully jammed	Do not drive

Driving conditions and user information

4. Ongoing Research and Studies to Improve Winter Maintenance

4.1 New technology and research

Research projects in the field of winter maintenance have experts in methodological and organizational approaches working closely together. Some of these projects aim to define more exactly the road conditions used to establish levels of service.

Research projects currently underway include:

- Modeling of the thermal behavior of roads and atmospheric interface;
- Development of test protocols for the qualification of RWISs;
- Radiometric measurements;
- Detection of ice using fiber optics;
- Knowledge of the winter sensitivity of a network (thermal mapping);
- Real-life behavior of snow on a road;
- In-lab characterization of the adhesion in winter of various surface layers;
- Development of tests for the qualification of spreaders (DORSA devices);

DORSA device

- Optical analysis of the distribution of melters on a road surface;

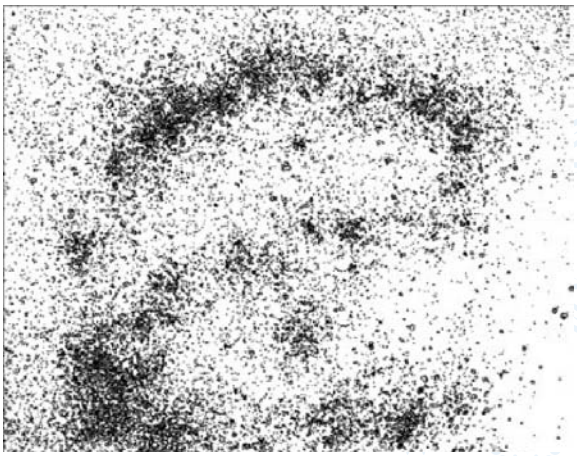


Image of the distribution of pellet NaCl

- Experiments on the guidance of winter service units ([GSM/SIG]);
- Development of test protocols to evaluate the "use value" of melters.

4.2 New management and organizational approaches

The methodology for defining levels of service was updated in 2009 and a new circular regarding its application for the national road network will be released shortly.

Snow plans and traffic management plans are operational. A review of the consistency of the levels of service resulting from the government reform and the management of part of the former national network at the local level is now—more than ever—relevant.

4.3 International cooperation to improve the levels of service between neighboring countries

There is significant collaboration at the European level, and the work of the COST 353 has laid the foundation for a review of the levels of service in Europe.

5. References

A website compiling knowledge in the area of winter maintenance is operational and accessible to all.

www.viabilite-hivernale.developpement-durable.gouv.fr/

Glossary

WSOF: "Winter Service Organization File." Document on the organization of winter maintenance.

WSOP: "Winter Service Operating Plan." Local version of the WSOF.

DIR: "Direction interdépartementale des routes" [interdepartmental roads directorate]. Interdepartmentally delegated operational service reporting to the MEEDDAT.

CRICR: "Centre régional d'information sur la circulation routière" [Regional Traffic Information Centre]. Organization reporting to the MEEDDAT, the police and the army and responsible for centralizing road information and informing users.

MEEDDAT: ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire [Department of Ecology, Energy, Sustainable Development and Territorial Development].

GERMANY

snow and ice databook 2010

1 Demographics and Roads

1.1 Information about the country

Germany in the centre of Europe borders on the Netherlands, Belgium, France, Luxembourg, Switzerland, Austria, Czech Republic, Poland and Denmark and has sea accesses to the North and Baltic Sea.

The Federal Republic of Germany, consists of 16 Federal States, the 3 "City-States" (Berlin, Hamburg, Bremen) included, whose territories are of different size between 71,000 km^2 (Bavaria) and 2,700 km^2 (Saarland). Each German State has its own constitution and public authorities. Road Authorities exist in each State.

Federal motorways in use (grey), under construction (blue) or planned (red and yellow)
Status 2009

Area		356,700 km²	
Latitude		47°16' to 55°03'N	
Population		82.1 million	
Length of road	Federal trunk roads	Federal motorways (Autobahnen; 4 and 6 lane divided highways)	12,500 km
		Federal highways	40,700 km
	Other federal-aid roads	State highways	86,600 km
		County roads	91,500 km
		Community / urban roads	413,000 km
	Total		644,300 km
Capital		Berlin	
Latitude		52°30'N	
Inhabitants		3.4 million	

1.2 Road network and traffic

During the past decades Germany was faced with an enormous increase of traffic on the highways. Today passenger traffic (passenger-km) on the road amounts to more than 90%, commercial traffic (tons of merchandise-km) to about 67% of the total traffic while the remainder traffic distributes itself to other travelling and transportation modes, i.e., on rail, water ways or air. Motorways in Germany (so called "Autobahnen"); all together 12,500 km, carry more than 40% of the total traffic of the entire classified rural, interurban road net (consisting of Federal Motorways, Federal, and State-Highways and County roads), although they represent only about 6% of the total length of this road net.

The enormous increase of traffic volumes in recent years will continue even more rapidly in the future as a consequence of the ongoing political and economic developments, especially the European process of unification. The extension of the European Union to the east is expected to bring great amounts of traffic to the "transit-country" Germany within the next years due to intensified economic cooperation's.

GERMANY

The extension of the road network in the last years and also in the near future is not keeping up with the increase of the traffic. Consequently, traffic volume and congestion on the roads is increasing.

Maintaining traffic safety, optimum driving conditions and availability of sufficient capacity of highways all around the year, even during winter season is of crucial importance. As a consequence in future road operations and especially winter maintenance will become much more important.

The State Road Administrations are in charge of planning, construction and maintenance including winter maintenance for Federal motorways and highways and for State highways. The Federal Ministry, respectively Department of Transportation has the right of legal and technical supervision for the federal trunk roads.

Road Class		Property and financial obligation for planning, construction and maintenance	Administration of planning, construction and maintenance
Federal trunk	Federal motorways	Federal government	Federal states on behalf of the federal
	Federal highways		
State highways		Federal States	Federal states
County roads		Counties	Counties partially federal states on behalf of counties
Community / urban roads		Communities / Cities	Communities / Cities

2 Climate

2.1 Overview of climatic areas

Germany has a moderate climate, often weather changes are characteristic. From the low lands in the northwest to southeastern regions there is a gradual transition from maritime to continental climate. Mostly western winds and precipitation during the whole year are characteristic. Typical are frequent cold (continental) winds and snowstorms, from eastern European in southeastern Germany. In the northern lowland the yearly precipitation amounts to 500 mm to 700 mm in the lower mountain ranges, in the middle part of Germany between 700 mm and 1,500 mm and in the south, close to the alpine region up to 2,000 mm.

The daily and yearly temperature variations are not extreme, except in southeastern Germany and in the alpine region. The average temperatures in January vary from + 1,5 °C and - 0,5 °C in the lowlands, in the alpine region the average temperature may get below - 6 °C, depending on the altitude (see Table below).

Typical for the German climate is the frequent change of temperature around 0 °C with freezing and thawing periods following each other. This creates many problems for winter maintenance.

Meteorological Stations (close to motorways) (m above sea level)		Meteorological Data (Average d-30 years) - Main Winter Months -									
		Average daily minimum temperatures [° C]				Average precipitation[mm]					
		Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Total	Total year
1	Kiel (17 m)	- 0.3	- 2.1	- 1.8	0.4	74	65	40	54	233	777
2	Schwerin (59 m)	- 0.9	- 2.6	- 2.1	0.3	55	46	33	42	176	620
3	Hannover (53 m)	- 0.7	- 2.2	- 2.0	0.3	60	52	37	48	197	665
4	Berlin (48 m)	- 1.0	- 2.7	- 2.1	0.7	53	43	34	37	167	584
5	Bonn (62 m)	1.0	0.0	0.5	2.6	52	47	37	46	182	678
6	Erfurt (312 m)	- 2.2	- 3.6	- 3.4	- 0.5	30	25	26	36	117	492
7	Frankfurt (112 m)	- 1.0	- 2.1	- 1.6	0.9	54	44	40	51	189	658
8	Hof (474 m)	- 3.3	- 5.0	- 4.5	- 1.8	63	53	44	47	207	708
9	Stuttgart (373 m)	- 2.2	- 3.3	- 2.4	0.3	48	44	42	44	178	719
10	München (527 m)	- 3.7	- 5.1	- 4.0	- 0.8	60	53	52	56	221	967
11	Villingen – Schwenningen (720 m)	- 3.5	- 5.0	- 4.5	- 2.5	85	77	74	68	304	915
12	Kempten (705 m)	- 5.1	- 6.2	- 5.0	- 1.9	90	83	78	79	330	1,273
13	Bad Reichenhall (455m)	- 4.0	- 6.5	- 4.5	- 1.0	128	125	110	120	438	1,665
14	Garmisch-Partenkirchen (719 m)	- 5.7	- 6.5	- 5.1	- 2.3	92	85	77	96	340	1,364

GERMANY

There is snowfall to a larger extent only in mountainous regions and the surrounding areas. Bavaria, the most southern State including the north edge of the Alps therefore is the most "snowy" region in Germany with winter maintenance from November to April, whereas in other parts of Germany there is a shorter winter period. But even in Bavaria there are great differences concerning the amount of snowfall in different parts of the State as follows:

State of Bavaria	Annual cumulative snowfall (measure at motorway maintenance stations)	
	average of the last winter periods	Maximum: Winter 2005/06
Front of alpine region	440 cm	1,030 cm
Lower mountain regions	210 cm	645 cm
Lower areas, river valleys	50 cm	125 cm

Large parts of central and northern Germany receive the same amount of snow as the lower areas and river valleys in southern Germany.

Other typical features of the climate are the great variation in the severity of consecutive winters, in relation to temperature and amount of snowfall. Main problems for the winter maintenance management are the often temperature changing around 0 °C or short heavy snowfalls.

2.2 Winter index

In 1995 the Federal Highway Research Institute completed a research project to define a winter index in order to find a correlation between winter severity and salt consumption necessary for snow and ice control, and to prove the effectiveness of pre-wetted salt technology.

The Investigations revealed that most relevant factor for salt consumption is the amount and frequency of snowfall in the snowy regions. In regions with less snow the relevant factor is the number of temperature changes around 0 °C.

3 Winter Road Management

3.1 Standards and rules

The legal obligation to do winter maintenance results from a general duty out of the German Civil Code. It is reduced in the federal laws (Bundesfernstraßengesetz), the state laws (Straßen und Straßenreinigungsgesetze der Länder) and in the statutes of the cities.

Regulations about the requirements, organization and realization of winter maintenance are given in the Guidelines for Winter Maintenance Performance (Richtlinien für den Winterdienst auf Straßen, Entwurf 2009).

For snow clearing vehicles the following service cycle time-periods for motorways and highways are stipulated:

Motorways and highways which in connection with the motorway network have a significant traffic function	2 hours (daily 24 hrs)
motorway interchanges	2 hours (daily 24 hrs)
federal and state highways	3 hours (daily 6 am to 10pm)

For pure salt spreading activities distinctly shorter time-periods are standard. The Level of Requirement for Winter Maintenance is given in Table below.

Level of Requirement for Winter Maintenance					
	road with traffic function	period of traffic stand by	weather or road condition		
			snowfall, icy roads, hoarfrost	heavy continuous snowfall	Severe drifting, avalanches, freezing rain
1	Federal motorways and additional stretches of highways, which in connection with the motorway-network have a significant traffic function	24 hours (daily)	trafficability on through lanes, interchanges, ramps in junctions and interchanges; passability on parking facilities, shoulders	trafficability on at least one through lane per direction of traffic, the most important ramps in junctions and interchanges as well as access roads to service areas, if required with snow chains; passability on parking areas without service cannot be any longer guaranteed.	trafficability cannot be any longer guaranteed
2	important rural roads, roads with strong rush hour traffic, roads with public transport	from 06.00 a.m. to 10.00 p.m. (daily)	trafficability	trafficability, if required with snow chains; on multilane highways at least one through lane per direction of traffic, if required with snow chains	
3	Further rural roads	appropriate to local traffic demands	trafficability	trafficability, if required with snow chains	
4	sidewalks, bicycle route, multipurpose lane	appropriate to local traffic demands	trafficability, usability for pedestrians	trafficability cannot be any longer guaranteed	
5	parking facilities in connection with important and other roads (row 2 and 3)	appropriate to local traffic demands	passability	passability cannot be any longer guaranteed	

"trafficability" means that obstructions as a result of remaining snow or – according to duration of winter maintenance operation – locally uniform snow covering must be expected, similarly possible local occurrence of slippery roads as a result of hoarfrost or icy roads even after spreading.

"usability for pedestrians" demands that one lane is kept clear of snow and ice to allow two pedestrians to pass each other carefully (approx. 1.0 to 1.2 m).

"passability" on parking facilities and shoulders means that access roads and lanes on parking facilities and shoulders can be used with an adjusted driving behavior appropriate to existing obstructions and that proper parking is possible.

"appropriate to local traffic demands" means that winter maintenance is carried out at times demanded by specific traffic. In the individual case this may mean that no winter maintenance is carried out.

3.2 Organization and Operation of Winter Maintenance

Organization and planning of winter maintenance activities have to be done early and comprehensively because the exact beginning and extent of the coming winter is nearly unforeseeable. Winter maintenance has to work effectively and efficiently from the very beginning of winter. Only careful planning guarantees a most economical realization of winter maintenance. Therefore, the following plans must be made in advance:

Priority Plans

These plans regulate the priority and intensity of treatment of the various routes of the road network and prescribe which gritting agents – deicing or abrasive – agents are to be used on theses roads.

A priority list is necessary, especially in urban areas because there winter maintenance can be carried out only successively and not everywhere at the same time. Useful criterions are:

- road category (motorways, federal highways, etc.); in major cities, secondary roads, residential streets;
- traffic volume (average daily traffic);
- special traffic (roads with public transport or school bus traffic, access roads to rescue service stations, etc.);
- special accident-prone spots (steep grades, dangerous curves and crossings, stretches with frequent slipperiness in winter such as bridges, roads through forests, extremely shady roads).

GERMANY

Plans for snow clearing and salting

These plans assign crew and vehicles for winter maintenance activities to certain routes and in certain sequences. For different weather conditions or different tasks there are different plans.

Schedule for standby of personal, working shift plans

These plans regulate on a day-to-day or week-to week basis, which personal has to be appointed to standby for short term readiness outside of regular working time, in order to meet the Level of Requirement for Winter Maintenance. The 24-hour service on motorways requires shift plans.

Snow and Ice Control Strategy

The strategy persuade in Germany on rural and main urban roads in connection with winter maintenance activities is to achieve again "black" i.e., snow-and-ice-free pavements as soon as possible, with the aim of maintaining traffic flow as long as possible and to improve road safety: so-called "bare pavement policy".

In cases when icy roads can be expected in the near future depending on the weather forecast this policy leads to preventive salt spreading which has been used more frequently in the last years.

On secondary and lower rank roads in urban areas and in municipalities, in general, where lower driving speeds prevail, "differentiated winter maintenance" is performed. According to the function and the traffic volumes of these roads and streets and depending on weather conditions there is a gradation in the winter maintenance policy: application of de-icing agents on major roads and so-called "zero-gritting" e.g., only snow clearing, on the lower, the residential streets.

Gritting with abrasive matters which was used in former times has become very less common in the last years. A study on behalf of the German Umweltbundesamt (Federal Environmental Agency) has shown by screening of life-cycle analysis (LCA) that de-icing materials have less negative ecological effects than abrasives. And other studies concerning traffic safety showed that de-icing materials lead to a much lower accident risk on main roads and steep grades in urban areas. On residential streets with very low and slow traffic there is no safety problem without any spreading.

For optimization of winter maintenance management actual information and forecasts about weather and road conditions are necessary. Detailed road weather observation and surveillance by the nationwide Road Weather Information System – RWIS ("Straßenzustands- und Wetterinformationssystem – SWIS") is standard today in Germany.

RWIS combines synoptic extensive weather forecasts of the German Weather Service (Deutscher Wetterdienst - DWD) with data based on local meteorological stations and ice detection installations throughout the road net. The results are separate forecasts for areas with different local climates. The DWD provides several times a day very detailed middle term (3 days) and short term (24 hours) road weather forecasts to the road maintenance stations. In addition, weather warnings are issued for sudden critical occurrences, which are not yet included in the general road weather forecasts. Information is distributed by computer network and reaches the RWIS-computers directly in the maintenance stations.

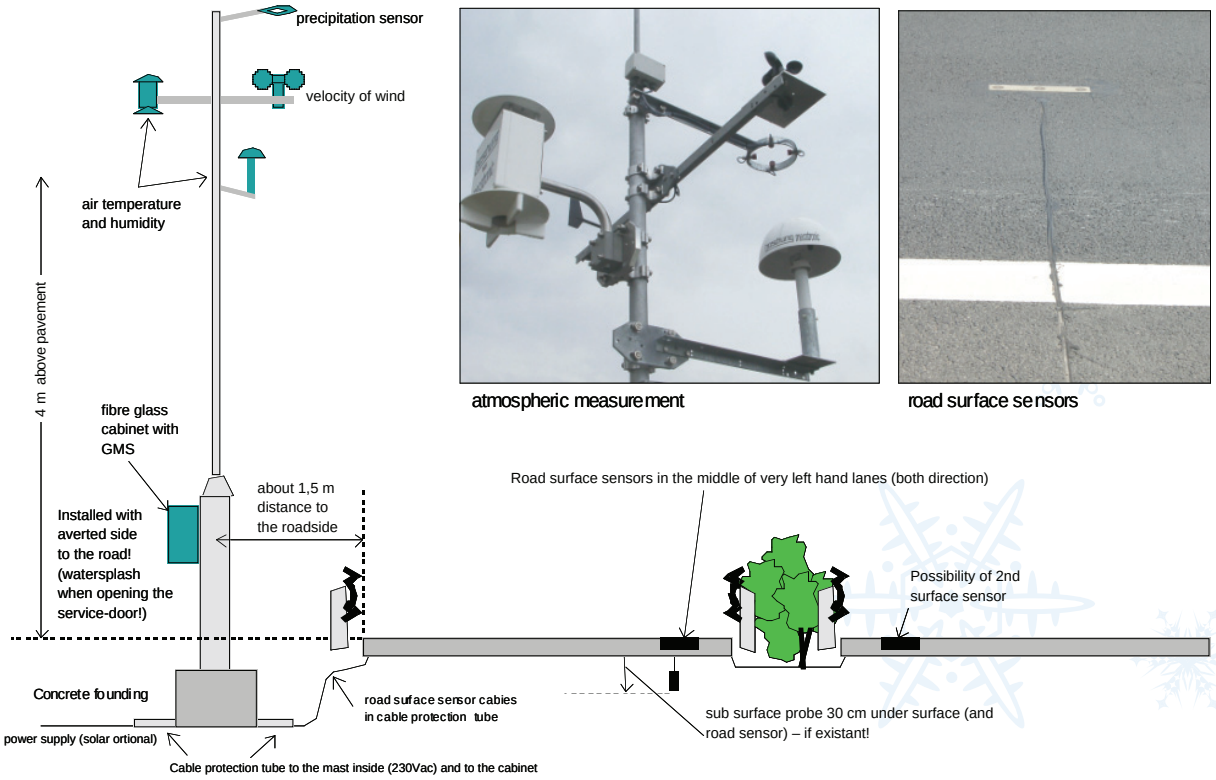
Improvements are on the way to extend the service by installing meteorological surveillance stations and pavement sensors for ice detection at all critical points of the road net. At present, roadside meteorological stations exist mainly on motorways, but also on other rural roads, approximately 1,000 installations in Germany.

Additional the surveillance centers get information and data of their roadside meteorological stations with atmospheric and surface sensors.

Following data are measured and provided:

- air temperature;
- road surface temperature;
- relative humidity;
- dew point (calculated out of air temperature and relative humidity);
- precipitation (type, intensity);
- road surface condition optional:
  - road structure (sub surface) temperature in various depths;
  - wind (direction, speed);
  - freezing temperature;
  - residual salt.

GERMANY

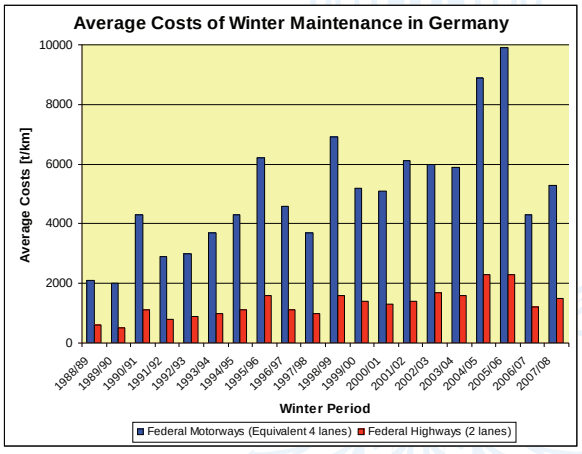


Reference: Institute for Highway and Railroad Engineering, Universität Karlsruhe
Roadside meteorological station with atmospheric and surface sensors

3.3 Assessment of snow and ice control measures

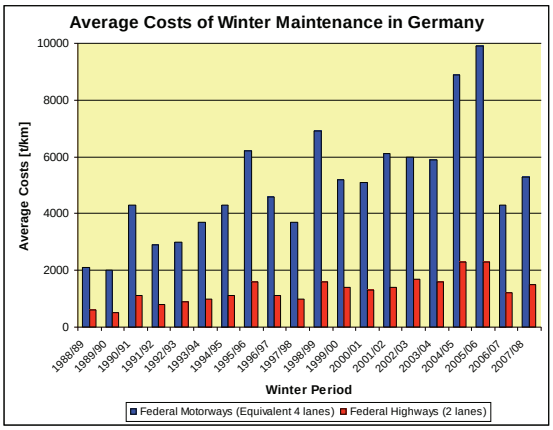
According to variable climatic conditions in consecutive winter periods salt consumption and expenditures for winter maintenance show large differences as follows. All data is given for motorways and federal highways. The winter periods 2004/05 and the following 2005/06 were the most heavy in the last 20 years bringing a great amount of snow leading to a high salt consumption and high costs.

On average over the last 20 years there were spread 21 tonnes per km motorway and 7 tonnes per km highway each winter period. On motorways were spent 5,000 € per km each winter period, on highways 1,300 € per km.



There is no special budget for winter maintenance, only a yearly budget for road maintenance. Yearly variable expenditures for winter maintenance have to be covered by the budget for road maintenance. This means, that after extreme winters even other road maintenance tasks have to be postponed to a certain extent; after extreme strong winters even additional funds from the construction budget are necessary.

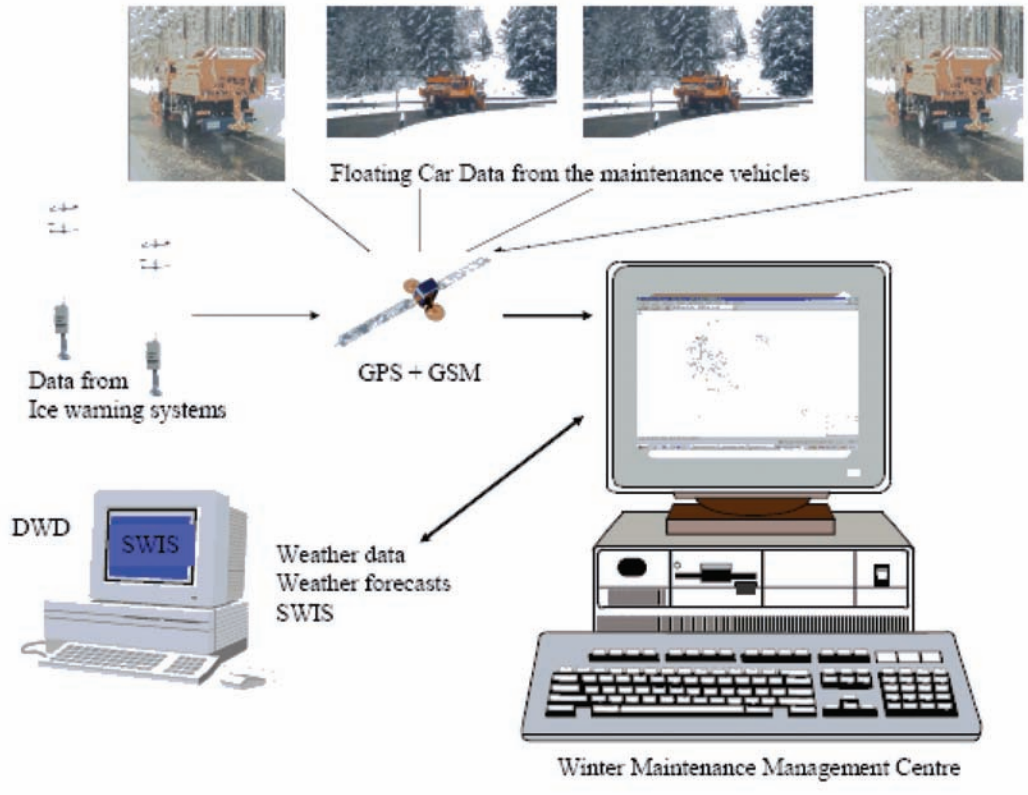
GERMANY



In the last decade a lot of research was done to optimize winter maintenance and to decrease the expenditures and environmental impacts. Pre-wetted salt (with 30% brine) is the standard technique in Germany today.

Today the following quantity of salt is recommended for practical use (pre-wetted salt):

- preventive use on dry pavement surface — 5 - l5 g/m²
- preventive use on wet or moist pavement surface — 5 - 40 g/m²
- light white frost (icing up) and slightly icy roads — 5 -30 g/m²
- black ice — 15-40 g/m²
- snow fall / snow slipperiness — 20-40 g/m²
- before freezing rain — 30-40 g/m²



Winter Maintenance Management System with floating car data from the maintenance vehicles

3.4 Traffic safety and information

Information concerning weather forecast and road conditions is available on several systems such as radio broadcast, television, internet and telephone. Additionally, drivers will be informed by radio broadcast, if chains are necessary or if truck drivers, especially drivers of trucks with dangerous loads, have to stop at the next parking place or rest area.

In mountainous regions traffic signs give information, whether mountain passes are closed and whether winter tires or chains are obligatory. On several motorway sections variable road signs of traffic control systems are also used for traffic safety, for example during snowfall or during slippery conditions.

Winter Maintenance Management Systems are deployed more and more in the German States. When using all actual information from RWIS, from ice warning systems and from the maintenance vehicles (floating car data) improved winter maintenance is possible.

4. On-going Research and Studies to Improve Winter Management

There are several actual research projects and studies to improve winter maintenance management and their measurements in Germany.

Optimizing time for loading by using salt storage silos

As a consequence of the enormous increase of traffic volumes on German motorways, the standards of winter maintenance for heavily travelled or problematic road sections of federal motorways have become very high. Successful winter maintenance in these areas considerably contributes to avoid or at least reduce winter-related restrictions and thus, the costs entailed for the road-user. In connection with early and quick winter maintenance, road safety is also improved and micro-economic and economic costs of freight and public transport are reduced through fewer accidents, loss of time, etc.

Therefore, several research projects concerning winter traffic and winter maintenance on German motorways were carried out in the last years. They dealt with:

- traffic flow and capacity under winter road conditions;
- traffic congestion in wintertime;
- traffic safety under winter road conditions;
- measures to optimize winter maintenance;
- winter traffic and winter maintenance inside of motorway crossings and intersections.

There are many measures to optimize winter maintenance. Several pilot projects were led through:

- use of mobile de-icer spraying installations;
- use of a high-performance vehicles;
- reducing loading times;
- special truck guiding systems in snowy areas.

Echelon plowing with high performance winter maintenance vehicle

GERMANY

Another main focus of research projects in the last years was the optimizing of the spreading technique. There was research on the following topics:

- spreading patterns depending on different spreading techniques, speeds and widths;
- optimizing spreading patterns;
- requirements and test methods for spreaders;
- duration of salt lying on the surface and influences on this;
- brine-spreading: equipment, methods and fields of practical use.

The aim is better spreading techniques and recommendations for their practical use.

Testing area for spreading patterns
Spreader which can spread either pre-wetted salt or brine only

ICELAND

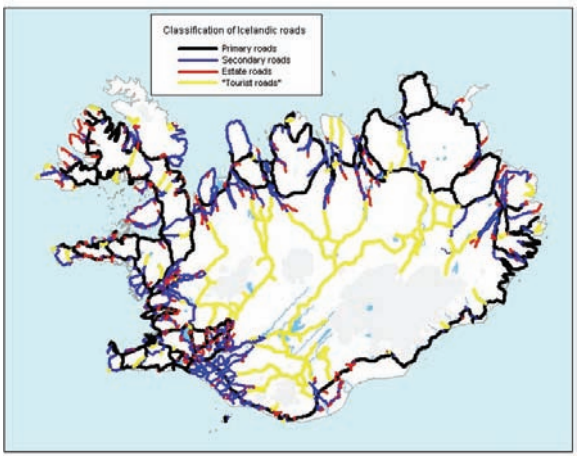
snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Iceland is situated in the middle of the North Atlantic Ocean, approximately 290 km east of Greenland and 970 km west of Norway. Consisting mainly of a plateau, Iceland's average height above sea level is 500 m, the highest point being 2,110 m. Only one quarter of the country lies below the 200 m contour line. The island is mountainous, surrounded by coastal lowlands, fjords and valleys shaped by marine abrasion and glacier erosion.

Area	103,000 km^2
Latitude	64°08´N
Population	313,000
Density	3.0 per km^2



In the absence of other natural resources (except for abundant geothermal and hydropower), the economy depends on the fishing industry, which provides 42% of export earnings and employs 12% of the work force. Other industry provides 39% of export earnings. The economy remains sensitive to declining fish stocks as well as to fluctuations in world prices for its main exports: fish and fish products, aluminum, and ferrosilicon. Iceland's economy has been diversifying into manufacturing and service industries in the last decade, and new developments in software production, biotechnology, and financial services are taking place. The tourism sector is also expanding, with the recent trends in ecotourism and whale watching.

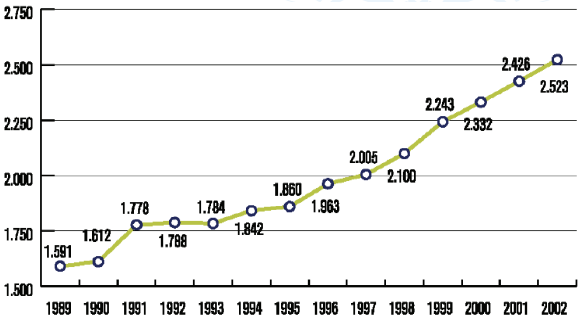
1.2 Road network and traffic

The road network comprises 12,867 km thereof 4,780 km of paved roads. It categories into:

- **Primary roads** (4,498 km) which mainly reach areas with a population of 1,000 or more and form a connection between such areas.
- **Secondary roads** (2,799 km) which mainly connect estate roads to primary roads.
- **Estate roads** (3,223 km) connect farms to secondary and primary roads.
- **"Tourist roads"** (1,347 km) covers roads across mountains and moors.
- **Number of vehicles by December 31st 2008:**
  - 244,000 vehicles total(21,000 passenger cars, 34,000 commercial cars)

Source: The Road Traffic Directorate

Heavy vehicle commercial traffic has increased considerably since sea transport along the coast ceased by the end of year 2004.



Million km driven annually (all vehicles)

ICELAND

2. Climate

2.1 Overview of climatic areas, main winter events to be mastered

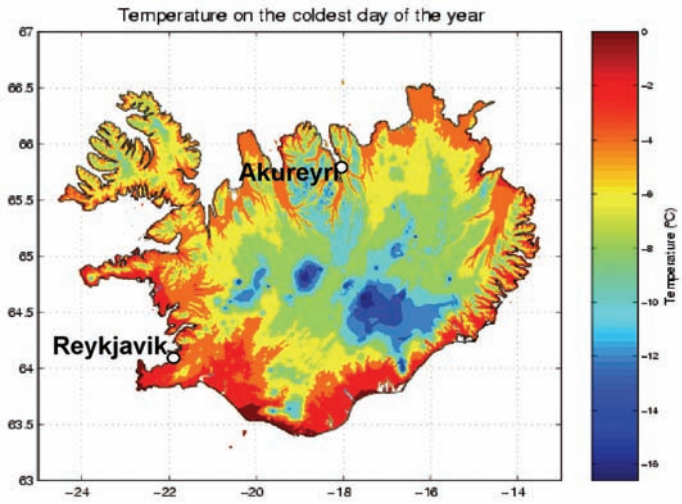
Iceland has an oceanic climate and doesn't experience the extreme temperature conditions of continental climates. The winters are mild, but the summer is cool. There is a considerable difference between respectively the coastal lowland climate, the climate of the main highland plateau and the climate of the highest mountain areas. There is also some difference between the north and south. Temperature decreases and precipitation increases with height above sea level. The north of Iceland is somewhat cooler and is subject to more precipitation than the south. Strong winds are frequent, especially during the winter. Road service is challenged by icing, snowfall and drifting snow, which due to sparse vegetation and absence of forest is acting on the whole road network. Snow avalanches threaten a few low-traffic volume roads in rural areas.

2.2 Statistics on temperatures, icing and precipitation

According to experience, snow is covering the ground during most of the mid-and late winter in areas where the mean temperature of the coldest month is below -4 °C. At the station of Reykjahlíð in the northeastern inland the snow is covering the ground completely for 135 days per year. In Reykjavík in the southwest this number is 55 on the average. The temperature minimum drops below 0.0 °C on 123 days per year on the average in Reykjavík, 161 days in Akureyri in the north. These are typical lowland values.

The north is on the average drier than the south, although significant exceptions can be found locally. Usually the precipitation is light. Reykjavík thus has some precipitation on 221 days per year, but on 148 of these the precipitation exceeds or equals 1mm. In Akureyri the corresponding numbers are 171 and 103. Snow or sleet is recorded on 82 days per year in Reykjavík, but 96 in Akureyri. Freezing rain occurs, circa once per year, per location. Blowing snow is a significant traffic problem, especially outside the main towns.

The conditions outlined above are only valid for the lowlands. The winter problems increase considerably with height above sea level. In the vicinity of Reykavík the frequency of total snow cover days thus e.g., increases from 55 in Reykjavík (52m a.s.l.) to 91 at Stardalur (a few km to the East, at 185 m a.s.l.). Mean annual precipitation in Reykjavik for the period 1961-1990 is 800 mm, for Akureyri it is 490 mm and for Eyrarbakki on the south coast the mean annual precipitation is 1,370 mm.



The map shows the spatial distribution of the mean minimum temperature 1961-1990.

2.3 Winter indexes used in the country

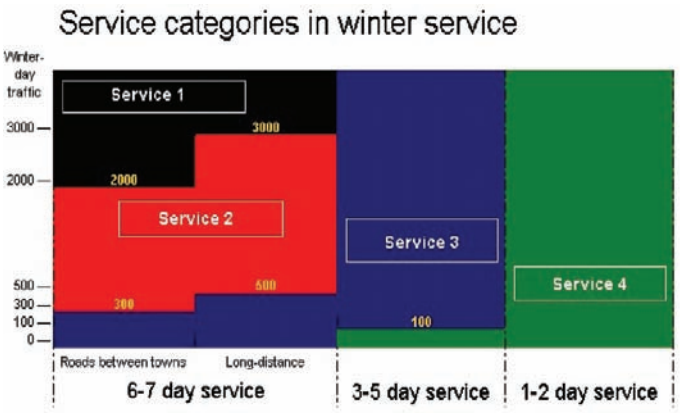
A winter index for ICERA, Icelandic Road Administration (Vegagerdin) purposes is under development. A suitable winter index for use in Iceland should consider drifting snow as well as other informative climatic parameters.

3. Winter Road Management

3.1 Standards and rules

Snow and ice control, traffic information and winter road management is carried out by ICERA, which is a governmental office, according to rules set by the Minister of Communications. Snow clearance and friction control is mostly outsourced to private entrepreneurs. The ICERA is financed by state budget and road-user taxes.

ICELAND



Summary of Winter Quality Standards		Service category *(categories 3 & 4 omitted)*	
		1	2
Service hours	In town	24 hour service 7 days a week	06:00-22:30
	60 km from town		08:15-22:00
	120 km from town		10:30-21:30
Critical snow depth for service start		2 cm	4 cm
After snowfall, snow removal is completed within		2 hour	3 hour
After road closure, snow removal is completed within		-	3 hours
Max. service cycle duration		2 hours	2 hours
Max. length of service route		50 km	50 km
Maximum snowdepth		5 cm	12 cm
Maximum track depth		1 cm	2 cm
Min. Friction coefficient	General	0.25	0.15
	Hazardous spots e.g. curves and slopes	0.25	0.25
Whenever road temperature is to low for effective salting (-10°C or lower), then sanding should occur within		2 hours	3 hours
Visual obstructions due to snow-banks at road junctions should be cleared within		24 hours	48 hours
Clearance of snow banks on the road shoulder within		24 hours	48 hours

Service categories consider road function and traffic volume. Stretches of road linking towns or defined connection points are from 5 to 20 km (towns if the number of habitants is 200 or more).

Quality requirements for winter services concern the following factors:

- Service aims;
- Service level/category;
- Timing of actions;
- Maximum snow depth and road surface evenness criteria;
- Ice conditions/friction;
- Visibility at intersections and leveling of snow banks.

Friction control is mainly applied as a preventive measure. Actions to improve the friction once slippery conditions set in are:

- Traffic is likely to eliminate the icing – No action;
- Reduce the snow amount on the road;
- Scraping of packed snow and ice;
- Sand- or salt spreading on hazardous spots;
- Continuous spreading;
- Road heating system installed on critical spots.

See deicing agents used, in the table below.

Use of de-icing agents	
Condition	**Material**
Preventive measures	Salt solution
Snowfall	Pre-wetted salt (or dry)
Slipperiness on wet ice (smelting)	Fine sand
Slipperiness on dry ice	Rough sand
Packed snow and ice	Salt solution
Other slippery condition	Pre-wetted salt

3.2 Organization and operation of winter maintenance

Organization of winter maintenance

The ICERA has 18 operation centers countrywide. Approximately 45% of winter service is privatized. Contractors operate mainly on a target-price contract depending on actual weather conditions. The winter service is active from October 15th until April 30th.

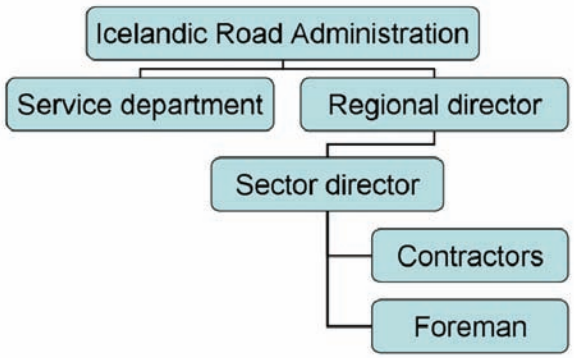


Diagram: Organizational hierarchy for winter services at the ICERA.

In larger towns the ICERA is serving the major roads according to the ICERA standards based on contracts with the local municipal authorities.

The service equipment fleet is mainly lorries with snow-plows, pay loaders and graders. Rotary blowers are very important in winter service on mountain roads and exposed primary roads. Grader works, such as removal of hard snow and ice are increasingly overtaken by plow trucks with under body blades. Graders are, however, still important to level snow banks on the road shoulder in exposed areas.

Depending on the service category, the service route per vehicle is 50-120 km. Usually there are 1 or 2 men per truck.

The ICERA´s internal codes define the responsibility for different tasks concerning winter services:

Task	Responsibility
Service standards and rules	ICERA management
Selection of service category	Service Department in cooperation with ICERA management
Local operation rules	Regional director department in cooperation with Service department
Equipment plan	Regional director / sector director
Labor- and shift-plan	Regional director / sector director
Training and safety issues	Regional director / sector director
Decision on additional plowing	Regional director / sector director
Quality control	Division for quality control

Road closures are enforced by the police under adverse weather conditions according to the ICERA´s evaluation. Snow-Avalanche hazard, flooding, etc., may also lead to road closure.

Road weather information

ICERA has contracts with the Icelandic Meteorological Office and the Danish Meteorological Office. In the current information system for the ICERA, data is gathered into a central database. Forecast period up to six days is used. There are approximately 50 km between road weather stations (60 stations countrywide). For 10 stations, 5 hour specific forecast is provided.

ICELAND

3.3 Assessment of the snow and ice control measures

Cost & benefits of winter maintenance activities

The average annual cost of the winter maintenance in 1997-1999 on the primary and secondary road network (8,242 km) is listed below (year 2000 price levels):

Total all-year maintenance cost (summer and winter)	4,840 EUR/km/year
There of winter maintenance	21 %
Plowing cost : Salting cost	40% : 60%
Road network treated with salt, ∑(2-lane kilometers)	922 km
Amount of salt used	15.2 t/km/year

Snow & Ice control Measures leading to additional cost reductions and environment preservation

Brine and pre-wetted salt is preferred instead of dry salt for most situations except under snowfall.

The advantages of brine are that there is little salt in the solution and almost 100% of the quantity distributed remains on the road surface. The brine is usually made from a NaCl-solution but sometimes from a $CaCl_2$ solution, which is more effective and more expensive as well. Brine has proved favorable for preventive measures, on thin ice or on rime.

The purpose of pre-wetting salt is to increase its weight, bind fine-grained salt, make the salt stick better and increase its moisture content to hasten its melting.

Assessment of the work

Winter service administrators in each region oversee the maintenance work of contractors. Sixteen operation centers have Coralba breaking skiddometers to measure road surface resistance. Road user feedback has also proved to be valuable in service assessment.

3.4 Traffic safety and information

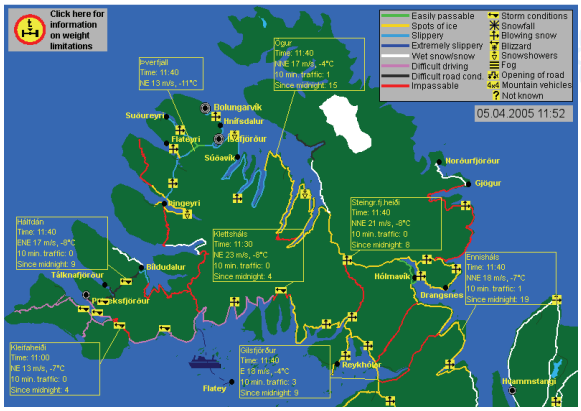
Information provision to the road user

Information is provided through various media, see below. Information provided is; condition of road (slipperiness), weather (wind speed, gust and wind direction, temperature), road temperature, humidity and dew-point, traffic (last 10 minutes, traffic from midnight), estimated time of opening if road is closed, maintenance works, axle-load restrictions, ferry schedules etc.

Use of weather related road sensors and variable road signs

Most of the ICERA´s weather stations have temperature sensors in the road surface, and some have road surface humidity sensors for management use only. Experiments with a visibility meter are in progress on one mountain road.

Frost depth sensors are used to determine weight restrictions on roads. Variable message signs are used to show wind speed, wind direction, temperature and in extremely exposed areas wind gust. Variable roads signs are also used to show if a road is closed.



ICELAND

Use of information technologies for efficient management and for avoidance of danger by providing information to road users

Information and warnings are provided through radio, internet, text-TV, phone service and message signs.

Specific new adaptations of infrastructure to improve winter maintenance and traffic safety

Use of narrow-profile pipe-type guardrails is increasing, especially in areas exposed to snowdrift. The planning of new mountain-passes considers advanced snowdrift studies for snow-control design. 3 winter centers are under development.

International exchange of road information

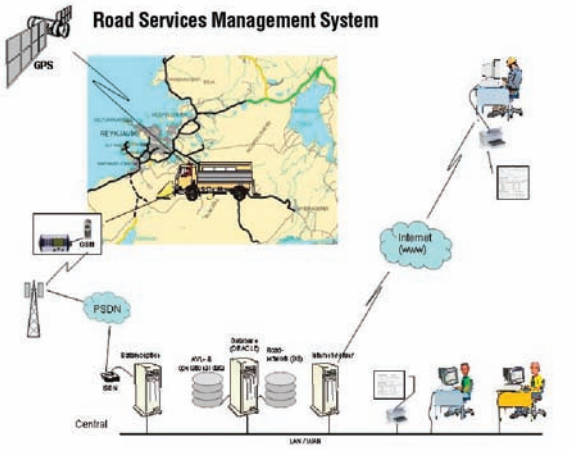
Cost Action 344 and 353, RoadEx under the Northern Periphery Program, number of actions under the Nordic Road Association.

4. On-going Research and Studies to Improve Winter Management

4.1 New technology

Road Services Management System

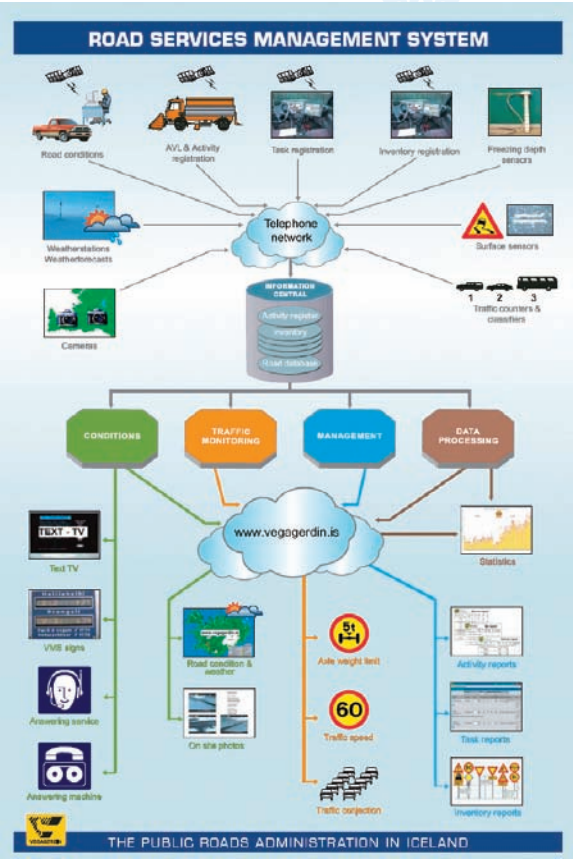
Experiments on automatic vehicle location and activity registration utilized for settlement of winter services have been successful in areas with good GSM-coverage. The system is gradually introduced in every region. Automatic vehicle location equipment, consisting of a telecommunications device (GSM) and sensors, is installed in snow removal equipment with a salt and brine spreader as well as front and under teeth to automatically collect information about location, activities, speed, distance and time. Upon receipt of data from a device, the grid position is plotted into the road system, i.e., information about activities is collected for certain roads and stretches of road for further processing. In this way, additional information can be collected about the scope of service programs, activities, driving, use of materials, lengths of road cleared, etc., for each road, region, etc., for any period.



The results indicate that, after processing, the information obtained with the above-specified equipment provides so good and reliable an overview of quantities, for example, driving and time spent for each section of road that the findings may be used for final settlement of winter services and quality control.

4.2 New management and organization approaches

A review of the ICERA data system is now taking place while simultaneously a new, administration/management and information system for the winter service, linked to the former, is being prepared.



Monitoring of bearing capacity

Innovation in thaw weakening management at ICERA

Road condition monitoring with respect to bearing capacity due to frost-thaw cycles and the resulting measures of axle-load restrictions has advanced considerably due to a new technology developed in Iceland. An instrument that measures temperature, humidity and conductivity in the road construction as a function of depth and time has been developed.

On the Icelandic road network, thaw weakening is responsible for excessive deterioration of the roads and frequent application of axle load restrictions. This results in additional costs for both the road authorities and the transport industry.

Rising mean temperatures the several past winters has led to more frequent freeze-thaw cycles in the period from December to April, increasing the number of necessary load restriction periods. In order to fight break-down of road pavement and sub-base, and simultaneously minimizing the number of days with load restrictions, a precise management of load restrictions during thaw periods is important. For monitoring of frost depth in the road sub-base, ICERA commenced the development of a measurement device which is installed on more than 40 locations on the Icelandic road network and is planned for 20 more sites.

Based on measurements of temperature and electric conductivity in the road structure, the device indicates the current frost depth level in the road sub-base. For maximum utilization of the system, a road surface temperature and frost depth forecast model has been developed. The purpose of the model is to predict the frost depth development in the next few days to allow timely declaration and dismissal of load restrictions. The model relies on the weather forecast and real-time measurements from frost depth sensors and automatic weather station. The frost depth measurement system and forecast model are a part of the ICERA road weather information system for traffic management and road service due to weather, surface and sub-base conditions.

4.3 Trans-national cooperation to improve levels of service between neighboring countries

As an island, Iceland does not share administrative boundaries on land with any other country. However, international exchange of information and technologies is regarded as important for further development.

5. References

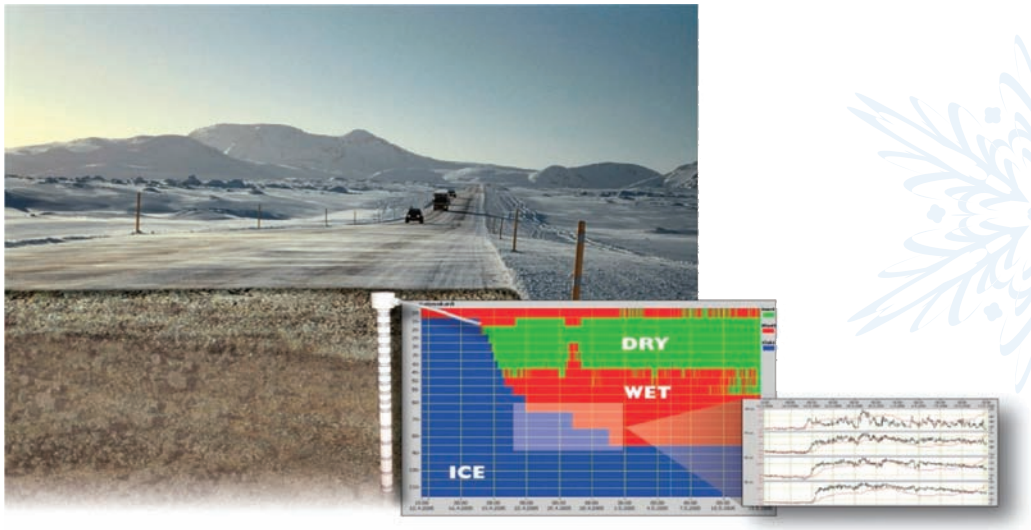
Traffic and weather information in English on ICERA's internet site:

www.vegagerdin.is/english/

Statistics Iceland: www.statice.is/

The Road Traffic Directorate:

www.us.is/page/english



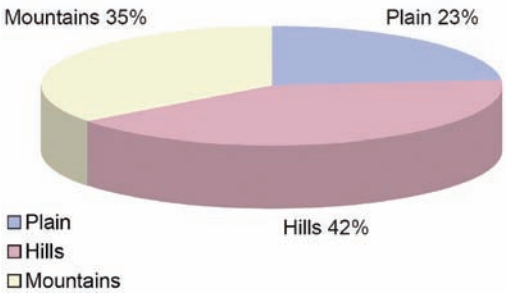
ITALY

snow and ice databook 2010

1. Demographics and Roads

Area	301,302 km²	
Population	57 million	
Vehicles on the roads	47 million	
Length of roads	National roads and highways	31,000 km
	Prefecture roads	141,000 km
	Municipal roads	300,000 km
Latitude (capital)		41°53'N

Country and Road statistics



	Plain	Hills	Mountains	Total
Area (km²)	69,902	125,342	106,058	301,302
%	23.2	41.6	35.2	100.0

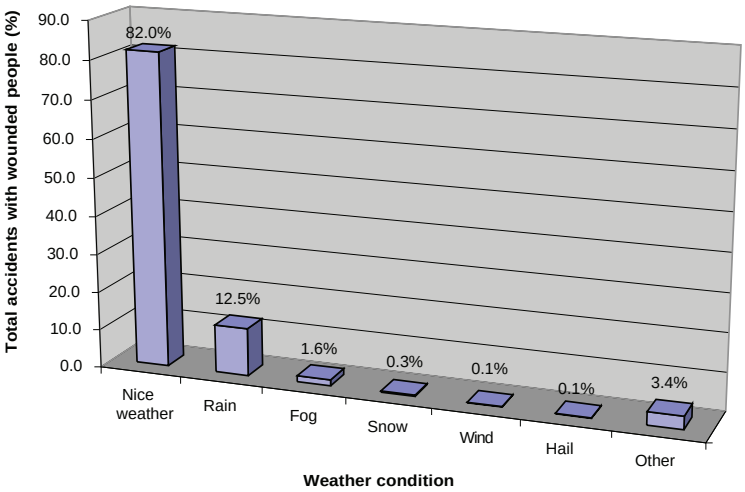
Orographie

2. Climate

		Alt.	Monthly mean temperature (5-year average) (°C)				Daily minimum temperature (5-year average) (C°)				Snowfall (4-year average)	Precipitation (5-year average)
		(m)	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar	days	mm.
Lombardia (North)	Milano	107	3.6	3.4	4.7	9.3	-4.0	-4.9	-3.2	0.3	3	720
	Monte Bisbino	1,319	2.4	1.3	1.2	3.6	-2.7	-5.3	-7.7	-3.8	21	1,363
Lazio (Center)	Roma	18	9.1	7.4	7.9	9.5	-1.5	-2.1	-2.2	-0.1	1	490
	Monte Terminillo	1,874	-0.1	-0.1	-2.1	0.5	-7.7	-8.3	-10.9	-9.4	7	1,045
Calabria (South)	Reggio Calabria	11	13.1	13.4	11.9	13.4	5.9	6.4	5.7	6.9	1	341
	Monte Scuro	1,710	0.5	-0.2	-1.3	1.1	-7.3	-6.9	-7.9	-7.4	4	841
Sardegna (Islands)	Cagliari	4	11.0	10.3	9.8	11.9	3.8	1.5	2.3	3.6	1	378
	Fonni	1,022	6.8	6.5	5.8	6.5	0.8	-2.5	0.5	-0.4	5	808

Temperature and precipitations statistics

ITALY



Accident rate valuation - % of accident for different weather conditions (4-years average)

Nice weather	82.0%
Rain	12.5%
Fog	1.6%
Snow	0.3%
Wind	0.1%
Hail	0.1%
Other	3.4%

Annual road accident / weather conditions (4-years average)

3. Winter Road Management

3.1 Standards and rules

The aim of winter road management is to keep road users on the move and/or re-open to traffic in winter. This is to be achieved also by means of very urgent interventions along the managed road and motorway network subjected to snow falls and ice.

Description

Winter road management embraces the following activities:

- *Snow removal:* it includes the removal of the layers of snow, mud, ice from the pavement from the verges of the carriageways, from bridges and viaducts and tunnels (entrance-exit portals).
- *De-icing treatment:* it consists in spreading before-hand de-icing salts on roads and/or anti-icing mixtures (salts and aggregates) in order to prevent ice formation on pavements, on bridges and viaducts, near tunnels (entrance/exit portals).
- *Emergency assistance:* it consists of snow removal and anti-icing treatment by means of ad hoc teams operating for urgent interventions to be carried out (upon a call).
- *Felling of dangerous trees and removal of the discarded material;* removal of the trees damaged by snow showers by means of cutting of branches and subsequent cutting them to pieces.

Service supply

The Departmental Offices provided for a constant planning of such activities according to the weather and altitude characteristics of the relevant areas. The availability of men and means to tackle sudden emergency and/or unforeseeable situations is guaranteed apart from bad weather conditions (snow falls and/or ice) and considering the need of keeping a high standard level of service, while reducing the risks on the managed road and motorway networks. All these activities are carried out by means of trained teams equipped with mechanic equipment, snow blowers, blades and salt-spreaders.

The foreseen activities are normally carried out continuously for a 6 month period (November-April) all day long and in working days and holidays. All such activities are carried out in such a way to give the least traffic congestion possible. Furthermore they are all carried out by means of ad hoc signals and barriers.

Supply times

The above activities are generally implemented according to the following scheme:

- Snow removal and anti-ice treatment, according to the frequency of snow falls and frost formation for a period of 4 up to 6 months, following the topographic characteristics of the network;
- Emergency activation: upon call (ANAS monitoring personnel, police etc) due to emergency situations, generally within 60 minutes from the call all day long in working days and holidays.

ITALY

Performance indicators and monitoring

- Frequency of the intervention (see supply times);
- Execution times/occupation of the pavements for carrying out the activities.

3.2 Performance indicators and relevant indicators related to roads and motorways service

The Ministry of Infrastructure and Transports has established standards and rules for Service level and snow and ice removal activity on national roads and motorways.

Performance indicators and standards related to the national roads network:

TRAVEL SAFETY

- Inspections meant to prevent the formation of holes on the roadway and frequency of the inspection: n. of times/month : **2**
- Pavement cleaning to eliminate debris, discarded material, branches etc. Proportion of interventions made within 48 hours from the emergency call **75%**
- Holes upgrading within 48 hrs from the emergency call **80%**
- Upgrading of damaged barriers in risky areas - Proportion of the cases of activation and beginning of the intervention within48 hrs from the notification out **60%**
- Vertical signs upgrading in risky areas - Proportion of cases of activation and beginning of the intervention within 48 hrs from the notification out..... **70%**
- Anti-ice treatment - Proportion of the cases of intervention by means of salt spreading 3 hrs before the predicted event **80%**
- Annual increase of the open graded pavement on the existing one for the next 10 years..... **20%**
- Grass cutting from slopes and shoulders – frequency : N. of times/year **2**
- Plants trimming – Frequency: N. of times/year **1**

SERVICE PUNCTUALITY (REGULARITY)

- Snow removal - Proportion of the cases of activation and starting of the intervention within 60 minutes from notification **85%**
- Maintenance job-sites for the road network - Proportion of the network where interventions are carried out during low traffic hours (off-peak traffic, quiet hours) for those works requiring only one turn **80%**
- Re-opening to traffic following accidents - Proportion of the cases of activation and starting up of the interventions within 8hrs from the notification **90%**

USERS INFORMATION

- Installation of new variable message signs **68**

LEVEL OF SERVICE COUNTER

- Proposal/complaints – Time for inspection (days)..... **2**

Performance indicators and standards related to the motorways network:

TRAVEL SAFETY

- Pavement cleaning to eliminate debris, discarded material, branches etc. - Proportion of interventions made within 3 hours from the emergency call **85%**
- Road pavement monitoring frequency: N. of times/ year **1**
- Upgrading of damaged barriers in risky areas - Proportion of the cases of activation and beginning of the intervention within 24 hrs from the notification out **85%**
- Vertical signs upgrading - Proportion of the cases of activation of intervention within 24 hrs from notification **85%**
- Anti-ice treatment - Proportion of the cases of intervention by means of salt spreading 3 hrs before the predicted event **90%**
- Annual increase of the open graded pavement compared with the existing one for the next 10 years: 10%
- Grass cutting from slopes and shoulders Proportion Frequency: N of times/year..... **2**
- Plants trimming frequency: Nb of times/year **1**

SERVICE REGULAR FREQUENCY

- Snow removal - Proportion of the act and start of the intervention within 30 minutes from notification: . **90%**
- Road job-site Proportion of the network along which a minimum distance of 5 km between job-sites is guaranteed: **50%**

ITALY

- Road maintenance job-sites - Proportion of the network where interventions are carried out in quiet hours for works requiring 1 turn only: **70%**
- Re-opening to traffic following accidents - Proportion of the cases of action and starting of the intervention within 1 hr from notification: **95%**

TRAVEL COMFORT

- Service on Rest areas - efficiency level checks N. of times/month **1**

SERVICE FOR HANDICAPPED PEOPLE

- Service stations efficiency level checks: N. of times/month **1**
- Service stations also dedicated to people with disabilities - Proportion on the overall number of stations: ... **80%**

USERS INFORMATION

- Installation of new variable message signs: **28**

COUNTER LEVEL OF SERVICE

- Proposals/Complaints – Times for detections (days): .. **2**

3.3 Organization and operations for winter maintenance

With regards to winter climatic conditions, Italy has very different features along the territory. The northern borders of the Italy territory flank countries with cold seasons longer than its own, whilst the south is characterized by a long hot and sunny season. Mountains are in all the Italian regions and so the territory and climate are variegated everywhere. Only 23% of the Italian territory is on a plain. The Alps cross all the Italian northern regions with Mount Blanc at 4,810 m as the highest mountain. The Apennine mountain chain runs north to south. Here many mountains are over 2000 m with the Gran Sasso reaching 2914 m. On the two bigger Italian islands too there are tall mountains such as Etna (3,340 m) in Sicily and Gennargentu (1834 m) in Sardinia.

These features give a big variety in climate and in microclimate so special attention must be given to the possibility of snowfall as well as where it appears unlikely in regions located in the southern latitude and near the sea. The snow is different in the northern regions, where it is dry and light, compared with, wet and heavy snow in the southern regions.

ANAS (the Italian Agency for National Road construction and management), highway management organizations, local authority and municipality offices carry out winter maintenance with their own equipment and with the assistance of private firms to ensure safety for road users in winter.

Meteorological information and forecast

Meteorological information and forecast are provided by Italian Air Force (Aeronautica Militare Italiana) which sees to the collection, processing of data and meteorological products (analyses, forecasts, advice and so on) all over the national territory.

The surveys are carried out by satellites and by a strict network of meteorological stations along the national territory.

ITALY

3.4 Traffic safety and information

Meteorological and traffic information to users broadcasted by radio are processed and spread by the information center CIIS by means of the following national networks:

- RTL (102.5 MF) updated every 30 minutes between 06.30 and 21.00;
- RADIO RAI : updated maximum every 30 minutes;
- ISORADIO: (103 MHz): every 30 minutes covering the motorway network.

The information Center CIIS was created in 1990 on the initiative of the Ministry of Infrastructure and Transports (the then Ministry of Public Works) and of the Interiors Ministry, for road safety regulated by law n.556 of 30.12.1998 and subsequent regulations.

This service is carried out in co-operation with ACI, ANAS S.p.A., Autostrade per l'Italia S.p.A., Arma dei Carabinieri, Polizia Stradale, RAI and Polizia Municipale in Rome

4. References

ISTAT – Statistiche Meteorologiche

www. istat.it

ANAS – Carta dei Servizi Stradali e Autostradali

www.radio.rai.it

www.autostrade.it

www.meteoam.it

www.aci.it

www.stradeanas.it

JAPAN

snow and ice databook 2010

1. Demographics and Roads

Some of the urban areas of Japan receive much more snowfall than any other urban areas in the world. In the cold, snowy regions of Japan, when it snows, traffic is often paralyzed. Roads are damaged by freezing in extremely cold regions.

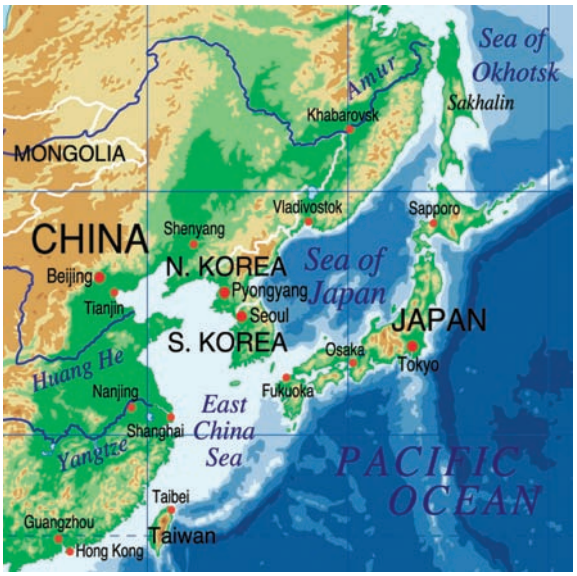


Figure 1 – Location of Japan

To ensure the reliable and safe flow of road traffic in severely cold, snowy regions of the country, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted in April 1956.

Cold, snowy districts account for nearly 60% of Japan's land area, some 40% of its municipalities, and about 20% its population (Table 1).

Area	Total	377,737 km²
	Cold, snowy region	232,553 km²
Population	Total	126,926,000
	Cold, snowy region	28,036,000
Length of Road	National highway	54,004 km
		Cold, snowy region: 26,431 km
	Prefectural road	128,719 km
		Cold, snowy region: 55,914 km
	Municipal road	992,674 km
		Cold, snowy region: 334,671 km
Latitude (capital)	Tokyo: 35ºN	

Table 1 – Area, population and roads in Japan

2. Climate

2.1 Overview of climatic areas

Japan is more southerly than most other cold, snowy countries. Even so, most of the country receives snowfall, expect for the southern part of Kyushu Island. The areas indicated as cold and snowy on the map (Figure 2) are those designated as such by the Law. The climate in these areas is much colder than elsewhere in Japan. Temperatures drops far below freezing, and winters see extreme snowfall. As shown on the map, snow falls heavily in the northern Japan Sea coastal area (Hokuriku region). This is one of the features of winter in Japan.

JAPAN

The heavy snowfall on the Japan Sea side occurs when cold air from Siberia absorbs great amounts of moisture over the Japan Sea and then meets the high mountains that make up the northeast-by-southwest backbone of northeastern Honshu Island. The rising air cools, forming snow clouds.

Japanese cities are snowier than cities in Canada and Sweden. More than two million people live in and around Sapporo, the capital of Hokkaido, despite an annual snowfall that exceeds 5 m. It is the only city in the world where such a great number of people live amidst such extreme snowfall.

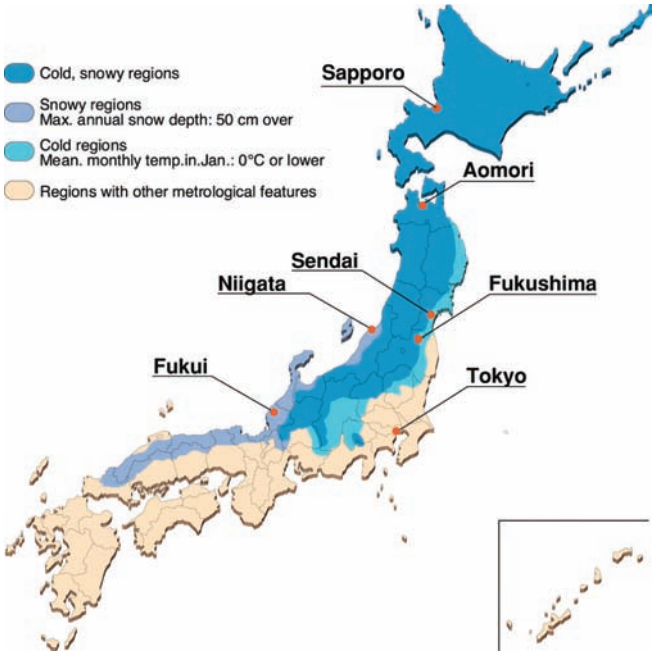


Figure 2 – Overview of climatic areas

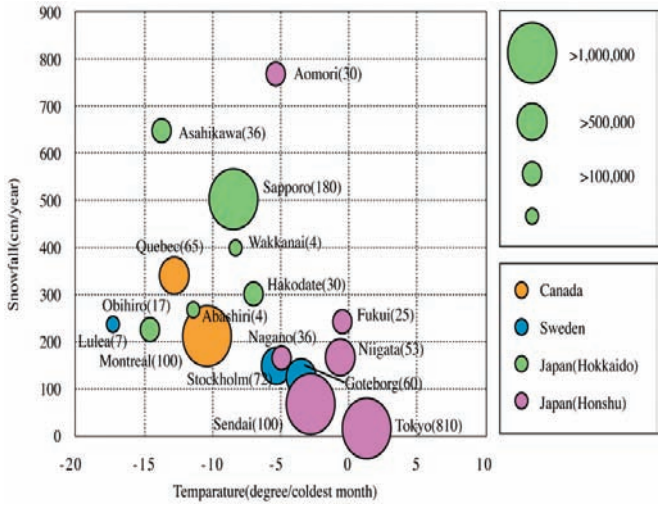


Figure 3 – Air temperature of the coldest month & annual snowfall

2.2 Statistics on temperatures, icing, precipitation

Table 2 – Temperature and precipitation (30 year average)

	Daily min. temperature [°C]				Snowfall [cm]			Precipitation [mm]				
	Dec.	Jan.	Feb.	Mar.	Daily maximum snowfall	Maximum snow depth	Cumulative snowfall	Dec.	Jan.	Feb.	Mar.	Total
Sapporo	-4.4	-7.7	-7.2	-3.5	40	101	496	104.8	110.7	95.7	80.1	1,127.6
Aomori	-1.6	-4.3	-4.3	-1.8	42	114	765	148.6	144.9	116.0	69.5	1,289.9
Sendai	0.6	-2.0	-1.8	0.5	17	17	70	26.4	33.1	48.4	73.0	1,241.8
Niigata	2.3	0.0	-0.3	1.9	27	39	165	204.4	180.3	128.0	104.6	1,775.8
Tokyo	4.6	2.1	2.4	5.1	7	7	13	39.6	48.6	60.2	114.5	1,466.7
Fukui	2.4	-0.3	-0.1	2.2	33	61	240	270.8	279.6	185.3	148.0	2,257.9

3. Winter Road Management

3.1 History and background of snow- and ice-control programs

In 1956, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted. Snow- and ice-control programs were established to ensure smooth winter traffic that supports winter living in cold, snowy regions, because snowfall causes road closures and traffic accidents including slip accidents on icy roads, and the roads are damaged by frost heave in such regions. The Law was legislated to reduce local governments' mounting financial burdens and to provide measures against these hindrances amidst a rapid increase in vehicle ownership.

An emerging issue is the need for measures against the extremely slippery roads that have emerged since studded tires were banned. Such roads have caused increases in vehicle skidding and pedestrian falls. Road administrators also are requested to provide the same road service level regardless of hour or season, because road users wish to enjoy the same conditions year-round. To increase the mobility of people between snowy and non-snowy regions, there is the need to improve the road service level.

As shown in Figure 5, the annual snow- and ice-control expenditure on national highways and prefectural roads subject to national snow- and ice-control projects amounts to nearly 40 billion yen, although it fluctuates from year to year depending on the snowfall. In addition, prefectures and municipalities conduct snow and ice control at their own expense.

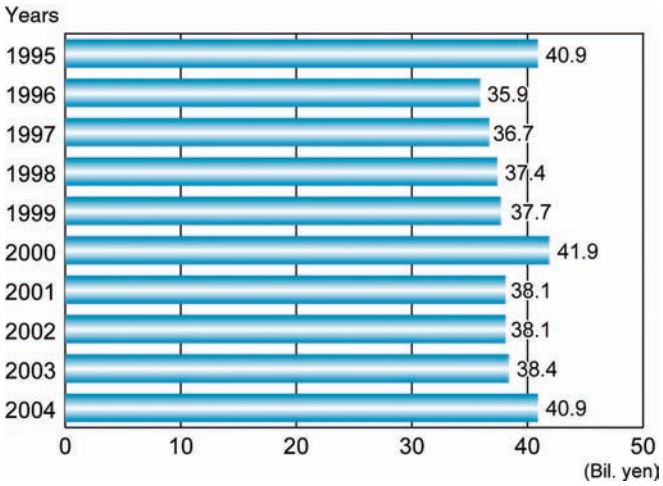
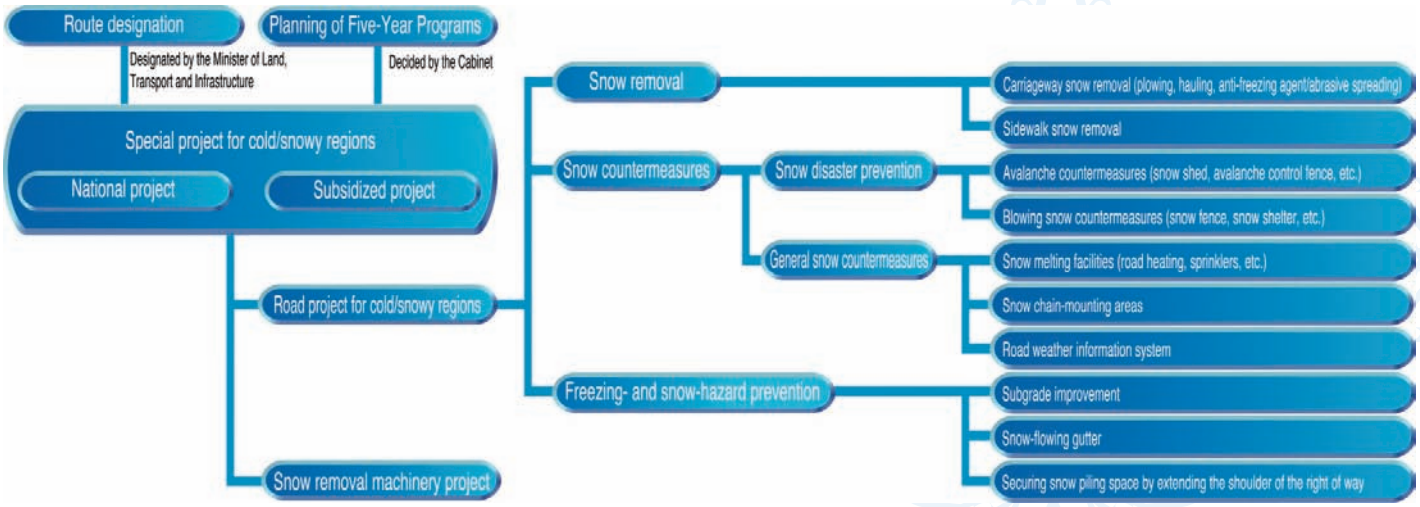


Figure 4 – Expenditures for national snow- and ice-control programs



Roads to which the Law applies: Roads within the region designated under the Law that meet the traffic volume criteria set by the Minister of Land, Transport and Infrastructure and where securing of traffic is especially important for the promotion of industrial and daily life activities.

Figure 5 – Outline of The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas

3.2 Level of Services (LOS)

Criteria for the mobilization of snow- and ice- control staff and vehicles and winter road LOS are set for each road category according to the snowfall, air temperature and traffic volume in each cold, snowy region. Winter management, including the plowing of newly fallen snow, the application of anti-freezing agent and the operation of snow hauling, is based on such criteria and on LOS.

The Hokuriku Regional Bureau of the Ministry of Land, Infrastructure and Transportation sets mobilization criteria for each type of winter maintenance operation (Table 3). The City of Sapporo sets LOS (Table 4) using photographs and descriptions of snow and ice conditions (Figure 6).

Operation		Mobilization criteria
Patrol		1. Monitor snowfall and freezing forecasts, and dispatch patrols as necessary. 2. Dispatch additional patrols as necessary. 1) Snow/ice-related traffic disruption is anticipated. 2) Notification of traffic disruption is made by police, road condition monitor, other road user or local resident.
Snow removal	Plowing	There is 5 to 10 cm of snow on the road, and further snowfall is expected.
	Surface leveling	1. The great amount of snow on road is anticipated to cause traffic disruption unless it is leveled. 2. This is done to prevent the compacted snow layer from thickening and to eliminate unevenness.
	Compacted snow and ice scraping	Due to temperature fluctuations and the load of passing vehicles, compacted snow has become uneven enough to disrupt traffic.
Plowing with rotary blower		1. Heavy snowfall has prompted the need for plowing to secure the effective road width. 2. Snowbanks at the shoulder have become so large that they are expected to disrupt traffic when wind moves the snow.
Hauling		Roadside snow banks have grown so large that they hinder vehicles passing each other in opposite directions, and further snowfall is forecast. Or snow removed from roofs of houses along the road is expected to enlarge the snow banks.
Sidewalk		At the instruction of a supervisor
Salting		Road freezing is forecast or has been reported.
Operation of snow-melting facilities		1. Snow has fallen. 2. Icy roads have been reported (road heating operation is necessary).
Other operations		At the instruction of a supervisor

Table 3 – Criteria for initiating snow- and ice-control operations Example on national highways in the Hokuriku Region

Road category	LOS and the target road condition
Major trunk road, trunk road	Level 4 (daytime): Powder snow, wet snow, slush
Connector road A	Level 3 (daytime): Compacted snow, or wet snow over ice
Connector road B	Level 3: If possible, compacted snow, or wet snow over ice
Residential road	Level 2 (daytime): Ice sheet, or powder snow over ice

Table 4 – Winter road surface management criteria by road category in Sapporo City

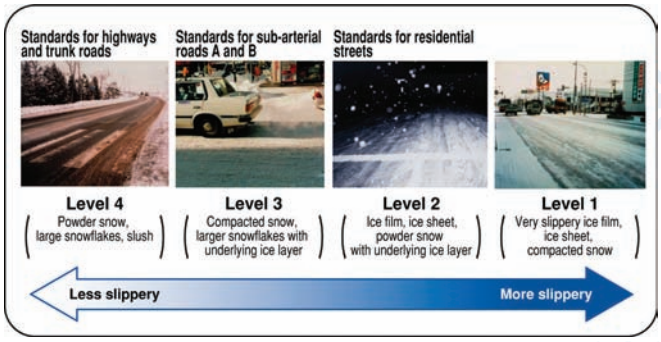


Figure 6 – Winter road management standards and winter road LOS

3.3 Snow- and ice-control measures

Snow removal

Snow removal on roadways

To maintain the trafficability of national highways and principal prefectural roads and to promote interregional exchanges and living activities, snow removal on roadways is conducted around the clock.

Figure 7 – Three-lane snow removal

JAPAN

Snow removal on sidewalks

Snow removal on sidewalks is promoted around schools, railway stations, downtown, and social welfare facilities, to ensure the safety and reliability of walking spaces in winter.

Figure 8 – Sidewalk snow removal

Application of anti-freezing agents

Figure 9 – Application of anti-freezing agents

Since the ban on studded tires, extremely slippery road surfaces frequently have emerged in winter. Anti-freezing agents are efficiently applied to reduce traffic congestion and slip accidents.

Snow-control measures

Various facilities are constructed as countermeasures to avalanche and blowing snow.

Snowbreak woods

These catch falling snow and hold it in snowdrifts within the woods or on their windward side to prevent snow from blowing onto roads on the downwind side.

Snow fences

These keep snow from blowing into drifts on the road. This improves sight visibility.

Avalanche control fences

These are constructed on avalanche-prone roadside slopes.

Snow sheds

These are constructed over roads so that avalanches will pass over them without endangering the safety of the roads.

Light-emitting delineators on the Asahikawa Airport Road (Hokkaido)

The delineator, which runs on eco-friendly solar energy, is easily recognized, and it improves the efficiency of snow-removal.

Snowbreak woods *Snow fence*

Avalanche control fence *Snow shed*

Figure 10 – Snow-control facilities

Figure 11 – Light-emitting delineator: diagram, and onsite installation

Snow-Melting Facilities

Road heating

Road heating systems melt snow or prevent road surface freezing by heating the pavement using heating pipes or electric wires, rather than by sprinkling the road with water.

Without road heating *With road heating*

Figure 12 – Effect of road heating system

Snow-melting sprinkler

Groundwater is pumped up and sent through pipes for sprinkling from nozzles to melt snow. The pipes and nozzles are embedded in the road.

Figure 13 – Effect of snow-melting sprinkler

Snow-flowing gutter

The City of Sapporo has been promoting the construction of snow-flowing gutters, to dispose of snow with the cooperation of local residents. These gutters are constructed at the roadside. Snow on the street is dumped into the waterways, where it is swept away by water running down a natural incline. An underground box culvert is used. In general, the water source is river water. However, Sapporo also uses processed sewage effluent at 10°C from sewage-treatment plants.

The use of processed sewage water has the advantage of requiring less discharge capacity than in the case of using river water, because the higher temperature of sewer water reduces the snow volume by melting the snow.

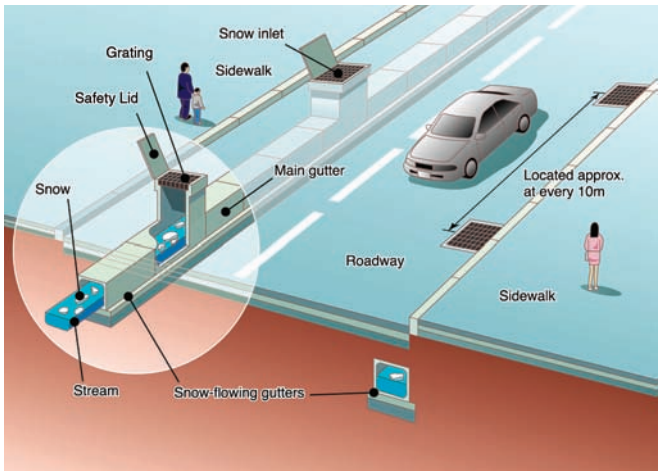


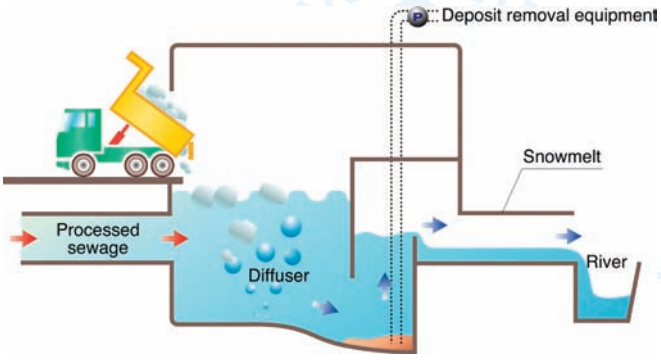
Figure 14 – Diagram of snow-flowing gutter

Residents using the snow-flowing gutter *Maintaining the effective road width in summer and winter*

Figure 15 – Effect of snow-flowing gutter

Snow-melting tank

The construction of snow-melting tanks in urbanized districts has been actively promoted by the City of Sapporo, because the facilities melt a large quantity of snow while occupying relatively small areas of land. Snow-melting tanks dispose of snow that is removed from roads, carried by dump trucks and dumped directly into the tanks of heated water. The energy used to melt snow is from sources previously considered as waste, including processed sewage and the heat generated in garbage incineration. The tanks are used not only during winter, but also during other seasons, as fire-fighting water tanks and balancing reservoirs to retain rainfall and sewage.



Heat source of snow-melting tank: warm processed sewage, residual heat from incineration plants, etc.

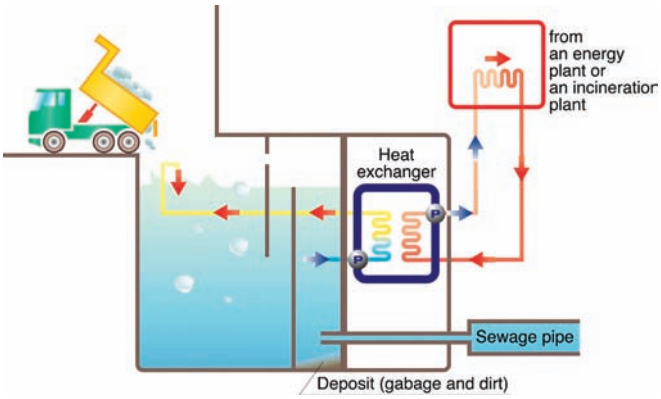


Figure 16 – Snow-melting tank

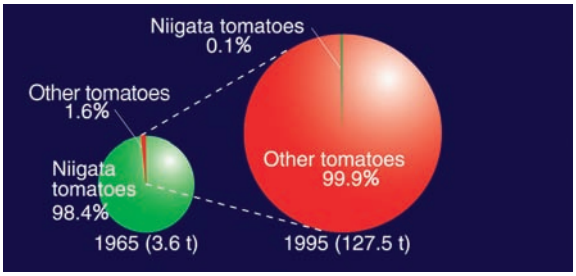
3.4 Assessment of the snow- and ice-control measures

Achievements

Snow- and ice-control projects have yielded great effects. Snow removal has improved, and various snow-control facilities including snow fences, snow-melting facilities, and snow-flowing gutters have been constructed. The gap between snowy regions and elsewhere in convenience of the living environment is being narrowed.

Promotion of interregional road transport

The removal of snow from most national highways has contributed to improved winter mobility, which promotes interregional exchanges. Snowy regions previously isolated in winter have become more accessible. Improved conditions for interregional exchanges have resulted in greater mobility and shorter travel times, greatly increasing the volume of cargo, including agricultural and industrial products.



Source: Niigata Prefectural Government

Figure 17 – Tomatoes unloaded at the Niigata Central Wholesale Market in February

Reduction in traffic accidents

Figure 18 shows the significant reduction in the number of traffic accidents at Harushinai Tunnel after installation of a snow-melting facility.

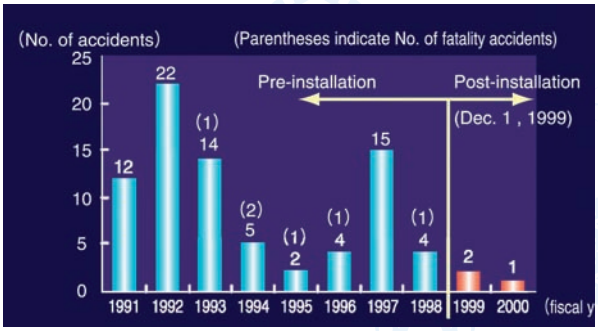
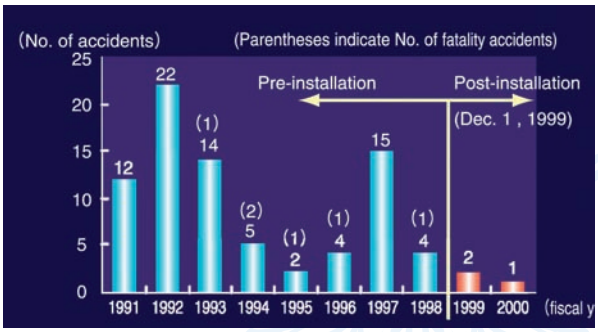


Figure 18 – Reduction in traffic accidents

Mitigation of traffic congestion

Construction of snow-flowing gutters has shortened travel times in Asahikawa City by as much as 25%.



Source: Hokkaido Regional Development Bureau

Figure 20 – Increase in travel speed by installation of snow-flowing gutters.

Improvement of snow-removal for pedestrians including the elderly

An online opinion survey on snow removal was conducted at a website from February 1 to March 30, 2001. The survey found a high need for snow-removal improvement for pedestrians including the elderly. Most respondents were in their thirties.

JAPAN

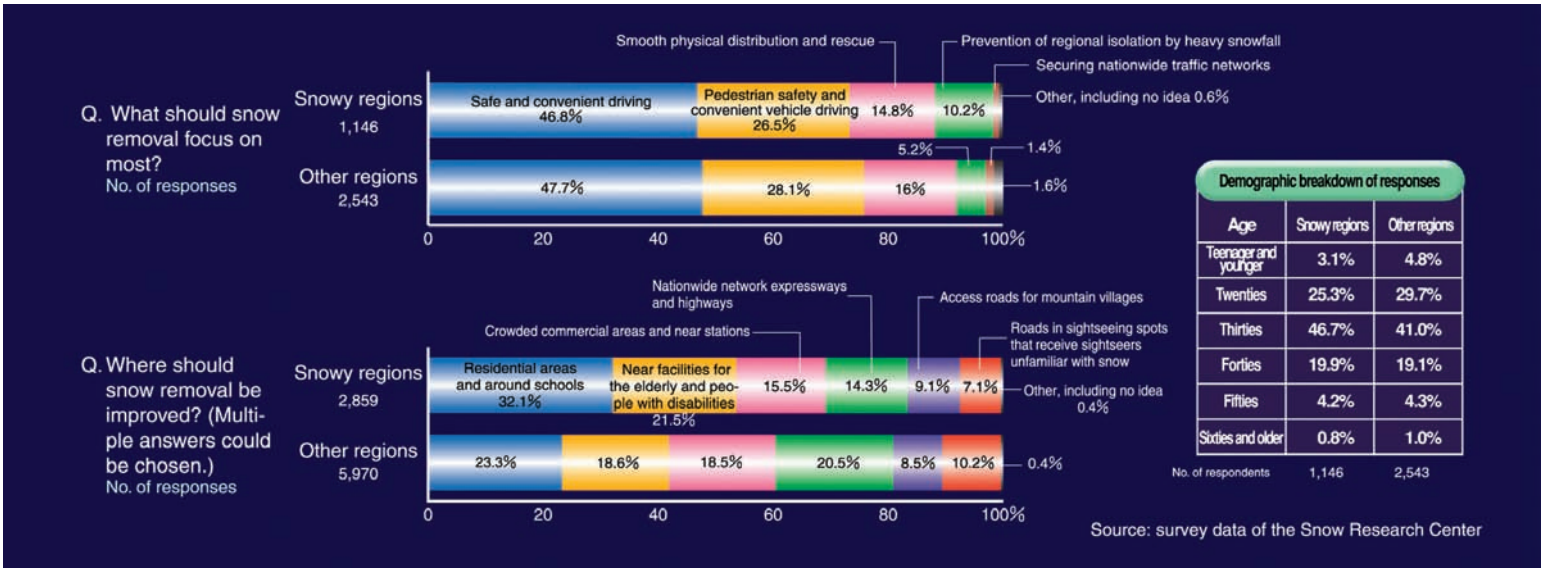


Figure 19 – Road users' expectation for snow- and ice-control

3.5 Traffic safety and information

Road weather information system — Pilot system in the Yuzawa district

The system is on National Highway 17, which is managed by the Nagaoka National Road Works Office, Ministry of Land, Infrastructure and Transport.

National Highway 17 is a trunk road connecting the Tokyo metropolitan area and Niigata, the largest city in the Hokuriku district of northwestern Honshu. The highway passes through areas of severe meteorological and topographic conditions. The 25 km of this highway between Mikuni and Kandatsu area, on the border between Niigata Prefecture and Gunma Prefecture, run through one of the snowiest areas in Japan. The geography of part of the highway is complex: there are seven sharp curves, with radii of 50 m or less, and there are 14.4 km of steep sections, with gradients of 4% or more. The Ministry has implemented advanced snow and ice-control measures on a part of the highway that has been designated a pilot area.

Monitors *Ice sensor*
Figure 21 – Road weather information system

Management using real-time images *Variable message board*

Winter road information systems

Winter road information systems can be divided into two categories: those that support road administrators in winter maintenance, including snow removal and friction management, and those that provide road users with information on weather and road-surface conditions.

The former include a system that monitors and forecasts weather and road-surface conditions, a system that detects and predicts avalanches and snow damage, and systems for traffic information control rooms that comprehensively handle information. The latter include: 1) systems with devices for road information provision, such as variable message boards, those with roadside-radio broadcasting equipment, and those with vehicle information and communication capabilities; 2) facilities for road information provision, such as "Michi-no-eki" roadside rest areas and road information stations; and 3) Internet-based road information provision systems that use personal computers and mobile phones.

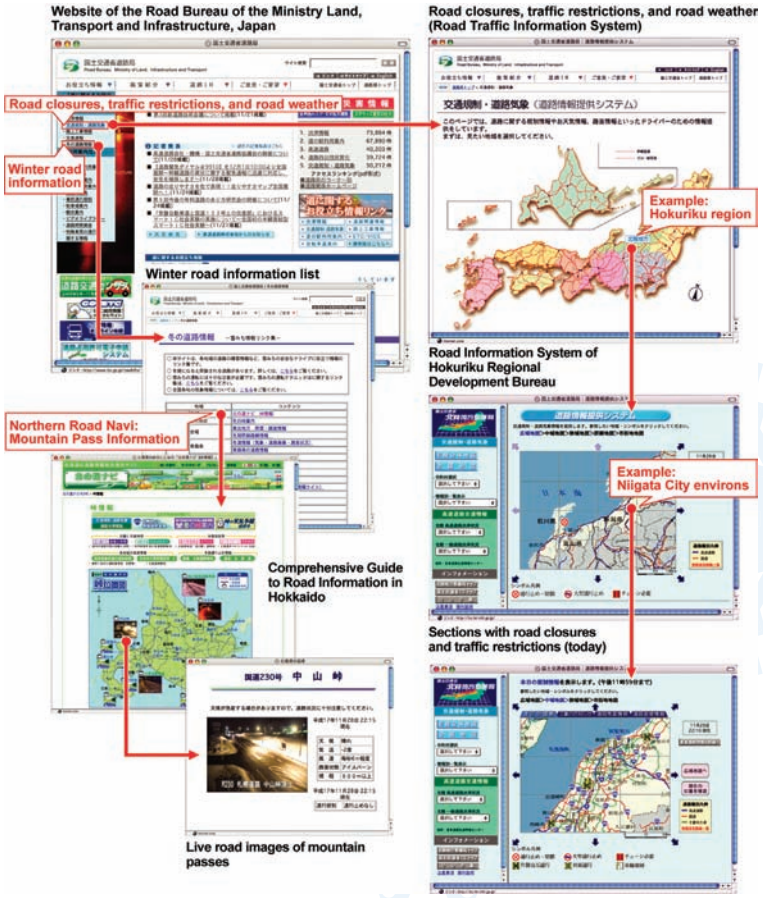
JAPAN

The Civil Engineering Research Institute for Cold Region (CERI) has developed the Winter Maintenance Support System to support measures against slippery, icy winter roads, including de-icing prior to the emergence of such road conditions. The system provides weather and road icing forecasts to road administrators and managers (Figure 22).

The Road Bureau of the Ministry of Land, Infrastructure and Transport, Japan, has developed a comprehensive road information provision system on its website to provide nationwide information on road closures and traffic restrictions, and on weather and road surface conditions, by means of a unified interface. In addition, each regional development bureau has developed a portal website that is tailored to local circumstances and that provides regional road information and links to local road information websites as well as to the Ministry's road and weather information sites (Figure 23). Road administrations have recently used visits to web sites, including mobile phone-accessible websites, as an accountability indicator. Visits to road-administration-related websites numbered 44.16 million in FY2004. In winter, most of such visits were to road information provision sites.

(left: home; right: enlarged map). Home displays all of Hokkaido Island. When a region and a forecast item (weather or road icing) are selected, the system displays a map with the selected information on any scale.

Figure 22 – Winter Maintenance Support System



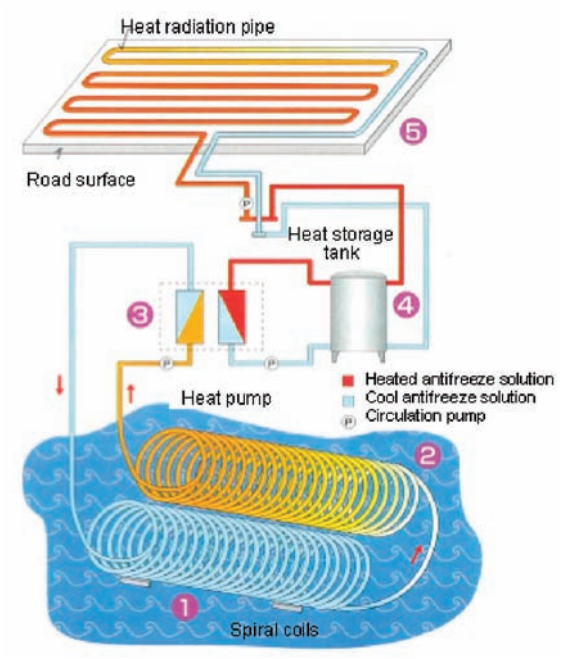
The comprehensive road information provision system on the website of the Road Bureau, Ministry of Land, Infrastructure and Transport. Top left: The left pull-down menu gives nationwide information on road closures and traffic restrictions (upper arrow), and links to a list of the weather and road surface conditions in each region (lower arrow). Top right to middle right: Click on the map for information from each regional development bureau (e.g., Hokuriku Regional Bureau). Middle right to bottom right: Click for information on road closures and traffic restrictions (e.g., those in the Niigata City environs). Middle left to bottom left: Click to access the winter road information of a specific region. (The figure at the bottom left shows mountain pass information from the Northern Road Navi website).

Figure 23 – Website of the winter road information system

4. On-going Research and Studies to Improve Winter Management

A snow-melting system using heat from lake water

The road section approaching Nagoyama Snowshed on National Highway 49 is steep and curved, and it tends to be icy in winter. For these reasons, there are safety concerns. To address the problem, a snow-melting system that uses heat from water in the nearby Lake Inawashiro has been introduced (Figure 24). The lake almost never freezes in winter, and its water at the depth of about 5 m stays between 3 °C and 6 °C degrees in every season. The lake water heat is transferred by heat pump to the snow-melting system. The use of renewable energy such as that from lake water does not emit CO_2 and is environmentally friendly.



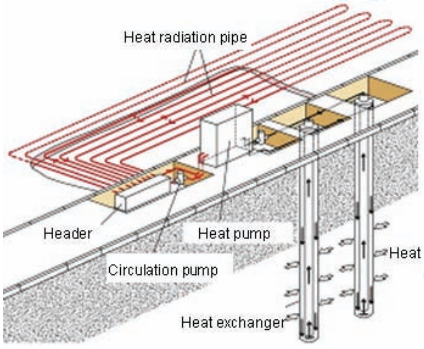
System configuration

Underwater spiral coils *Snow melting with the system*

Figure 24 – The snow-melting system that uses lake water heat

A snow-melting system using ground heat

This new snow-melting system uses ground heat and passive solar heat by means of a ground heat exchanger and heat pump (Figure 25). In summer, the pavement becomes warm from solar radiation. That heat is transferred by heat exchanger to the ground for storage. In winter, the stored heat is transferred in the opposite direction. The heat pump raises the temperature of the antifreeze solution that circulates in heat radiation pipes in the pavement to melt snow. This system also uses renewable energy that does not emit CO_2.



System configuration

Snow melting with the system

Figure 25 – Configuration of the snow-melting system using ground heat

Snow-melting facility that uses wind-generated electricity

Nakayama Tunnel on National Highway 49 has suffered problems including blowing snow and road surface freezing at both ends, because of strong winds in winter. Such conditions have reduced the traffic safety there. The Ministry of Land, Infrastructure and Transport installed a road-heating facility to melt snow by utilizing the strong winds as a resource for generating electricity.

This system (Figure 26) is beneficial because of its low environmental impact and low operation costs. The generated electricity is used in summer to power the tunnel's jet-fan ventilation and lighting.

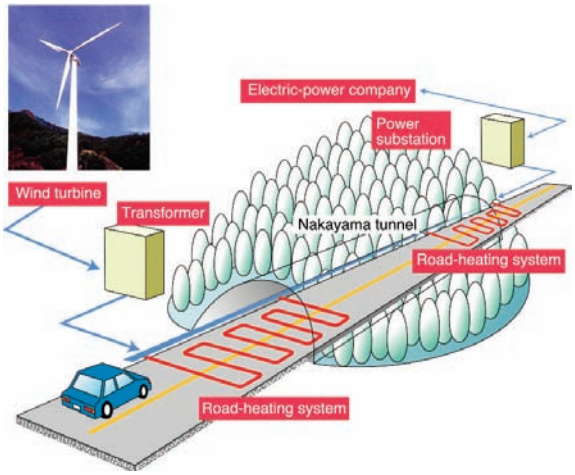


Figure 26 – Snow-melting system that uses wind-generated electricity

Website of winter road friction monitoring data

The road surface condition in winter varies bytime and location. To quantitatively evaluate the road surface condition, CERI has been developing a method for monitoring the road surface friction continuously by a vehicle in motion and for displaying and distributing the monitored results (Figure 27).

Figure 27 – Website of winter road condition monitoring data

Promotion of measures for barrier-free winter mobility

Comprehensive snow removal measures have been formulated and implemented to remove barriers to wintertime mobility, such as the increased danger of pedestrian slip and fall accidents on frozen roads, reduction of walking space due to snowfall, and other inconveniences.

Toward barrier-free mobility, thorough snow removal on sidewalks around railway stations has been promoted and road heating has been installed.

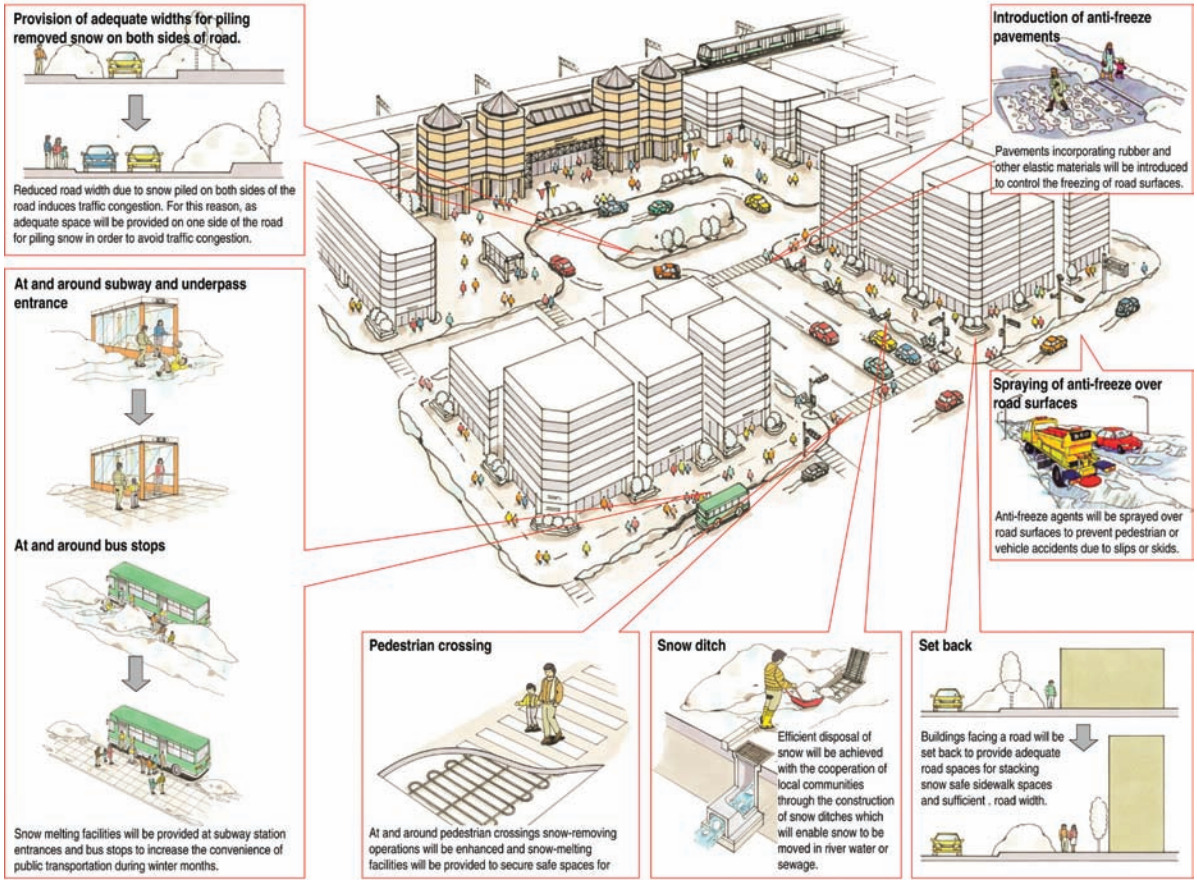


Figure 28. Measures for barrier-free winter mobility taken in conjunction with various other projects for snow- and ice-control

JAPAN

5. References

Website of the Road Bureau, Ministry of Land, Infrastructure and Transport at:

www.mlit.go.jp/road/

LATVIA

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Latvia is located in Northeastern Europe, on the east coast of the Baltic Sea. It borders with Estonia, Lithuania, Russia and Belarus. Most of the Latvia's territory is little higher than 100 meters above sea level. Highest point is Gaizinkalns, 312 meters. There are thousands of rivers and lakes in Latvia. Approximately one third of population of Latvia (732 thousands) live in the capital Riga. The unemployment rate is 10.7%.

1.2 Road network and traffic

Total length of paved state roads is 14,163 km. The average density of state roads is 1,079 km per 1 km^2. Total number of vehicles in Latvia is 1,205,900, including 932,350 cars. Only 638,123 vehicles, including 530,220 cars have passed technical inspection.

Area	64,589 km^2	
Population	2.3 million	
Density of population	35.8 pers/km^2	
Total road and street length	State roads	20,180 km
	Municipal roads	39,013 km
	Forest roads	6,995 km
	Private roads	3,500 km
	Total	69,688 km
Latitude (Capital)	Riga 57 ^{0} N	

In 2008 average daily motor vehicle intensity on state main roads was 5,622 vehicles, including 1089 (19.37%) trucks.

2. Climate

2.1 Overview of climatic areas

Latvia's climate is dependent on its location on the costs of the Baltic Sea and is governed by moderate oceanic climate, with pronounced cyclone activity that influences changes in weather 190-200 days a year. Western part of Latvia is characteristic by maritime climate with milder winters and considerable temperature variations; in the East the climate is more continental. Winter in Latvia usually lasts starting from the second part of November till the end of March. It starts gradually, usually moderate frost, clouded days, lots of snow, sometimes rains.

LATVIA

2.2. Statistics

The average temperature in January in coast regions is -2 °C, in Eastern parts -7 °C. Sometimes sharp short-term decrease of temperature down to -40 °C is observed. This is explained by inflow of high-pressure air masses from North or East.

Consistent snow cover lasts from the middle of December till middle of March. In the Western parts it lasts 80-90 days on average, in the Eastern parts – up to 100-120 days. Because of frequent thaws snow cover is not thick. It may reach 30–50 cm, but on the coast 15–20 cm, in heavy precipitation years and during cold winters it may reach 1 m, while during warm winters snow coat is inconsistent. The average number of days with thaws is <60 days per year.

2.3 Winter indexes

Winter indexes are not calculated in Latvia, however, there is a possibility to start, because Latvian Hydrometeorological Administration collects meteorological data and provides information about deviations from the average decade or monthly temperature, precipitation, as well as thickness of snow cover.

3. Winter Road Management

3.1 Standards and rules

Road maintenance standards, as well as winter standards, are set out in Road Traffic Law and State Regulation "*Requirements for routine maintenance of state and municipal roads and performance supervision procedure*" issued basing on this law.

Roads are divided into 5 winter service classes according to road importance and traffic flow:

AADT (vehicle per day)	Main roads	First class roads	Second class roads
> 5,000	A	-	-
1,000 – 5,000	A1	A1	A1
500 – 1,000	A1	B	B
100 – 500	-	C	C
< 100	-	-	D

Each maintenance class depending on weather conditions has definite requirements for the condition of road:

Requirements	Maintenance class				
	A	A1	B	C	D
	Acceptable conditions				
	Average snow depth				
No precipitation	snow free	snow free	4cm	10 cm	no limits
during snowfall fresh slush	 6 cm 3 cm	 6 cm 3 cm	 8cm 5cm	 10 cm 8 cm	
Ruts	no	Occasionally	up to 20 mm	up to 40 mm	no limits
Time for clearing	3 h	4 h	6 h	18 h	no limits
Time for skid prevention	3 h	4 h	6 h	no	no limits

"Latvian State Roads" has developed specifications for winter works. Requirements for equipment, materials, work performance and expected results are defined in these specifications. Snow plowing on state roads is mostly performed by trucks equipped with front and side plows. Rural municipality roads and private roads are basically cleared using tractors or motograders. For skid prevention on A and A1 class roads wet salt is used. Maximum dimension of a salt particle may not exceed 6.3 mm; various dashes may not exceed 4%. For skid prevention on B class roads wet salt as well as salt and sand mixture and pure sand is used, also grooves are worked in the road surface. 1 m^3 of salt and sand mixture must contain not less than 120 kg of salt, maximum dimension of a mixture particle may not exceed 6.3 mm. On C class roads skid prevention activities are performed only in separate sections – on intersections, on steep increases and sharp turns, scattering sand or working in grooves in the road surface. On freezing rain C class roads are spread with sand at full length. Wet salt is used to melt ice on the streets in bigger cities. Occasionally, in case of heavy snowfall, streets are cleared making snow banks along the side of the streets organizing removals later on. Rural municipalities mainly clear their own roads and streets of snow.

LATVIA

3.2 Organization and operation of winter maintenance

"Latvian State Roads" is responsible for state roads maintenance in winter, while the respective municipality is responsible for maintenance of municipal roads and streets. State road maintenance in winter is financed by state budget, and maintenance of municipal roads and streets is financed by municipal budget that receives earmarked subsidies from the state budget.

"Latvian State Roads" (LSR) elaborates the program for road maintenance in winter, classifies road network and calculates the necessary funding. State roads are classified in the winter of 2008/2009 as follows:

Class	Total km	Including		
		Main roads	First class roads	Second class roads
A	996	896	100	-
A1	2,900	860	1,913	127
B	1,755	-	1,202	553
C	12,886	-	2,116	10,770
D	1,759	-	-	1,759
Total	20,296	1,756	5,331	13,209

The program is approved by the Ministry of Transport. Basic data for the program is prepared by LSR regional offices, while the central office summarizes and draws the necessary corrections to provide unified maintenance policy. Before the start of winter season meetings together with contractors take place at LSR central and regional offices. During these meetings the objectives are defined more precisely and problems as well as solutions to respective problems are identified.

Road maintenance works (also in winter) were awarded through tender, what was held in the summer, 2007. The State road network was split in 12 contract areas. In each area the road network length is within 1,000-2,500 km and covers 1 – 3 districts. All contracts were won by one state owned enterprise, which won the rights to perform road maintenance works in winter and summer from autumn 2007 to autumn 2014.

Contract areas

Contractor undertakes full responsibility for road compliance with maintenance class, performs regular supervision of conditions on the roads and makes the decision on activities to be performed basing on visual inspections, weather forecast, RWIS data and experience. In each district there is a person on duty during winter season who keeps in contact with the contractor and the road users, transport enterprises, emergency services, LSR and local municipality. There are 49 road RWS installed on main roads in Latvia since 1996.

RWIS stations

Information on temperature and moisture, precipitation, as well as road temperature and state is updated regularly in a database. LSR started to equip RWIS with video cameras. All road maintenance units have access to the data through the Internet. Regional persons on duty provide news about current road conditions basing on the data from RWIS, as well as observations on the spot. This information is accessible on LSR web page and is used to inform drivers using the radio and television.

3.3 Assessment of snow and ice control measures

The aim of road maintenance in winter is to allow traffic flow for functioning economy. This is being done. Until now, losses and benefits to the economy because of road maintenance or non-maintenance in winter were not measured.

LSR keeps the register of all road user complaints and applications received; takes them up and replies. After winter season the report on the results of winter maintenance work is prepared. It is distributed during LSR meeting with contractor units. For anti-icing and de-icing mostly wet salt technology, as well as salt and sand mixture is used. Sand spreading and forming of grooves in compacted snow are used for skid prevention on low intensity roads.

Used technologies	Percentage
Wet salt	80%
Salt and sand mixture	11%
Sand	2%
Grooves	7%

Clearing roads of snow is now mostly performed by heavy-duty trucks equipped with several plows whose efficiency is many times higher than that of slow equipment formerly used.

About 80% of the spreaders are included in fleet management system. This system furnishes the contractor and LSR with the information about performed activities.

LSR regional offices supervise the quality of performed work and accept the work for final payments. LSR personnel inspect the compliance of state roads to maintenance class and pays for work activity. The contractor must have the quality control system approved by LSR in order to perform works on state roads. Currently LSR and the contractor have quality control systems correspondent to standards of ISO 9001:2008.

When essential offsets from quality standards are discovered, each case is examined and if it is confirmed that these offsets are due to negligence of the contractor, the contractor is inflicted a financial penalty.

3.4 Traffic safety and information

LSR has established a Traffic Information Center. The person on duty at the Traffic Information Center follows the situation on state roads, replies to road user inquiries and informs the contractor about road user claims. Traffic participants may receive current information about driving conditions on state main roads and general information about driving conditions on roads in each district from the Internet.

LSR is working on schemes for effective and unified dissemination of traffic information to the society with other authorities, which have or generate their own road data (emergencies, local and urban road departments, etc.) One direction is the creation and development of web portal for drivers called "RoadGuide" - a national platform for all traffic data. Another direction is a provision of maximum availability of traffic data for commercial services, which are dealing with on-route informative applications (interfaces: navigators, RDS receivers and mobile phones).

Before the start of winter season LSR informs drivers through mass media and its home page about driving conditions and road maintenance policy in winter, as well as organizes the distribution of information brochures in gas stations and local municipalities.

4. On-going Research and Studies to Improve Winter Management

LSR is working on different ITS projects, which are closely related to road winter maintenance. One of them is the equipping of all RWIS stations with weather cameras. Another project is the automation of fixed traffic counters on main roads, providing online traffic data from 21 important stretches of the main roads. This and other data, significant for decision making in winter works (professional weather forecasts, warnings, data from weather radars and meteo-satelites), is unified on a special web service for contractors and maintenance supervisors.

5. References

www.lvceli.lv
www.csb.gov.lv
www.csdd.lv
www.meteo.lv
www.celugids.lv

LITHUANIA

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Lithuania is an Eastern European country on the Baltic Sea. From the regional point of view, Lithuania is often described as a Baltic state. It is situated in the geographical center of Europe. The area of the country is comparable to that of Ireland and Latvia. The coastal line of Lithuania is 99 km long.

Vilnius is the capital of the Republic of Lithuania. It is the largest city of the country with the population of 544,000. The historic center, or the old town of the city, is among the largest in Eastern Europe and occupies an area of 360 hectares. Its unique value was acknowledged by the UNESCO and in 1994 the old town of Vilnius was included into the UNESCO World Heritage List. Vilnius is situated in the south east of Lithuania (54°41" Northern latitude and 25°17" Eastern longitude) and is the administrative center of the country with the main political, economic, social and cultural centers.

1.2 Road network and traffic

The road network of national significance consists of main roads (1,750 km, including 310 km of motorways), national roads (4,950 km) and regional roads (14,600 km). 64 % of roads have asphalt or concrete pavement. The total number of vehicles in the country amounts to 2.1 million.

Area	65,302 km²	
Population	3.35 million	
Length of state roads	Main and national roads	6,700km
	Incl. motorways	310 km
	Regional roads	14,600 km
Municipal and other roads	Local roads	59,400 km

Lithuania is situated at the crossroads and has international transport corridors extending from the north to the south and from the east to the west. Hence, the development of the road network and its maintenance is among the country's top priorities.

LITHUANIA

2. Climate

2.1 Overview of climatic areas

Climatic conditions. Geographical position: Lithuania is located in middle latitudes, fairly close to the sea and the ocean. From the point of view of the country's climatic variety, it is described as being located in the northern part of the climatic zone of middle latitudes. The climatic region of the Baltic seashore is closer to the climate of Western Europe. For a longer period of a year the weather in Lithuania is determined by atmospheric fronts, the number of which reaches 160-170 per year.

Forests. Forests cover 31.7% of the country's area.

Waters. The country has approximately 748 mm of rainfall, whereas only 512 mm volatilize away. The remaining part, 236 mm (or 32% of rainfall) flow down to the sea by the surface of by underground flushes directly or through neighboring countries.

Internal water bodies of Lithuania (rivers, lakes, ponds and the Curonian Lagoon) cover 1903 km2, which is 2.9% of the country's area.

Rivers. Lithuania is crossed by 17 rivers longer than 100 km. The longest river is the Neman's, starting in Belarus, southwest of Minsk. It is the 14th longest river in Europe and the 4th in the watershed of the Baltic Sea. The total length of beds of rivers and canals in Lithuania amounts to 76.8 thousand km.

Curonian Lagoon. The largest internal water body in Lithuania is the Curonian Lagoon. It is a large lagoon of the Baltic Sea, separated from the sea by a narrow and long spit of sand. The total area of the Curonian Lagoon is 1584 km^2, of which 413 km^2 in the northern part of the lagoon belong to Lithuania.

2.2 Statistics on temperature

The **average winter temperature** fluctuates from -3 °C at the seaside to -6.5 °C in the Eastern part of Lithuania. In summer the average temperature is rather stable and its fluctuation is less varied (from +17 °C to +18.5 °C).

The **length of the factual solar radiation** in Lithuania comprises 50-55% from the maximum. The average length of the solar radiation per month ranges from 30 to 290 hours. In summer the average length of the solar radiation is 9.3-8.6 hours per day. In December the sun shines approximately for 1 hour per day.

Air humidity. The highest relative humidity (more than 90%) is usually at the beginning of winter, while the lowest (around 70%) can be expected in May. It becomes lower from the sea front towards southeast.

Fogs are frequent in Lithuania, especially in western regions (90-105 days per year; general duration of fog amounts to 600-650 hours).

Cloud cover. The cloud cover in Lithuania is 7 points on a 10-point scale (i.e., cloudy with bright intervals). In a year, fine days are 6-10 times fewer than cloudy ones.

Snow cover. Approximately on November 15, at the earliest, the snow cover is formed in northern and eastern regions of Lithuania, while about 10 days later, at the latest, it is formed on the sea front. In snowy winters the thickest snow cover reaches even 90 cm. The thickest average snow cover (around 30 cm) is usually on the eastern edge of Lithuania. In snowy winters the snow cover remains the longest (around 105 days) in North East Lithuania. Usually the snow cover disappears by March 25.

Blizzards are rather frequent in Lithuania. Days with blizzards in Samogitia and East Lithuania average more than 20. There have been winters, when blizzard storms lasted for 55 days. The average duration of one blizzard is 6-7 hours.

In Lithuania **precipitation** is mainly liquid (around 75%), mixed (17%), and hard (snow, ice; 8%). The rainfall in Lithuania averages 1,000-1,300 hours per year (in some years up to 2,000 hours; there are around 190 days with fall here).

3. Winter Road Management

3.1 Standards & rules

The Lithuanian Road Administration (LRA) is a public institution established by the Government of the Republic of Lithuania and is in charge of organizing and coordinating the rehabilitation, maintenance and development of roads.

Roads of national significance are divided into main, national and regional roads. Each road category is maintained following one of three maintenance levels: high (level 1), medium (level 2) and low (level 3). The level of maintenance applicable for a particular category of roads is selected by the LRA considering the level of financing. The level of maintenance is approved by the LRA when concluding road maintenance contracts with state maintenance companies. Before each winter season, they identify routes of road cleaning and spreading and make schedules, which are approved by the LRA.

LITHUANIA

Since the year 2002 Lithuania has had the Road Maintenance Management System. The system is described in the Road Maintenance Manual. It consists of 6 units and includes standards of road maintenance, economic standards of road maintenance, technology of work execution on roads, preparation of road maintenance program, road technical control, acceptance of works and payment, accounting of road maintenance works and standards of works, equipment and material consumption for road works. Anyone interested in the standards can refer to tkti@tkti.lt.

For main and national road spreading the 'pre-wetted salt' method is used, which helps decrease the amount of salt. As a rule, when spreading NaCl, from 5 to 30% of CaCl2 solution is inserted. Under extreme weather conditions (strong freezing rain, low weather temperature) roads can be spread with sand and salt. It improves the skid resistance. Regional roads are spread with a mixture of sand and salt or just sand. When the temperature falls lower than -8°C, roads are spread with a mixture of sodium chloride and calcium chloride (NaCl and $CaCl_2$) at the proportion of 88:12. Proportions might vary. The capacity of salt spreaders is from 5 to 7 m3. Depending on the quantity of salt and the width of the spread, one salt spreader can cover from 15 to 50 km, 30 km in average. In Lithuania, there are about 120 days when spreading is required. The anti-icing strategy allows reducing the amount of chemicals spread on the roads by 20-40%. NaCl, when pre-wetted by $CaCl_2$ solution, is less likely to cause corrosion, particularly if a small amount of inhibitors is added (e.g., some phosphate).

There are no marked differences between the climatic zones in Lithuania. Therefore, they hardly influence the length of spreading.

In accordance with the standards enclosed in contracts signed with contractors, the maintenance operations should start not later than 1 (one) hour from the beginning of rain, snow or freezing rain. Level 1 (approximately 200 km) maintenance operations (24 hours a day) of main roads are applicable on road A1 Vilnius-Kaunas-Klaipòda the road section from 10 to 115 km, i.e., from Vilnius to Sitkūnai, and road A5 Kaunas–Marijampolò–Suvalkai.

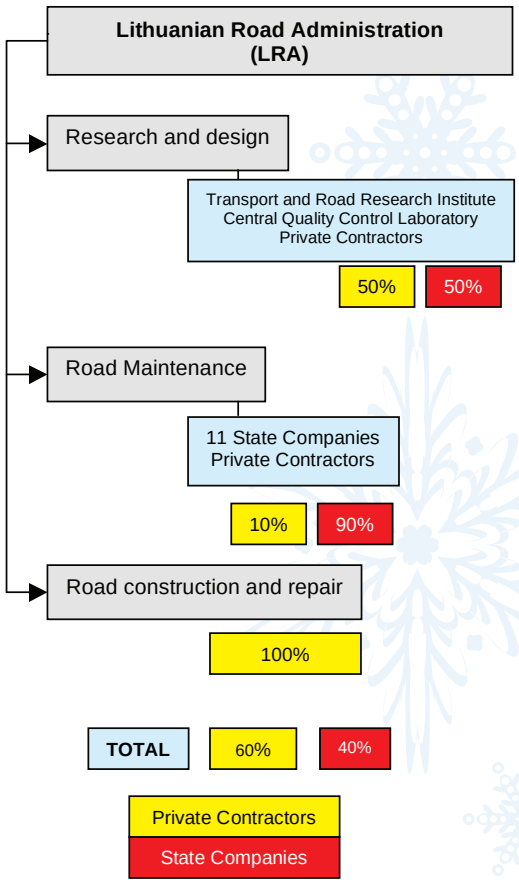
The maintenance service is on duty on other main roads from 4 to 22 hours, on national roads—from 6 to 19 hours, on regional roads—from 9 to 18 hours. From 10 November to 1 April vehicles with the total permitted weight exceeding 3.5 tonnes are not allowed to drive with summer tires in Lithuania. From 10 April to 1 November vehicles with studded tires are not allowed.

In Lithuania the relief is very flat, therefore, winter chains are hardly ever used and their use has not been defined.

3.2 Organization and operation of winter maintenance

The Transport and Road Research Institute and the Quality Control Laboratory are state enterprises. Road reconstruction projects in Lithuania are prepared by private design companies. Projects of a smaller scope can be prepared by the Institute and the Laboratory themselves. The majority of maintenance operations are performed by the road state maintenance companies. However, for some works private contractors are invited. Some equipment can be rented. Roads are constructed and reconstructed exclusively by private companies, on a contractual basis. The Lithuanian Road Administration (LRA) invites tenders for the works performed by private companies. The road maintenance is financed from the national budget (Road Maintenance and Development Program). 40% of the total amount for maintenance is allocated for winter maintenance. In the winter season of 2008-2009 the total sum of winter maintenance funds amounted to EUR 38 million.

Operating Management of Roads



LITHUANIA

Road maintenance in Lithuania is performed exclusively by state maintenance companies, which is why there are no tenders for road maintenance works. State maintenance companies, in charge of road maintenance operations, may hire contractors for some operations or rent some equipment.

Local roads and streets in cities and towns are within the responsibility of municipalities. They are in charge of road and street maintenance. Companies subordinate to the LRA are in charge of maintaining state roads. The funding for that category of roads shall not be used for local roads.

In Lithuania, even when winter is very harsh, there are no restrictions imposed on using roads. They are never closed. Main roads shall be accessible round the clock.

The traffic may only be interrupted under extreme weather conditions for no longer than 2 hours on motorways, no longer than 3 hours on other main roads, no longer than 8 hours on national roads, no longer than 48 hours on regional roads. The traffic is interrupted at the seaside area, which is flooded with melt-water from rivers in spring. Each year approximately 100 km of roads are flooded. Due to the same reason there might be weight restrictions imposed (up to 8 tons) on gravel roads in regions. There are no standards providing for the closure of roads or restriction of traffic. The issue is dealt with from the practical point of view, whether you can drive on the road and if the heavy vehicle does not damage it. The main parameter for the total weight of the vehicle is the depth of ground freeze.

The measurements of snow and ice are performed by the road maintenance companies. The quality of their work is under control of inspectors of the central Quality Control Laboratory.

The meteorological service of Lithuania broadcasts short-term (3-6 hours) weather forecasts for road specialists 5 times a day; a long-term (for the whole week) weather forecast is given once a day.

In the year 1998 on the basis of the Swedish company *AerotechTelub* the LRA set up the Road Weather Information System and started accumulating data on the road weather conditions. The data from field stations are transferred to the central computer located at the LRA. The data are accumulated, stored and processed in the server. The data users are of two categories: all road users and road maintenance specialists. The latter have their own special webpage which provides data from all field stations. In 2009, there have been 48 field stations installed and 27 video cameras. Road maintenance offices receive information on the road condition to their office working stations, whereas information is also provided to the public in the mass media and the LRA webpage (www.lra.lt).

The development of the traffic information system of the roads of national significance has commenced. At the present time activities of intelligent transport systems that are in line with the capabilities of the Lithuanian Road Administration and possible links with other intelligent transport systems in Lithuania are established, further possibilities and directions in the development of the traffic information system of roads of national significance and joining the single network of intelligent transport systems of Europe are provided for. The European Union is going to finance the project in part; the funds will be allocated from the European Regional Development Fund.

It is planned to implement the project within two years, the new system should start to operate in Lithuania at the end of 2010. These will be technologies, providing information about traffic conditions, traffic disruptions and traffic control measures used on the roads. When installing a modern traffic information system on Lithuanian roads of national significance, the following new electronic services will be started to be provided to the users:

- information about road works, their duration, detours, possible delays due to road works;
- real time information about traffic intensity and the average speed on separate sections of the road, warnings about traffic disruptions. Short-term forecasts of traffic intensity (on the roads where sensors of traffic intensity are installed). Information about possible delays due to traffic disruptions;
- information about restrictions on the roads due to climate conditions, traffic accidents or any other reasons. Information about duration of restrictions, detours, possible delays;
- information about the weather conditions on the roads, information about the condition of the road pavement (slippery ground), warnings about phenomena that are dangerous to traffic;
- planning of routes taking into consideration traffic restrictions and traffic conditions (a search for the shortest way, a search for the fastest route, a search for a rational way).

The traffic information system will be developed by installing sensors on the roads, which are necessary to collect information about traffic conditions and setting up the Traffic Information Center.

The technical servicing and maintenance of the field stations, variable message signs and video cameras are within the responsibility of a division of the central Quality Control Laboratory.

LITHUANIA

3.3 Assessment of the snow and ice control measures

Each year the LRA considers traffic volumes on the roads and the budget allocations, then with the help of RIS identifies road maintenance levels. The last estimations testify to the fact that optimum road maintenance, including winter road maintenance, requires the funding that is two times higher than the present allocations from the Road Maintenance and Development Program. Therefore, the efficiency of the road maintenance service conforms to the level of funding.

The central Quality Control Laboratory is in charge of road maintenance control, which is performed on a contractual basis. Regional inspectors at clearly defined intervals or after changes in the weather conditions inspect roads. The function is solely within the responsibility of regional road administrations. They identify if the quality of road works conforms to the requirements of the Road Maintenance Manual. Winter road maintenance works are attributed to routine maintenance. They are paid considering the resultant quality.

3.4 Traffic safety and information

The LRA collects information about the weather on roads and road condition in several ways. One of them is concerned with transferring information from regional administrations by telephone—twice a day. Another pertains to electronic transfer using the LRA information system—twice a day.

The third way is concerned with collecting information from the RWI system (in winter time every 15 minutes). The LRA processes the information and sends it to the mass media and the webpage of the LRA (www.lra.lt) four times a day. Also information on traffic restrictions is provided. The information is also radio broadcast. Other mass media receive it via news agencies. The information is transferred in electronic form. The LRA webpage provides information from all field stations.

On the Vilnius–Kaunas–Klaipòda road there are four variable message signs (VMS) installed. They provide data on weather conditions from the nearest field stations or any other information. The VMS are managed from the road maintenance company or the LRA.

Road users receive the following information on traffic accidents, their causes, traffic conditions etc.:

1. The following information on traffic accidents and their causes is given to news agencies, radio stations and television, the press, electronic mass media: on the situation during the day, week, month/s, year;
2. Publications (brochures, leaflets, calendars etc.) are prepared, printed and distributed;
3. Measures of safe traffic for children in winter time are taken: education on traffic peculiarities, skiing and other winter sports and their location etc.).

A system of improving traffic safety

In 2008, 4,897 fatal and injury accidents (with 498 people killed and 5,940 people injured) occurred. If compared to 2007, the number of accidents in 2008 reduced by 24.1%; the number of killed by 32.7% and the number of injured by 26.1%.

To improve the traffic safety situation, the following measures have been taken:

- Education (information in mass media, publications on traffic safety, instructing pedestrians, cyclists and horse drivers how to use reflectors);
- Engineering measures (lighting road sections, fencing, reconstruction of intersections and some road sections, constructing cycle tracks and pedestrian walkways, new roundabouts, speed humps, reflectors in road pavement, guardrails, etc.);
- Control of road users (administrative measures); more attention is given to the control of tires and lights;
- Special campaigns of traffic safety when education and control is coordinated.

From 1 November to 1 April the speed of transport on motorways is reduced. One of the most effective speed reduction measures was the installation of the network of speed enforcement cameras on the state roads. In 2007, there were 2 units, in 2008 – 12 units, in 2009 – 139 units installed.

LITHUANIA

The estimate of one killed person in Lithuania is approximately 2 million Litas (about EUR 0.58 million). One of our top priorities in the near future is the improvement of road traffic safety. The focus would be on road maintenance, including winter maintenance, by increasing financial allocations so that the accident rate drops to that of the other EU member states.

4. On-going Research and Studies to Improve Winter Management

Vilnius Gediminas Technical University from the very beginning of the RWIS has been involved in the data processing (1998) received from the field stations. Specialists of the University also analyze the data and provide forecast, identify the levels of road maintenance.

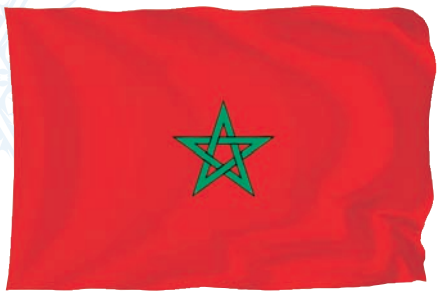
Road Maintenance Group at the Baltic Road Association is in charge of coordinating the work of all maintenance services of the three Baltic States. Members of the group exchange information on the development of road maintenance structures, introduce new national standards and other documents on road maintenance. They also submit proposals which serve as the basis for the countries when organizing the work of road winter maintenance services on the Via Baltica road and other international roads.

5. References

Lithuanian Road Administration (LRA) - www.lra.lt

Central Quality Control Laboratory (SE "Problematika") - www.probl.lt

Transport and Road Research Institute - www.tkti.lt



MOROCCO

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

The Kingdom of Morocco has a surface area of 710,850 square km. It is located in northwest Africa, merely 15 km south of Spain across the Strait of Gibraltar. Morocco is bordered by Mauritania to the south and Algeria to the east. It has a population of 30 million inhabitants, half of which live in urban areas. It has a Mediterranean climate in the north, an Atlantic climate in the west and a desert climate in the south. The climate is also generally temperate due to its proximity to the sea (approximately 3,000 km of coastline). The capital of Morocco is Rabat. Morocco's major cities include: Casablanca, Rabat, Tangier, Agadir, Tetouan, Fez, Marrakech, Meknes and Safi.

1.2 Road network and traffic

The Moroccan road network, which is managed by the Direction des Routes (Road Administration), consists of a total of 57,347 km of roads, of which 38,545 km are paved and 18,802 km are tracks.

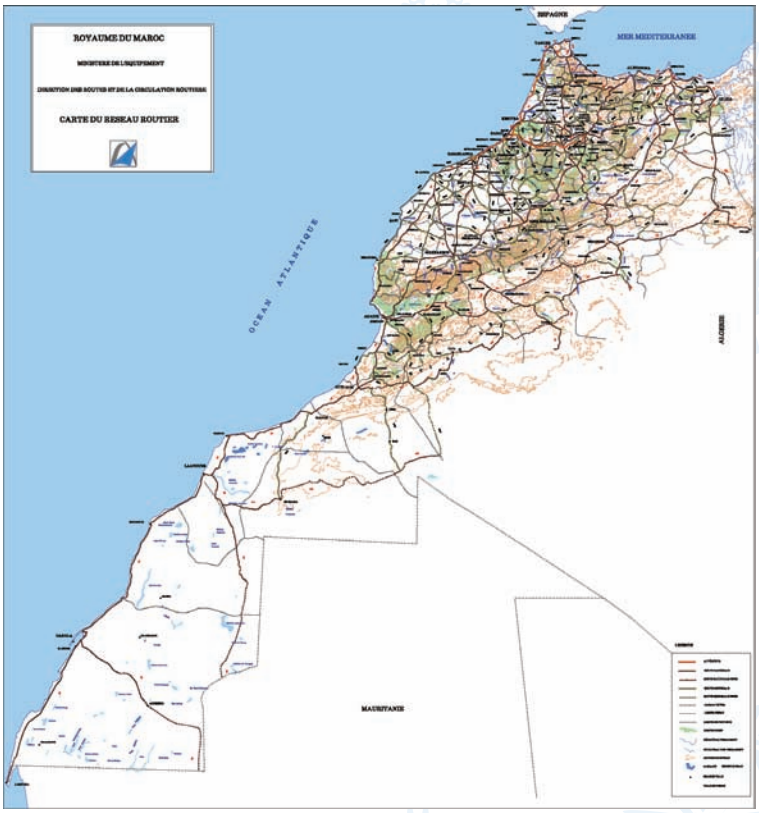
The paved road network is classed according to three categories:

- national roads totaling 9,994 km;
- regional roads totaling 9,324 km;
- provincial roads totaling 19,227 km.

This network undergoes standard maintenance throughout the year provided by the Administration and periodic maintenance (strengthening, surfacing, widening, road marking, etc.) carried out by private companies.

The highway network comprises approximately 920 km and 555 km of highway is under construction. This network is managed by the Société nationale des autoroutes du Maroc (National Highway Department of Morocco).

In 2008, road traffic reached 66.01 million vehicle-kilometers/day, against 60.41 million vehicle-kilometers/day in 2007, which is equivalent to a 9.27 rate of increase. The total number of vehicles on the road is approximately 2.2 million.



2. Climate

2.1 Overview of climatic areas and main winter occurrences to deal with

The climate in Morocco is very different in each region. Coastal areas enjoy a temperate climate which contrasts with the desert climate in the southern and eastern areas of the country. Although, considered a hot country, nevertheless, Morocco's climate is varied. With a Mediterranean climate in the north, an oceanic climate in the west, a continental climate inland and a desert climate in the south, the country's climate clearly varies according to the seasons.

MOROCCO

The summer is generally hot and pleasant on the coast and in mountainous areas, but is stifling in the south and in major cities. In winter, coastal areas experience relatively mild temperatures. In contrast, the winter in the elevated areas, which constitute a large part of Morocco, is cold and very humid.

On the western coast, average temperatures for the coldest and hottest day range between 8 °C and 21 °C in winter. In summer, temperatures range between 17 °C and 27 °C. Average winter temperatures inland range between 4 °C and 20 °C. Winters are cold and rainy with frequent frost and snowfall in the Middle and High Atlas. In these regions, snowfall is abundant during winter and can extend until May, and on the rare occasion, temperatures can drop to -18 °C, whereas during summer, temperatures are quite pleasant, averaging 20 °C.

The rainy seasons are generally between October and November and between April and May. It should be noted that the Rif region, in north west Morocco is the wettest area in Morocco.

The Moroccan Sahara and pre-Sahara have a dry desert climate. Even in winter, the climate of the desert is hot and dry during the day, but becomes very cold at night.

2.2 Weather statistics

In Morocco, services relating to weather and climate information and forecasts are provided by the Direction de la Météorologie Nationale (DMN) (National Meteorological Services Department). This data concerns a range of requested climate products relating to temperature, precipitation, wind, humidity, snow, fog, hail, etc.

General weather forecasts may have a range:

- of or less than 48 hours:
  - weather forecast bulletin for 1 to 4 parameters;
  - weather forecast bulletin for more than 4 parameters;
- of 72 hours:
  - weather forecast bulletin for 1 to 4 parameters;
  - weather forecast bulletin for more than 4 parameters;
- of five days (medium range):
  - medium-range weather forecast bulletin.

The DMN currently has 44 weather stations. Its strategic program provides for the modernization and expansion of its network.

In Morocco, annual rainfall is approximately 810 mm in Tangier, 550 mm in Rabat, 400 mm in Casablanca, 250 mm in Marrakech and Agadir, 350 mm in Oujda, 1200 mm in Ifrane and 30 mm in Dakhla.

2.3 Winter indexes used

Generally, in Morocco, winter season is characterized by the number of days of snowfall, the snow depth recorded on the road network, and the number of hours that road access is blocked because of poor winter conditions. Therefore, the past three years have been marked by the following conditions:

Description:	2005/2006	2006/2007	2007/2008	2008/2009
Number of hours of road blockage	5223	1027	700	9660
Number of days of snowfall on roads	17	15	12	74
Kilometers of snowy roads	4251	3714	2486	4900

3. Winter Road Management

3.1 Standards and rules

Road traffic is governed by the Code de la route (Highway Code) of 1953 whose amendments have recently been passed by the Chamber of Representatives.

In terms of winter services, there are no established standards regarding snow removal. Winter preparation is carried out by means of a circular published by the Direction des routes which outlines the strategy to adopt as regards preparation and intervention.

The signage for snow-covered sections complies with Moroccan directives regarding road signs. Prescriptive signs are installed along the road network in accordance with a by-law approved by the ministre de l'Équipement et des Transports (Minister of Public Works and Transportation).

Road blockages and closures due to snow are announced through press releases issued by the Direction des Routes and are broadcast on the radio and television in Morocco, so that the general public remains informed.

Snow removal is generally carried out by means of snowplows (trucks or graders) except when snow depth exceeds 50 cm. In this case, it is necessary to use snowblowers.

MOROCCO

3.2 Organization and operation of winter maintenance

The Direction des Routes (DR) is an operational department of the ministère de l'Équipement et des Transports (MET) (Ministry of Public Works and Transportation). Within the territory, it is represented by 16 regional public works and transportation divisions (DRETs), 36 provincial public works and transportation divisions (DPETs) and 7 logistics and equipment departments (SLMs). The latter are independent entities. They provide all DRETs and DPETs with the necessary equipment (heavy equipment and trucks) to ensure routine road maintenance as well as snow and sand removal.

One fundamental task of the Direction des Routes (DR) is to consistently and safely provide road users with a sustainable traffic flow on the road network. However, the road network is subject to natural phenomena which hinder traffic flow at different times during the year. Snow cover, sand cover and landslides are among the most common phenomena in Morocco. Snow cover is frequent in the Rif region, from the Middle to High Atlas which spans approximately 5,000 km. Sand cover occurs in the desert areas, south of the Kingdom. Dealing with these phenomena constitutes a major concern of the DR.

In terms of winter service, the strategy of the ministère de l'Équipement et des Transports is based on:

- maintaining the safety of road users at all times;
- re-establishing winter service as expeditiously as possible to ensure traffic flow.

In terms of re-establishing road service (regarding snow removal, flood, rockfall, etc.) in general, all operations are prioritized as follows:

- First, there is intervention on the structured and strategic network to enable inter-city travel as well as the delivery of consumer products from economic hubs;
- Second, there is intervention on the network with medium-level traffic to access administrative centers of rural towns, then intervention on the local network;
- Following the intervention on the main network, teams in the territory of the MET assist in relieving the isolation of the most remote rural population.

In terms of snow removal, the Direction des Routes acts according to the order of precedence of interventions, based on each type of network. The aim is to re-establish general service on the road network as quickly as possible for any given province and, therefore, first of all, access to goods and services, followed by easy travel for the local population.

The ministère de l'Équipement et des Transports has 800 heavy equipment machines and trucks, including 105 specific snow-removal machines (snowblowers, snow-plow trucks and graders) and 15 trailers for transporting equipment nationally and regionally.

Since snow-removal operations cannot be carried out simultaneously throughout the snow-covered road network, it is necessary to prioritize roads based on their economic and strategic importance. As a result, three levels of service have been specified:

Service level S1 (1,850 km)

Roads classified in this level of service receive continuous service (except during snow storms) both day and night, in order to consistently and adequately maintain traffic flow or, if necessary, within a short period of time, not more than 4 hours following a snow storm. In general, national and major regional roads are classed in this level.

Service level S2 (1,700 km)

Service on the roads classed in this level of service is not continuous. However, it is requested that acceptable traffic conditions are maintained during the day by organizing, if necessary, convoys when there is persistent snowfall.

MOROCCO

Service level S3 (1,360 km)

No time limit has been established for roads classed in this category. Acceptable traffic conditions are established as soon as possible.

The road network experiences relatively significant snowfall according to the region and the time of year. The period of highest snowfall lasts from November to March. Within the region, the following measures are undertaken when there is snowfall:

- snow barriers are closed in case of storms;
- all snow-covered sections are monitored;
- traffic is redirected to alternative routes, if possible;
- interruptions in service are announced;
- the intervention plan is implemented to remove snow from sections where road service is interrupted;
- blocked sections are reopened;
- information is disseminated.

Every year, winter preparations begin during the month of September. These are done at two levels:

- Central level by the Direction des Routes ; and
- territorial level (by DRETs and DPETs).

At the central level, winter service authorities:

- prepare a circular addressed to all DRETs and DPETs affected by the snow to mobilize human resources and equipment and carry out preventive maintenance operations at critical points of the road network;
- visit certain DRETs and DPETs to assist them and to acknowledge the measures taken regarding territorial winter preparations;
- hold a meeting with authorities at the office of the Direction des Routes to raise awareness and to verify that all office equipment (telephones, fax machines, photocopiers, etc.) is working well;
- visit all emergency bridges at Oued Zem (DPET at Khouribga) to find out about the preparations carried out.

At the territorial level, the DRETs and DPETs:

- prepare the office which must be equipped with, among other things, a fax machine, a telephone, radio communication equipment, a large map of the road network indicating all critical points and alternative routes (itinéraires bis) and the on-call program, etc.;
- verify and prepare snow-removal equipment and the radio communication system;
- carry out cleaning operations of sanitation works and ditches, maintain structures, maintain and/or replace vertical signage, put up markers (on the network covered by snow);
- visit critical points of the road network;
- maintain snow barriers and shelters;
- hold a meeting with adjoining DRETs and DPETs and winter service authorities of the DRETs and DPETs;
- provide de-icing materials (salt, grains of rice, pozzolana, etc.) to eliminate ice.

It is interesting to note that employees who work to maintain winter services are provided with basic services: accommodation, supplies, clothing, heating, bonuses for hard work, etc.

An external analysis identifies the opportunities and threats presented in the environment. These will be evaluated according to the PESTEL (political, economic social, technological, environmental, legislative) strategic analysis model.

Winter road service constitutes a serious issue in terms of its impact on these different factors.

Political factor

Increasingly, winter service is attracting the attention of officials and local authorities. In fact, they are becoming aware of the interruptions in road service caused by snow. Their concerns are echoed in press releases, questions posed in Parliament, letters addressed to the Ministre de l'Équipement et des Transports, etc.

Local and national officials are concerned about winter service, either because this action seems profitable and beneficial to their electoral efforts, or because they in turn, face pressure from road users, merchants, their associations and from the general public.

MOROCCO

As decentralization takes place, winter service management in urban areas falls under the authority of local officials. Regarding local authorities and decentralized services, particularly external services of the Ministère de l'Équipement et des Transports, these are responsible for public safety, traffic flow, the continuity of public services, the sustainability of economic activity, etc., within their area of expertise, under the supervision of their ministry. In principle, territorial communities (local authorities, municipal councils, regional councils) work jointly.

Economic factor

To state the obvious, the road is a key element in modern economic activity and the population's mobility. As such, in Morocco, 90% of the population use the road network and 75% of goods are transported via the road network. As a result, any interruption in road service is detrimental to the population and to economic and commercial activity.

Although snow has already become an economic asset (ski resorts, etc.) in the 20th century, it continues to pose many problems for those who, over time, have attempted to reduce its influence and negative effects.

Road network interruptions due to snow are expensive and very costly to the community. They:

- affect economic and commercial activity;
- reduce personal travel to tourist destinations;
- cause a shortage of food and disruptions in pharmaceutical supplies.

Consequently, the prices of essential products increase and affect the purchasing power of the population. This is already low since the areas concerned are all under developed.

Social factor

Road service interruptions due to snow on the network exacerbate the isolation and remoteness of many communities and hinder the transport of people and goods. They prevent access to health care and to educational and socio-administrative centers. These interruptions disrupt children's schooling. As a result, they cause dissatisfaction and discontent among the population and sometimes create a feeling of marginalization and exclusion. In fact, since road users are increasingly aware of the importance of quality and continuous service, they resort to complaining and protesting.

While infrastructures undeniably serve as a means of anchoring the population in certain disadvantaged geographic areas (mountains, areas that are far from urban centers, etc.), on the contrary, service interruptions encourage rural migration and cause rural communities to become deserted.

Technological factor

Increasingly, winter service incorporates technology:

- Road users can contact the Minister or send him messages to express their satisfaction or dissatisfaction via NICT (the Internet, GSM, etc.);
- Road users can express their opinion via the press, radio or television;
- Thanks to weather reports: weather forecasts can be used to better prepare for winter (planning head, prevention, positioning equipment at hot spots, etc.);
- Effective snow-removal equipment has a GPS and radio communication system and air conditioned cabins;
- Automatic salting spreaders to de-ice roads.

Ecological and environmental factor

Winter service has a significant impact on the environment due to:

- the over consumption of fuel and of lubricants;
- road de-icing chemicals (salt) that pollute the water table and decrease flora.

Road maintenance activities and operations are likely to affect the quality of native environment located near to roadways. In Morocco, ecological and environmental concerns are considered when developing and implementing winter service projects. Therefore, as regards road de-icing chemicals, we use pozzolana, a natural material that is found in abundance in Ifrane and Khenifra regions, and which makes it possible to reduce the impact on flora and fauna and on the water table.

MOROCCO

Legislative, legal factor and safety instructions

Winter service requires strict compliance with legal and statutory provisions which govern management and organization. It is particularly important to act in strict accordance with the provisions of the Highway Code. When there is snow, safety standards especially include complying with signage, driving in convoys, obeying speed limits, maintaining safe distances between vehicles and snow barriers, etc.

Besides weather reports, television networks and radio stations regularly broadcast reports regarding road service interruptions due to snow and the closing and reopening of roads.

Road users have access to a telephone number for the DR (05 37 71 17 17) 24 hours a day, 7 days a week, so that they can learn about the present and progressive state of the road network.

Moreover, just as road users, snow removal officials must face the same traffic during their different operations and, as a result; they are exposed to potential hazards. Their safety must be particularly and constantly ensured, specifically through sufficient signage.

3.3 Road safety and road information

The first priority of Direction des Routes officials is the safety of road users. Provisions have been implemented to ensure the safety of road users and to avoid incidents on snow-covered roads.

Thanks to the vigilance of the winter service teams, we recorded no loss of human life on the snow-covered road network due to road service interruptions caused by snow. Before snow barriers are closed, teams always search snow-covered sections to ensure that there is no road user in these sections. These fences are only opened after snow-removal operations are completed and roads are treated with road de-icing chemicals. Travel in convoys, which often takes place on the snow-covered network, is always escorted by snow-removal equipment.

Internal communication

When there is road service interruption due to snow, the DRETs and DPETs concerned immediately communicate information to the DR and to the neighboring DRET and DPET by telephone at 05 37 71 17 17, by fax at 05 37 71 32 54 and by the information highway (SMS and the Internet).

Radio communication

Since 1993, the DR has implemented a radio communication system based on VHF/UHF bands. This system, which is generally used in the 51 DRETs and DPETs, makes it possible to:

- control information;
- closely monitor intervention teams operating on the ground during snow removal operations, salting, sand removal and routine road maintenance, etc.;
- have a distinct communication network outside the congestion of existing networks;
- reduce decision-making time and prevent hasty actions and delays in the event of natural phenomena and as a result, improve the public utilities provided to road users;
- improve coordination between neighboring DPETs.

All maintenance and snow-removal equipment have a radio communication system.

Information highway

In effort to modernize its management tools, in 2005, the DR developed a computerized system for managing information regarding road incidents of which there are five, involving snowfall, sand cover, traffic accidents, flood damage, problems with structures and road works.

This system, which is based on the Internet and on SMS messaging through GSM telephones, makes it possible to:

- improve the time taken to gather information;
- share information, in real time, with different officials at the Ministère de l'Équipement et des Transports to assist decision-making;
- improve the storage of information for the general public;
- create a database of road incidents.

Therefore, information on road incidents is sent either by SMS from the incident site in the form of summarized information or through the Internet. In this case, the authorized system user adds information on road incidents. The information communicated includes the number of the road, the kilometer marker, the type of incident, the death toll and possibly, an incident report.

MOROCCO

The system also enables the administrator to semi-automatically prepare press releases regarding traffic conditions (in French and Arabic) and send these to recipients attached with maps indicating the location of the incident.

External communication

Telephone number: 05 37 71 17 17

As regards information for the general public, the DR allows access to a telephone number (05 37 71 17 17) that can be used 24 hours a day, 7 days a week and which informs the public about the state of the road network, particularly concerning traffic conditions during snowfall.

Media

Information is also broadcast to the general public through press releases on the radio, television and in the press. These press releases (regarding road service interruptions or the reopening of roads) are prepared by the service exploitation et viabilité (Operations and Winter Service Department) of the DR.

Signage with varied messages

In terms of improving traffic conditions and the level of service on main roads, the DR has installed signage with varied messages to inform road users, in real time, about the state of the network, especially during snow removal when there are possible detours. Signs are installed on the following roads:

- at Meknes, on the RN8 at the Meknes exit towards El hajeb;
- at Fez, on the RN8 at the Fez exit towards Ifrane;
- at Ifrane, on the RN8 at the exit towards Azrou;
- at Azrou on the RN13 at the exit towards Midelt, in the middle of Ifrane.

These signs are managed by system control centers linked by a modem via the switched telephone network. The main control centre is located at the DPET in Ifrane.

Fax and telephone

Information regarding road service interruptions and the reopening of roads is also communicated by telephone and fax to the local authority and the Royal Gendarmerie.

In order to follow weather changes and as a result of an agreement with the Direction de la Météorologie Nationale (National Department of Meteorology), the departments of the DR daily receive medium range (4 days) weather reports which include information on the weather observed and forecasted and, if necessary, weather reports with warnings concerning inclement weather and announcing snowfall.

In the case of alert bulletins, the central departments of the DR warn the external services concerned in due time, and very closely monitor the different operations carried out on the ground to mitigate the risks caused by inclement weather.

The territorial departments affected by these warnings launch reconnaissance operations to establish the status of critical points and monitor and verify the state of interruptions.

4. On-going Research and Studies to Improve Winter Management

4.1 New technologies

In terms of snow-removal equipment, since 2005, the Direction des Routes has acquired 31 snow-removal units and 3 additional snowblowers are currently waiting to be delivered. Each of these machines is equipped with a radio communication system.

Variable message signs (VMS) have been installed in Ifrane to inform users about road conditions.

4.2 New management and organization approaches

The Direction des Routes is giving a valuable, strategic and creative dimension to its human resources. The employees who work in the winter service sector are experienced and devoted and demonstrate a sense of membership similar to that of an elite group. These employees do not count their work hours and do their best to satisfy road users. New management approaches are based on the logic of intervention via the road. Limitations between provinces do not exist when it comes to snow removal operations. In fact, snow-removal teams in any given province continue to clear snow on the same road until they meet teams from other provinces.

Efforts have intensified for the development of forecasting and road monitoring (patrolling) in order to improve the reaction and response speed to weather conditions and environmental forces.

4.3 Transnational Cooperation to Improve Levels of Service between Bordering Countries

The need to better manage winter service constitutes a major concern of the Direction des Routes. Since it was established, it has chosen to develop technical cooperation with its counterparts which include industrialized nations as well as developing countries.

This cooperation is aimed at improving management and procedures to respond to current and future issues encountered in the field of winter service.

Therefore, bilateral cooperation has been implemented between Morocco and other contributing countries in fields relating to winter service, such as:

- Cooperation between Morocco and Sweden in the field of road safety has provided the departments of the DR with technological tools for management, operations and road safety, with special emphasis on the information and operating system for snow-covered roads or roads subject to inclement weather. Significant recommendations have been presented that focus on the following aspects: snow removal equipment, road equipment, techniques for snow removal and ice elimination, information systems, and road infrastructure.
- Cooperation with Japan, which has resulted in the construction of an institute for equipment training and road maintenance. Since 1993, over 5,000 Moroccan technicians and 200 executives from African countries have benefited from training at the institute;
- Cooperation with France in the field of road signs has made it possible to develop a guide to road signage in urban areas and to introduce new road signs.

5. References

Bibliography

Mr. JANATI IDRISSI, La gestion de la viabilité hivernale au Maroc, published in the revue générale des routes et aérodromes (France) n° 852, October 2006.

Mr. JANATI IDRISSI, thesis entitled Développement stratégique de la viabilité hivernale au Maroc for a Master's Degree in Public Management.

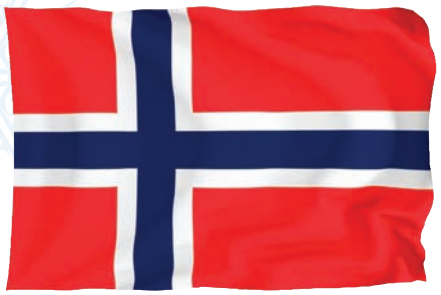
XII International Winter Road Congress, Torino (Italy), March 26 to 30, 2006.

Webography

www.internaute.com/voyage/maroc/climat

www.marocmeteo.ma

www.mtpnet.gov.ma



NORWAY

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

The Kingdom of Norway is a constitutional monarchy. Area of the Kingdom of Norway is 385,155 km^2, mainland: 323,758 km^2, Svalbard and Jan Mayen is 61,397 km^2. Population is 4,554,000 as of January 1, 2003. Monetary unit is Norwegian kroner (NOK). One Euro was 8.42 NOK in August 2004. Length of coastline is 25,148 km, including fjords. Largest lake Mjøsa is 362 km^2. Highest mountain Galdhøpiggen is 2,469 m.

Much of Norway is mountainous. The western coast is gouged by deep fjords and dotted with islands along the coast. Norway is the country with longest coastline in Europe. The most important economic factor is oil-related activity. It represents 40% of the Gross domestic product. Norway's administrative units are the Regjering (government) and Storting (parliament) with elections every 4 years. There are 20 counties and 434 municipalities. The latitude of the capital Oslo is 60° north.

1.2 Road network and traffic

The categories of roads in Norway are the following:

Road type	Length of road
Motorways with 4 lanes class A	213 km
Trunk roads including motorways	8,875 km
Other national roads	18,377 km
County roads	27,027 km
Municipality roads	38,234 km
Total public roads	92,513 km
Private, forest, farm roads	122,939 km

All national roads are paved. In the other types there are a lot of unpaved roads. There are 3.7 million vehicles including 1.9 million passenger cars. Total traffic on national and county roads is about 31.7 million vehicle km.

Domestic passenger transport, by mode of transport[1]

Type of transport	passengers (million)		passenger-km (million)		
	2000	2001	2000	2001	%
Total	4,290	4,378	62,690	63,499	100.0
Water	46	45	845	841	1.3
Rail	158	159	3,287	3,208	5.1
Road	4,076	4,165	54,137	55, 330	87.1
Air	10	9	4,422	4,120	6.5

[1] Passengers crossing borders and in transit are not included. **Source:** Statistics Norway.

NORWAY

Domestic goods transport, by mode of transport[1]

Type of transport	tonnes transported (million)		tonnes-km (million)		
	1999	2000	1999	2000	%
Total	446	*448	48,842	*48,772	100.0
Water	74	*76	12,958	*12,723	26.1
Rail	6	6	1,961	1,852	3.8
Road	265	270	12,796	13,468	27.6
Air	0	0	19	19	0.0
Transport between the continental shelf and mainland	101	96	21,108	20,710	42.5

[1] Excluding exports and imports across borders and goods in transit. **Source:** Statistics Norway.

Nine-tenths of the country's area is located north of 60º latitude, where there is heavy snowfall six months of the year. Winter road traffic (November through April) accounts for about 35% of the annual yearly traffic volume. In Norway 1/3 of the maintenance budget is connected to the winter condition.

2. Climate

2.1 Overview of climatic areas, main winter events to be mastered

The Gulf Stream makes the climate in Norway much milder than other parts of the world at the same latitude. The country rises with a mountainous area inside the coastline.

Norway experiences large climatic variations within short distances. In the lowland on the eastern part of the mountains the climate is drier with low temperatures down to –20 ºC, occasionally down to -30 ºC and -40 ºC. While the winter temperatures will vary around 0 ºC along the coast, and rarely below –10 ºC.

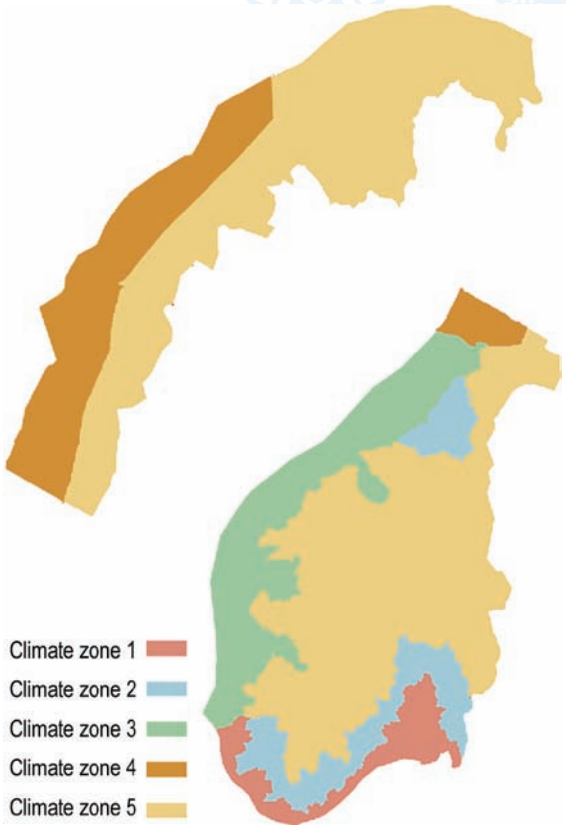
In the western part of the mountains there is a lot of snow and wind, and often extremely difficult conditions for winter maintenance. There is a lot of precipitation along the coast, often as snow, and also a lot of wind. The moist climate along the sea creates a lot of problems with humidity freezing to black ice on the roads.

As an average in the southeastern part of Norway there is 20-25 snowfall during a winter. The number of snowfalls is much higher along the coast and especially in the north of Norway. In recent years problems with freezing rain and rain on frozen roads has become more frequent. The roads get extremely slippery and it is very difficult to handle for the road users. For the road operators it is also very difficult to handle as the rain very rapidly reduces the effect of the salt.

There are many snowstorms during winter in the mountains and especially in the north of Norway. On roads crossing the mountains, there are many road closures and periods were vehicles only can pass in convoy due to snowstorms.

2.2 Statistics on temperatures, icing, precipitations

For winter maintenance purposes the country may be divided into five climatic zones, as shown in tables below.



NORWAY

	Climate-zones				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Length of winter, days	152	173	157	206	201
Snow-depth	41 cm	55 cm	41cm	63cm	72cm
Precipitation as snow	158 mm	225 mm	258 mm	332 mm	248 mm
Precipitation as rain	830 mm	734 mm	1,632 mm	860 mm	603 mm
Mean temp. Jan C°	-3	-6	0.7	-3.3	-7.8
Mean temp. March C°	1.1	-1.4	2.6	-1.6	-3.3

Climatic Parameters in Different Climatic Zones

Climate zone	Population	National roads	Transport volume	AADT
1	1.7 mill	2,900 km	7.7 billion km	2,605
2	0.6 "	4,000 "	4.5 -"-	1,125
3	1.0 "	4,900 "	3.6 -"-	744
4	0.3 "	2,800 "	1.3 -"-	453
5	0.75 "	11,900 "	6.4 -"-	118

Road Network Characteristics for Zones

2.3 Winter indexes used

A winter index system is established and implemented in two areas. The index is a theoretical calculation of the need for winter maintenance operations. It is now under testing, where the theoretical and actual numbers of actions are compared, and adjustments are made. The index compares the last winter with an average winter. Information about precipitation, wind, temperature variations around zero, humidity, etc. is collected from meteorological stations in the area. The computer then calculates the theoretical number of necessary winter maintenance actions based on the actual weather information. The contractor's tender is based on the average winter index. If last winter has a higher index he will be compensated accordingly.

3. Winter Road Management

3.1 Standards and rules

Legal obligation to perform winter maintenance?

According to the Norwegian Road Law the Ministry of Transport and Communication gives guidelines for maintenance of trunk and national roads. The Government finances the maintenance. The Norwegian Public Roads Administration (NPRA) acts on behalf of the Ministry of Communication. NPRA also manages maintenance activities on county roads for the counties.

Maintenance of roads is financed from three different sources: (i) The state (trunk and national roads), (ii) the counties and (iii) the municipalities.

Classification of the roads - Levels of service - Route optimization

The road classes are:

- Trunk roads connects different part of the country, and also Norway to other countries;
- National roads, including trunk roads, connect the different counties to important centers and are the main transport roads for goods and traffic within the country;
- County roads brings traffic from the countryside to the national roads and county centers;
- Municipal roads take care of traffic from the homes and businesses within towns and municipalities to the other roads;
- Private roads.

Quality standards, performance indicators

Level of Service

The level of maintenance standards for trunk and national roads is described according to the importance of the roads and the annual average daily traffic flow. Traffic safety, traffic volume (average annual daily traffic (AADT)) and environmental effects are the parameters considered to make the most cost efficient standard. The level of service for national roads in Norway is described in the maintenance manual, handbook 111 "Standard for Maintenance and Operations", dated May 2003. The "county roads" and "municipal roads" have their own levels of standard. Below is a translation of handbook 111:

Passable roads, traffic safety and regularity during the winter period

The road should be passable for vehicles, which are normally equipped for winter driving. This can be achieved by reducing the amount of snow and ice on the road together with measures to provide sufficient friction for the road user.

Winter maintenance is performed according to two different strategies:

1. Strategy **Winter Roads**: Roads where snow- and ice cover can be accepted during the winter period;
2. Strategy **Bare roads** (roads without snow and ice): Roads that normally shall be free from snow and ice during the winter period. Bare road includes driveway and edge lines.

NORWAY

Maintenance strategy for winter roads

Snowplowing

During snowfall: Plowing should be started and be completed according to requirements in the table below:

AADT	Start plowing at snow depth		Finished plowing before (snow depth)	
	Dry snow (cm)	Dry snow (cm)	Wet snow (cm)	Wet snow (cm)
0 – 500	6	4	15	12
501 – 1,500	4	2	12	8
1,501 – 3,000	3	2	10	7
> 3,000	2	1	7	6

On roads with AADT < 1,500 snowplowing should be done after all snow falls > 3 cm.

During continuous snowfall, the frequency of snow plowing should be as high as is necessary to meet the requirement to the maximum snow depth.

During extreme weather condition, the above requirements might be deviated from.

Drifting snow

Action should be taken when the height of the drift in the middle of one of the traffic lanes reaches:

AADT < 1,500	15 cm
1,501 – 5,000	10 cm
AADT > 5,000	8 cm

Snow and ice clearing

Threshold levels and time limits before action should be completed are shown in the table below:

Tasks	Triggering criteria and maximum time for action for different AADT			
	< 1,500	1,501 – 3,000	5,001 – 10,000	> 10,000
Snow and ice: - max. thickness: - removed within:	3 cm 3 days	2 cm 2 days	2 cm 1 day	0 cm
Removing of snow at intersections within:	1 day	1 day	1 day	1 day
Removing of snow for visibility, e.g., removing snow in front of traffic signs etc., within:	1 day	1 day	1 day	1 day
Visibility clearing at intersections within:	3 days	3 days	2 days	1 day

Shelters at bus stops should be cleared before 7 am, or no later than four hours after finishing plowing, or according to instructions.

Ice "patches" should be removed before danger arises for the road-user.

Spreading (road-grip and friction)

Spreading should be done when low friction prevents normally winter-equipped vehicles to drive up and down hills, etc. Action takes place as shown in table below:

Class of road	AADT	Local sanding		Continuous sanding	
		Start at	Finished within	Start at	Finished within
Trunk Roads		μ< 0.30	1 hr.	μ< 0.20	2 hrs.
All other roads	> 1,500	μ< 0.25	1 hr.	μ< 0.20	2 hrs.
	501 – 1,500	μ< 0.25	2 hrs.	μ< 0.15	3 hrs.
	0 - 500	μ< 0.20	2 hrs	μ< 0.15	4hrs

Local spreading takes place in curves, hills, junctions and on straight roads with private access roads with low visibility.

Salt or salt-solution (brine) can be used during the transition periods in spring and autumns.

Mountain roads:

Mountain roads and other similar roads are maintained and operated according to special instructions.

Strategy for winter maintenance on bare roads

Snowplowing

During snowfall: Plowing should be started when the snow depth is 2 cm and should be finished before maximum snow depth is 6 cm, regardless of AADT.

During snowfall, the frequency of snowplowing should be as high as is necessary to meet the requirement of maximum snow depth.

During extreme weather condition, the above requirements might be deviated from.

Drifting snow

Action should be taken when the height of the drift in the middle of one of the traffic lanes reaches:

AADT < 1,500	15 cm
1,501 – 5,000	10 cm
AADT > 5,000	8 cm

NORWAY

Snow and ice clearing

Required time limits for completion of snow and ice clearing after completing plowing of the road:

Tasks	Time limits for different AADT		
	0 – 5,000	5,001 – 10,000	> 10,000
Removing of snow at intersections within:	1 day	1 day	1 day
Removing of snow for visibility, e.g., removing snow in front of traffic sign within:	1 day	1 day	1 day
Visibility clearing at intersections within:	3 days	2 days	1 day

Shelters at bus stops should be cleared before 7 am, or no later than four hours after finishing plowing, or according to instructions.

Ice "patches" shall be removed before danger arises for the road user.

Salting (road grip and friction)

Salt and salt-solution (brine) should be used to improve friction. Other chemicals may also be used.

Action takes place as shown in the following table:

Tasks	Triggering criteria and maximum time for action in regard to different AADT		
	< 3,000	3,001 – 5,000	> 5,000
Preventive salting	If expected friction value < 0.4	If expected friction value < 0.4	If expected friction value < 0.4
After snowfall: Bare road before	6 hrs.	4 hrs.	2 hrs.

If the road for technical reasons could not be maintained according to "bare road strategy", it can for such periods be maintained as the highest class for "winter road strategy". During transition periods in spring and autumn, the road shall be maintained at one higher class (AADT) than the normal standard as shown in the table above.

Special winter works

Clearing after avalanche

Clearing and mending should be done as soon as it can be done safely.

Permanent repair should be done as soon as possible.

Standard maintenance specifications for pedestrian pavement, footpaths and bicycle-roads:

Plowing:

Pedestrian footpaths and bicycle-roads should be ploughed before 6 am. If snowfall between 6 am and 10 pm, plowing should start at snow-depth 3 cm.

Inclination of sidewalks (pavements) should be kept up during the winter.

Spreading

Pedestrian pavements, footpaths and bicycle-roads should be spread before 6 am or within 2 hours when friction is less than 0.3.

Pedestrian foot- paths and bicycle-roads could be divided into one spread half and the other half not spread, only after special instructions.

Rules regarding type & characteristics of material

Functional requirement

There are only requirements to the achieved result. It is up to the contractors to choose the ways and means to achieve the required winter standard on the roads.

Deicing products

Sodium chloride (NaCl) is used for chemical anti-icing and is used where the policy is "bare roads". Sand, gravel or crushed stones (maximum stone size is 6 mm) are used where the policy is "winter roads". Salting has been used on the Norwegian road network since before 1970 and is used today on about 8,000 km of the highway network. The last five years the total amount of salt used has been between 60,000 and 85,000 tonnes per year. The "winter road" policy is used on about 46,000 km of national and county roads.

NORWAY

Specification

The contractors can use NaCl for salting of roads. Other types of salt can only be used after approval by the NPRA.

Studded tires were until the late 1990`s commonly used. However, that has changed due to improved friction measures, better effects of non-studded tires and for environmental reasons. In Norway today 75% are using studded tires. The studded tires create dust and air pollution is measured throughout the day in five major cities. These measurements are used to make local restrictions if necessary. In the largest cities no more than 20% of the vehicles are supposed to use studded tires. The three larges cities have now nearly achieved their goal, and non-studded tires were used on 70% of the vehicles in the winter season 1999/2000. In two of the largest cities the users will have to pay a toll for the use of studded tires. This is a measure decided by the city councils to ensure that not more than 20% of the vehicles use studded tires.

During summer it is not allowed to use studded tires, and users will be fined. There are no penalties for the use of summer tires in winter. However, one will be penalized for not securing proper road-grip during the winter period. Winter speed limits have been tried out to reduce accident rates, and so far it has given satisfactory results.

There is a "law for the working environment" which gives allowed working hours and a "law for driving- and resting time" for professional drivers. The contractors have to obey to all the laws and if necessary apply for exceptions.

There are no specific standards for winter maintenance equipment; they have to follow the standard rules and regulations for each type of equipment. If needed the contractors have to apply for exceptions for snowplows and other equipment that are wider than the vehicle. The same goes for special headlight for trucks carrying snowplow. The maintenance vehicles have to use special warning light during operations, if they do not follow the traffic rules.

3.2 Organization and operation of winter maintenance

Organization of winter maintenance

The NPRA is responsible for;

- planning, construction, maintenance and operation of the national and county road networks;
- vehicle inspection and requirement;
- driver training and licensing.

The NPRA is under the leadership of the Directorate of Roads, which is an autonomous agency subordinated the Ministry of Transport and Communications. The NPRA encompasses 5 regional offices and 30 district offices. Since January 1, 2003, all construction, operation and maintenance of roads have been tendered and contracted after a competitive bidding procedure.

Cooperation with other levels of road management organization

For matters pertaining to national roads, the NPRA is under the direction of the Ministry of Transport and Communication. On those related to county roads, the Regional Roads Officer is subordinated the county legislature.

Operational management of winter maintenance

- The contractors are responsible for achievement of the maintenance standard and have to plan, inspect and take the necessary actions. The contractor cannot decide to close a road on his own. Roads can only be closed with the approval of the NPRA;
- The contractor must prepare and maintain a plan for winter operations. The plan should contain: Personnel, stand by teams, equipment, storing facilities, routes, prioritized roads, points of special attention, etc.;
- The contractors must keep a journal for all inspections and all enquiries received from the public. They should report each activity, all consumption of abrasives and salt and the number of plowing kilometers;
- According to the contract, drivers and operators of snow plowing and spreading equipment must undergo training before they can start their activities. The training is given by the NPRA.

Road closures and traffic restrictions

Most vehicles use studded tires. Due to air pollution (dust) there are restrictions for use of studded tires in the biggest towns. In Oslo there is a tax to pay for vehicles using studded tires. The tax in combination with information campaigns has reduced the use of studded tires to 20% in Oslo, but in rural areas the use is more than 95%.

All trucks, trailers and buses are obliged to carry chains with them if there is a risk of slippery roads.

Roads crossing mountains may be temporarily closed during snowstorms. Sometimes the vehicles can only pass in a convoy between two snowplow trucks.

NORWAY

Some roads crossing mountains are closed during winter. They will be opened in May or June. Sixteen national roads and 10 county roads crossing mountains are closed from the autumn until spring. Special equipment is needed to open a road that has been closed during winter. The layer of snow can be more than 4 meters thick. A special attachment for a snow cutter unit has been developed. The snow cutter is mounted on an excavator. The excavator has chains and can move on top of the snow and cut layer by layer. When the top of the snow can be reached from the road surface the unit will be shifted to a wheel loader for the last layers.

To open the closed mountain roads in summer a road finding system based on GPS has been developed; it works very well. It replaces the poles that have been used up to now.

Avalanches are a big problem on many roads alongside the coast and in the north. They can be closed in periods with danger of avalanche. In some cases NPRA provokes the avalanche by the use of dynamite. Contractors who are working on roads that are exposed to the danger of avalanches have to undergo special training given by NPRA.

Also some roads and bridges along the coast can be closed during storms. Some bridges are closed automatically when the wind reaches above a certain speed.

Road information provision method & system

Meteorological information

There is an agreement between the Norwegian Public Roads Administration (NPRA) and the Norwegian Meteorological Institute (met.no). Met.no provides NPRA with weather forecasts and climate data at a market value. It includes the following forecasts from met.no:

- Graphical prognoses for wind speed, wind direction, precipitation, air temperature, air pressure, dew point temperature and cloud cover;
- Written forecasts;
- Wind, temperature, and precipitation fields for ground level and 1,500 m above sea level;
- Weather radar images;
- Satellite images;
- Separate forecasts under special weather situations, like freezing rain.

These products cover the whole country and are provided on a regular basis throughout the year. NPRA also buys special products for parts of the country, for example special written weather forecasts for Oslo and special forecasts for polluted air in 5 cities during the winter season.

Besides the forecasts, a lot of historical data are bought for different projects. An example of that is the development of a winter index for Norwegian conditions, which requires a lot of historical data. Data are available both in tables and visualized on maps.

The forecasts bought on a regular basis are spread to the internal users via NPRA intranet and presented in a web-application for external contractors.

The graphic forecasts, the written prediction and the meteorological fields are updated three times a day. The radar images are updated every 15 minutes. The satellite images are updated four times a day.

NPRA has approximately 230 road weather information stations spread throughout the country. Most stations have sensors for:

- Air temperature;
- Relative humidity;
- Precipitation;
- Road surface temperature.

Some stations also have sensors for:

- Road surface condition;
- Wind direction;
- Wind speed;
- Long wave emission;
- Video.

Met.no also uses data from road weather information stations in two counties (approximately 23 stations) to provide these counties with forecasts through Vaisalas IceCast system (forecasts for road conditions).

As of today only the two counties using the IceCast system have access to forecasts on road surface temperature and road surface condition. It is highly desirable that all counties have similar forecasts. It is also desirable to have some kind of forecasting related to weather radar images.

- Forecast period: According to the above document, two of our counties have road weather temperature forecasts. There exists two different models in their system (IceCast); one has a forecasting period of 3 hours the other 24 hours. Since it's only few stations that are connected to such a forecasting system the total ratio is very low. In Rogaland where there are 19 field stations 8 of them are forecasting stations. In Oslo they have 3 stations and all of them are used as forecasting stations;

- The thermal maps were used to locate difficult areas. This knowledge was used to determine where to locate RWIS. The RWIS are located at places the road gets slippery before other places; early black ice or early snowfall. There are a couple of stations in each maintenance district;

- No special attention to resurfacing, as resurfacing is done during the warm season and is not supposed to be more slippery than the old surface that is replaced.

3.3 Assessment of the snow & ice control measures

There are several research and development projects every year. In 1991-1994 a nationwide study to examine the effect of road salting on traffic safety was conducted. The result showed that road salting reduces the number of police reported accidents by 20%. A study of the environmental effects of salt on the area surrounding the roads was carried out in the period 1992-1996.

Maintenance quality through competition of contractors

The contractor must report to NPRA if he has not achieved the requirement in the maintenance standard. The NPRA takes random inspection to see if the contractor has fulfilled the contract. The inspection will focus on the contractor's use of his quality system. If the performance is not according to the specification, a deduction in payment as a penalty can be demanded. The size of the penalty will depend on if it is a repeated problem, how serious the problem is, does it represent a danger to the road users, and how much money has the contractor saved by not doing the work.

The maintenance contract has to be won through a competitive bidding procedure. The contractors and their performance are evaluated by NPRA two times a year. The number of penalties is part of this report. This information can be used in the process of evaluating the tenders.

3.4 Traffic safety & information

Information provision to the road user

The Traffic Information Centers provide information twice daily to the media about road conditions and road closures in the mountains. This information is also available on Internet and text TV. The national radio stations give traffic information every morning and evening. Drivers can call 175 by telephone to get updated information about the road condition for special warnings the RDS radio will inform drivers.

The local radio stations very often have programs with a traffic theme at times when there is a lot of traffic on the roads. They give information about the traffic situation on the main roads and play music and give other traffic related inputs. These programs are quite popular. They are on the air morning and evening on weekdays, Sunday evening and in connection with winter holidays and Easter.

Systems improving traffic safety

The NPRA is responsible both for maintenance and road safety. The Traffic Department in NPRA is responsible for driving license, vehicle inspection and road maintenance. This department has the responsibility of investigating accidents and trying to reduce them. Assembling all these specialists on different aspects of traffic safety in one department allows for the efficient improvement of traffic safety.

The cost connected to winter maintenance is roughly 30% of the maintenance budget for the country. It is more in the north. Winter maintenance has a great importance for traffic safety. Traffic safety has top priority. If the winter cost is higher than budgeted, money will be taken from summer activities to compensate. The NPRA will conduct user's survey every year. They inquire the opinion of the user about winter maintenance and driving condition.

Use of weather related road sensors and variable road signs

A friction-measuring device which is fixed to the road and sending friction data via Internet is under testing. Some main roads with heavy traffic have variable signboard that can inform about traffic jam and alternative driving route. These roads are supervised by video cameras.

NORWAY

4. On-going Research and Studies to Improve Winter Management

4.1 New technology

Educational material for winter tasks has been developed and all contractors are trained. Today there are some projects going on with the aim to study:

- improved methods of spreading sand heated with hot water;
- the effects of salt and residual salt on one of the main trunk roads;
- effects of different salt types and salting methods;
- methods and equipment for measurement of friction;
- and an improved system for follow up of maintenance contracts.

4.2 New management and organization approaches

The management of road maintenance through contracts is quite new to the organization. The country is divided into 107 maintenance contracts. Each contract covers an area with a mixture of trunk, other national and county roads. The contract contains almost all operations and the most common routine maintenance. The first contracts that were won through competitive bidding started their work on the roads on September 1st of 2003. To educate the client's personnel, a special course was introduced. Thirty personnel are trained every 6 months. They are assembled 7 times receiving 3 days of training each time. The contract documents and follow up systems are revised and improved every year. The Road data bank is improved to better comply with the new situation.

4.3 Trans-national cooperation to improve levels of service between neighboring countries

Several visits and studies have been carried out to neighbor countries, and also to countries far away that have organized the maintenance in a similar way. The studies aimed to learn how they perform their role as, and to benefit from their experience with the purpose of adapting the best ideas into our systems. It is common for the Scandinavian countries to invite their neighbors to seminars and to share experience. The Nordic Road Association, which can be compared to PIARC, has put this into its system.

5. References

More information about Norway can be found on http://odin.dep.no.

The URL to DNMIs web site is: http://www.met.no.

SLOVENIA

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

Slovenia lies at the juncture of the Mediterranean, Alpine and Pannonian geographical areas as well as at the cross-point of the Roman, Germanic and Slavic language areas in Europe. Slovenia is a member of the EU from May 1, 2004. Since December 21, 2007, Slovenia has been a member of the Schengen area.

Its surface encompasses 20,273 km^2, 63% of which are covered by forests. Due to this, Slovenia is one of the countries in Europe with the most forests. 48% of its surface lies at an altitude higher than 500 m, which is characteristic for hilly areas.

Slovenia borders four countries: Italy (a 280-km border), Austria (a 330-km border) and Hungary (a 102-km border), all of which are members of the EU, and Croatia (a 670-km border).

In terms of political organization, Slovenia is a parliamentary republic. Its capital is Ljubljana. Currency in Slovenia from January 1, 2007 onwards EURO. In 2006, there were 2,008,500 inhabitants living in 5,996 agglomerations and 211 municipalities; 7.6% were farmers. Several nationalities live in Slovenia; however, most of the inhabitants are Slovenes (83.06%). There are two minorities in Slovenia: 0.32% of the total population is Hungarian and 0.11% is Italians.

The population density is 99.07 inhabitants/km^2. Economy: Gross National Product (GNP): 17,076 EURO/inhabitant.

Slovenia's natural resources are well preserved. There are 144,509 hectares of protected areas and natural parks:

- the Triglav National Park with 84,805 hectares;
- 9 nature reserves with 1,515 hectares;
- 4 regional parks with 5,168 hectares;
- 10 natural monuments, and;
- 25 natural landscape monuments.

NATURA 2000 includes a 36% portion of Slovenia.

On 29 April 2004, the Government of the Republic of Slovenia determined, with the Decree on Special Protected Areas (Natura 2000 areas), which areas in Slovenia would be part of the Natura 2000.

286 areas were identified; 260 of them were determined on the basis of the Habitats Directive and 26 on the basis of the Birds Directive. These areas extend over 36% of the surface area of Slovenia. Forests grow on most of the areas; however, there are large areas without vegetation (mostly cliff walls), 9% of the areas are above the tree line; an important portion is also grassland.

The protected areas (the Triglav National Park, regional and landscape parks, reserves and natural monuments) constitute 25% of the total surface of the Natura 2000.

SLOVENIA

1.2 Road networks and traffic

History of roads in Slovenia

Slovene transport routes developed some thousands of years ago due to Slovenia's geographical formations (Alpine, Pannonian and Mediterranean) as well as its location in the European region. Of course, man with his religious, social, economic and military tendencies played an important role in this development. Historical changes have affected the development of transportation routes.

As early as in the Stone Ages, the route from the Mediterranean along the Eastern Alps across the mountain threshold of Postojna and by the Ljubljansko barje moor in the direction of the Ptujsko polje flatland developed as the most convenient and direct longitudinal land transport axis, to which all transverse road routes have been connected. Later on, important long-distance trade routes led through Slovenia (Amber Road, Iron Route, Noricum Route and Salt Route); they complemented the road network and expanded it in new longitudinal and, especially, transverse directions.

In Roman times, the road network in this area was developed to a degree that satisfied the economic, commercial and military needs of the states which originated at later periods.

The medieval Slovene road network expanded on the foundations of the Roman network; nevertheless, the roads had an especially international and transit character, for there was no big trade centers in those times in Slovenia. After the Habsburgs had gained access to the sea, roads were increasingly developed in the Karst area.

Contemporary roads

The public roads in Slovenia are managed by the state and municipalities. The total length of the roads (as of December 31, 2004) is:

CATEGORY OF ROAD	LENGTH (km)
Motorways	576
Expressways	617
Expressways – 2 lanes	15
Major roads	598
Regional roads	4,897
Total state roads	6,703
Local roads	13,814
Public tracks	18,245
Total municipal roads	32,059
Total public roads	38,762

Besides the above-mentioned roads, the forestry service also manages 13,000 km of forest roads; these are, to a large extent, in public use.

Traffic loads on state roads

SLOVENIA

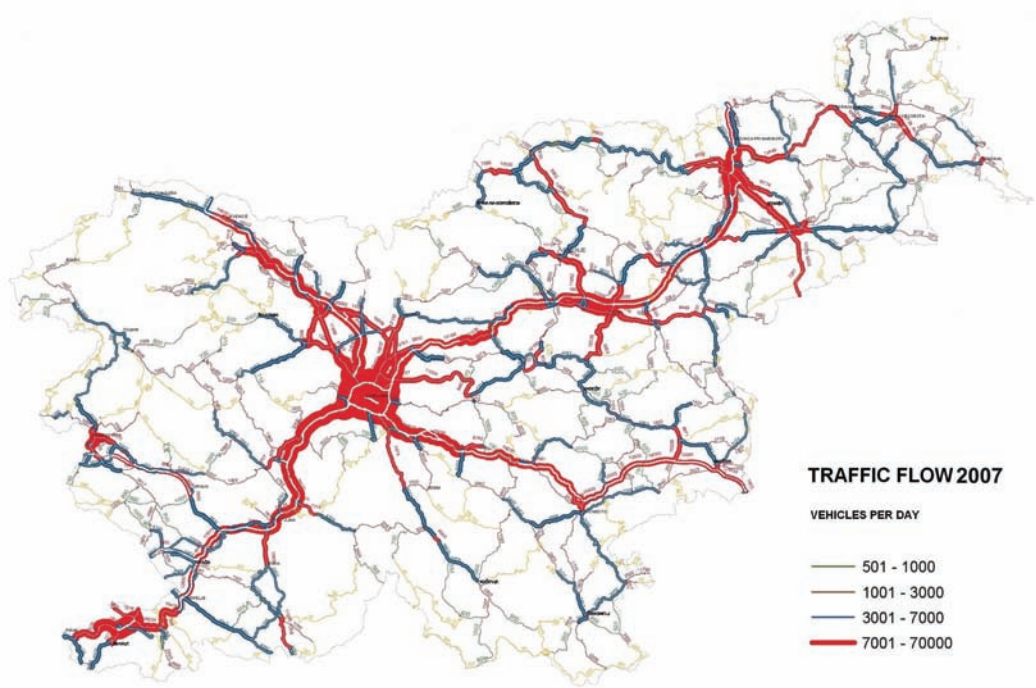
Traffic loads on Slovene roads are heavy, and they increase by around 3% per year. The biggest growth, i.e., 49%, was recorded in the 1992-1997 period.

The 2003 average daily traffic load on motorways was 22,616 motor vehicles per day. The portion of freight vehicles ranged from 10 to 20% on transit routes; the highest portion, namely 40%, was recorded on the routes in the direction to Hungary.

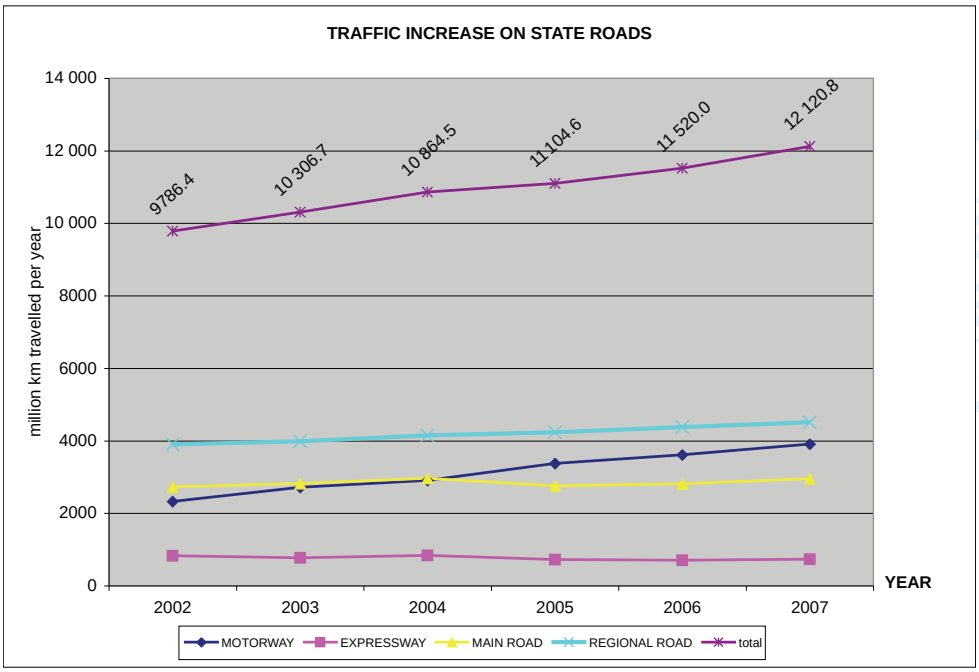
The motorization level has come to 1.3 cars/ household

YEAR	TOTAL	CARS
2004	1,151 758	938,166
2005	1,204 242	964,781
2006	1,235 297	985,567
2007	1,286 903	1,020,127

Registered motor vehicles



The 2007 traffic load map



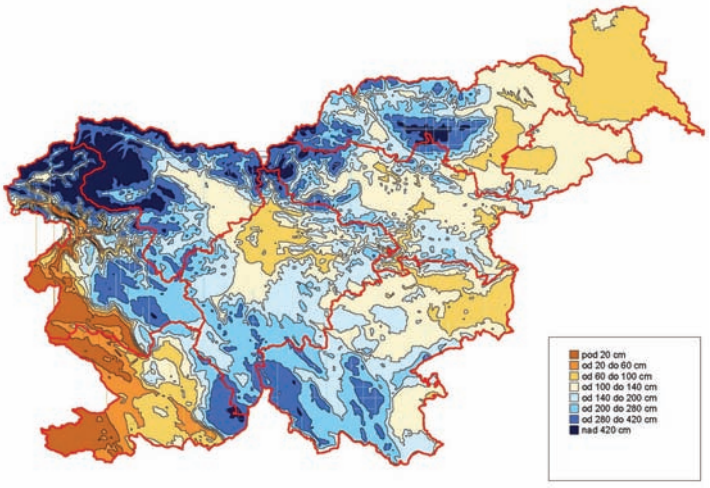
SLOVENIA

2. Climate

The unequal dispersion of population and the resulting branching of the road network are the reasons for extensive daily migrations. Therefore, roads, especially those with heavy passenger traffic, have to remain passable during the winter time, even in the early hours of the day.

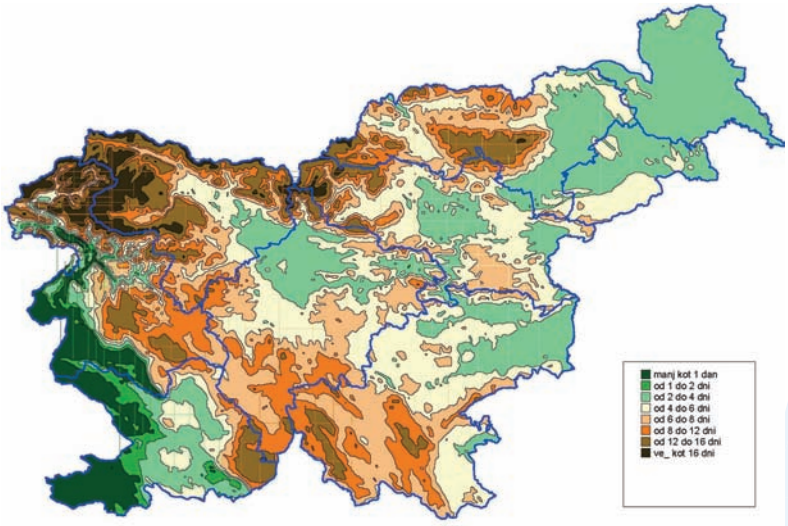
Because of Slovenia's position at the juncture of the Mediterranean, Alpine and Pannonian areas, its climate conditions vary significantly across the country; frequent daily and seasonal variations in temperatures and precipitation, causing variable road conditions, require from the road winter maintenance service frequent and quick response.

We can record substantial differences between the extreme western and eastern points of Slovenia, especially in the average number of days when the ground and roads are covered with snow.



Thickness of snow-cover

There are two such days (snow cover) in Primorje (the Slovenian Littoral) per year and 45 days in Postojna, which is 30 km from the sea. There are 50 to 70 such days in the lowlands and more than 100 in the highlands. An important data for the winter service is the average annual number of days with more than 10 cm of new snow; there are 15 to 30 days of such snow in the areas of both mountain barriers and 10 to 15 such days in the lowland areas. Primorje has special characteristics because snowfall is very rare; nevertheless, gale force winds, and sometimes also snow drifts, cause traffic problems.



Average number of days of snow-cover days

3. Winter road management

3.1 Standards and rules

Classification of the roads

The process of ensuring the passability of roads is carried out in accordance with six priority classes concerning:

- The category;
- The density and structure of traffic;
- Geographic /climatic conditions; and
- Local characteristics.

The passability of roads is ensured with regard to the priority classes:

Class 1: includes motorways and expressways, which must be passable 24 hours a day. When snowing, passability shall be ensured along the entire carriageway, as well as on important crossroads and access roads to larger car parks; however, emergency lanes also have to be passable. In the case of heavy snow, at least one carriage lane has to be passable, as well as access roads to larger car parks.

Class 2: includes major roads, major urban roads and important regional roads. These roads have to be passable between 5 a.m. and 10 p.m.; when snowing, two-hour traffic delays are permissible between 10 p.m. and 5 a.m.

SLOVENIA

Class 3: includes the rest of regional roads, important local roads, urban feeder roads and local roads, which have to be passable between 5 a.m. and 10 p.m.; when snowing, two-hour traffic hold-ups are permissible between 10 p.m. and 5 a.m.

Class 4: includes the rest of the local roads, urban roads and suburban roads. As a rule, these roads have to be passable between 7 a.m. and 8 p.m.; however, when snowing, shorter traffic holds-up are permissible. In the case of heavy snow, one-day holds-up are possible as well.

Class 5: includes public tracks, car parks and cycle tracks, for which the passability is ensured on the basis of local needs. When snowing, one-day holds-up are permissible, and in the case of heavy snow, holds-up may last even longer.

Class 6: includes roads closed for traffic in winter conditions.

The exclusion of freight vehicles from traffic

In accordance with the provisions of the Order on Traffic Restrictions on Roads in the Republic of Slovenia, freight vehicles with trailers and vehicles carrying hazardous substances are prohibited from driving on all Slovenian roads, when snowing or blowing hard, and they shall be excluded from traffic. On motorways and expressways, 25 locations in total are envisaged, at which vehicles are excluded from traffic; these locations have room for 950 freight vehicles; on other state roads, there are another 51 locations which can accept 1,990 freight vehicles. As a rule, these capacities are not sufficient, so occasionally, additional suitable areas are rented.

Rules regarding materials

The road gritting material, used in Slovenia, is sea salt (NaCl), and to a smaller extent also calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). The latter is mainly used for preventive gritting on motorways, expressways and major roads, and whenever there are low temperatures (-8 °C). In the last few years, roads have been sprayed also with a saline solution. In this way, salt is prevented from being blown off from dry roads under heavy traffic conditions and the response time for ice melting is shortened.

	MIN	MAX	AVER.	$CaCl_2$ portion
motorways	0.9	2.1	1.7	12%
other roads	0.6	1.85	1.34	0.6%

Use in kg/m_2

	GRITTING MATERIAL	EQUIPMENT PERSONNEL
motorways	1.75	13.25
other roads	3.10	13.2

The average costs for winter maintenance in the last ten years (in millions of EUR)

3.2 Organization and operation of winter maintenance

During the winter period, extending as a rule, from November 15 to March 15, roads are maintained in accordance with the winter service implementation program, which is prepared by the routine maintenance contractor, who submits it for acceptance to the specialist service at the latest by October 15th of the current year.

The winter service implementation Program includes:

- the organizational plan of management, competences and responsibilities of winter service operators;
- the schedule of preparatory works;
- the road network plan including the identification marks of priorities and starting points for the performance of winter services (road compounds);
- the allocation of machinery, equipment, gritting material and workers to implement the work planned;
- work crews on standby and available, level of preparedness and deployment schedules of work groups;
- snow removing plans and gritting plans for the prevention of ice formation;
- locations and methods of excluding particular kinds of vehicles from traffic in unfavorable road conditions;
- data collection methods and plan of informing the public on road conditions and passability.

The preparatory works are performed prior to the beginning of the winter period with the intention of ensuring efficient work of the winter road service. The works include in particular:

- the preparation of machinery, traffic signaling devices and equipment, gritting material;
- the preparation of roads and their surroundings (erection of supplementary signals at dangerous spots, placement of snow poles and other snow-drift protection devices);
- training and professional education necessary for the performance of winter road service.

After the end of the winter period, it is necessary to remove the remains of gritting materials (sand), as well as the temporary supplementary traffic signals, temporary traffic equipment, road devices and facilities for the protection of roads and traffic in winter.

3.3 Assessment of the snow and ice control measures

For some years now, the costs of winter maintenance for state roads have been rising; they come up already to approximately 50% of the total maintenance costs. At the same time, the use of salt is questionable with respect to the damage it causes to vehicles as well as to the environment, road facilities and groundwater.

It is not possible to stop salting completely, for traffic safety would be impaired. Replacing salt with sand materials is uneconomical and inefficient in regard to contemporary traffic. The economic benefits of using salt are several times higher than the costs and damages it causes.

In order to protect the environment, only that much salt is used as necessary for traffic safety; salt gritting of roads has been reduced to the minimum.

Up-to-date technical equipment and regular education of all participants in the winter road service are crucial for rationalization. The attitude of the technical staff towards the problems of maintenance has had to be changed as well. Modern equipment is also critical to ensuring quality maintenance. Clearing and salting have been optimized. Users are also obliged by law to use winter equipment on their vehicles.

What to do in the future

Analyses show that the fixed costs for road winter service, namely the costs for on-call and stand-by duty services, represent a large amount. To reduce these costs, a system is being introduced for monitoring road conditions at critical points and observing local weather conditions (road-weather station, video surveillance). It is being connected with the road-information system. Besides, up-to-date technical equipment is being introduced for calibrated dosing of gritting materials.

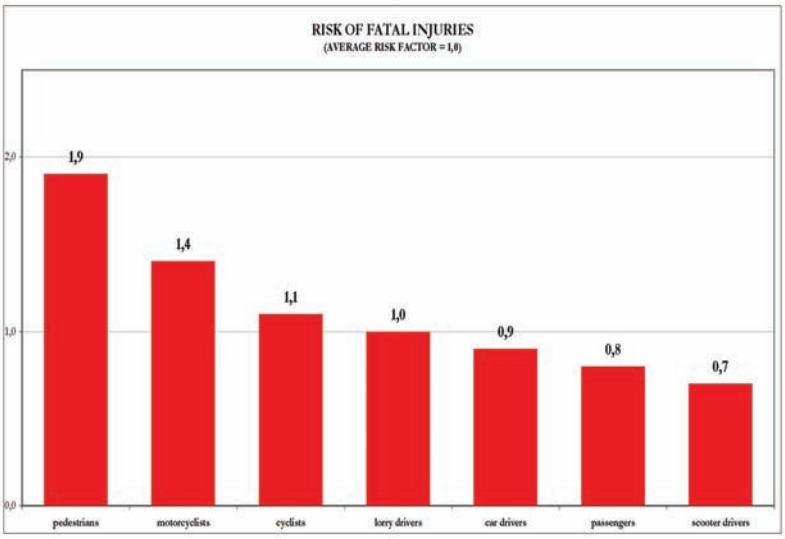
3.4 Traffic safety and information

Traffic safety

Traffic security in Slovenia is still not satisfactory. An analysis of the situation made for the needs of the preparation of the National Program for Road Traffic Security, showed that:

- 0.53% of fatal traffic accidents;
- 25.88% of traffic accidents with injures, and;
- 73.59% of traffic accidents with only material damage occurred during the 2007/2008 winter.

Road conditions and passability, as well as weather conditions and observing of regulations (e.g., on winter equipment for vehicles) exert a substantial impact on the occurrence of accidents and their increase in number.



Most of traffic accidents in winter occur in relatively good driving conditions; such accidents may end even with the worst results. These findings are based on the fact that most drivers are aware of the dangers of driving in winter conditions, but when conditions improve, they forget about the dangers and drive carelessly or even thoughtlessly.

SLOVENIA

The most frequent reason for traffic accidents in winter is improper speed, which is especially connected with favorable conditions on roads. The milder and drier the winters are, the bigger is the problem with speed.

The Ministry of Transport and, consequently road managers, are responsible for the below goals of the National Program for Road Traffic Security:

- Construction of the traffic infrastructure;
- Introducing measures to slow traffic down;
- Traffic education;
- Preventive measures and publicity actions;
- Surveillance.

Road users Information

During the time of winter maintenance, several methods of informing the public on road conditions are used:

- Radio and TV stations - in live;
- Telephone call to a specific number, directly via mobile appliances;
- Web pages of road managers and of the information center of the Automobile Association of Slovenia;
- Traffic data are communicated also to ERIC (European Road Information Center) at its registered office in Geneva;
- Through information portals on the roads;
- INFO-pillars at the rest areas along motorways;
- Personal advice at information centers.

In accordance with the provisions of the Public Roads Act and regulations on the maintenance of public roads, the road maintenance company has to report regularly and in special circumstances on the conditions and passability of roads.

A traffic–camera photo

4. On-going Research and Studies to Improve Winter Management

With the purpose of improving road winter maintenance and environment protection, several researches and studies have been made, such as:

- Quick and efficient methods to control the quality of ice-melting substances;
- Checking the possibilities of excluding freight vehicles from traffic in the event of strong wind conditions;
- The introduction of weather-road stations into winter road maintenance;
- Determining the basic hydro-geological criteria for increasing the active protection of groundwater in the case of pollution on the Slovene road network;
- Effects of road gritting on the environment;
- An analysis of the winter service organization and operation.

The conclusions of the studies could be summarized as follows:

- too many gritting materials are used which have negative impacts on road structures, vehicles, groundwater, vegetation and the health of people;
- the pollution (especially of waters) can be substantially reduced by introducing special facilities;
- damage to road structures and facilities can be reduced with appropriate maintenance.

Therefore, the Slovene road managers have employed wet salting, which results in a reduced use of salting materials; the materials used are purer and of higher quality with the least harmful agents possible. By using up-to-date machinery, by monitoring and timely informing road users on road conditions, we endeavor to foster winter road maintenance rationalization and environment protection.

SPAIN

snow and ice databook 2010

1. Demographics and Roads

Spain is a country in the South of Europe located in the Iberian Peninsula. Its extensive territory covers 505,954 km^2, bounded in the North by the Bay of Biscay and the Pyrenees, forming the border between Spain and France, in the East by the Mediterranean and in the West by Portugal and the Atlantic. The Straits of Gibraltar form Spain's southern boundary and constitute the point of greatest proximity between the continents of Europe and Africa (14 km). By 2008 Spain's population reached 45.3 million, representing a density of 89 inhabitants per square kilometer.

The relief of the Spanish Mainland is structured around a great central massif, known as the Castilian Plateau, covering virtually 50% of the country, standing at a substantial elevation and converting Spain into the number two country in Europe with the highest average altitude above sea level (660 masl) involving a significant East/West tilt. The waters of the Spanish Peninsula flow at different volumes into the three seas surrounding the country owing to the fact that the climate and above all the orographical features influence the distribution and importance of the hydrographical system, with the Atlantic receiving the largest inflow. The Plateau is subdivided into two sections by the central mountain chain and in its vicinity rise a number of mountain fringes encircling it except on the western side where the plateau tails gently off towards Portugal.

Spain constitutes a parliamentary monarchy, composed of seventeen so-called Autonomous Communities or Regions:

Andalucia	8.1
Aragon	1.3
Asturias	1.1
Balearic Islands	1.0
Canary Islands	2.0
Cantabria	0.6
Castile-La Mancha	2.0
Castile-Leon	2.5
Catalonia	7.2
Valenciana Community	4.9
Extremadura	1.1
Galicia	2.8
Madrid	6.2
Murcia	1.4
Navarre	0.6
Basque Country	2.1
La Rioja	0.3
Ceuta	0.072
Melilla	0.070

Numbers in million inhabitants

This political arrangement is similar to an organization of federal states. Spain's Regions possess a broad level of self-government involving legislative, budgetary, administrative and executive powers, guaranteed by the Central State to each Region through the corresponding statute of autonomy. Each Autonomous Community is in turn divided into one or more provinces, totaling 52 in all.

In administrative terms, the Spanish road network is organized under three different levels of authority, namely the State-run Road Network dependent on the Central Administration's Ministry for Development, the Regional-run Road Networks and the Road Networks and the Road networks run by County and Town Councils.

SPAIN

The State-run Road Network covers the national highways forming long-distance routes linking different regions. Regional Road Networks are regional in scope, as their name implies, while the road networks run by County and Town Councils are entirely local.

The different networks involve the following lengths of road:

Motorways		13,873 km
National Roads		15,407 km
Regional & Local Roads		137,060 km
	Total :	166,340 km

Spain's road network (main)

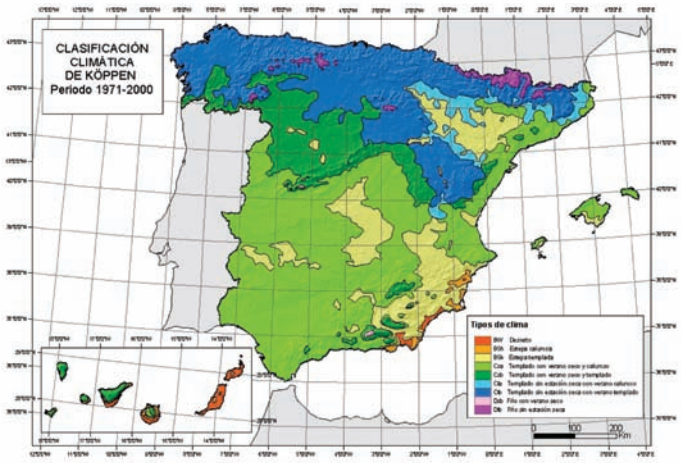
State-run Road Network	51.9% (17%)
Regional Road Network	41.8% (9.5%)
County and Town Councils Road Networks	6.3% (10.3%)

Traffic distribution in % (% heavy traffic)

2. CLIMATE

As can be seen on the map below, in accordance with the Köppen climate classification, in Spain we can distinguish nine climate zones:

In general, we can distinguish two winter climate zones (the coldest month has an average temperature under -3 ºC, and the hottest over 10 ºC). These correspond, on one hand, to the Pyrenees mountainous zones, some spots in the Iberico Range and the Cantabrica Range, which barely have a dry season and, on the other hand, to the Pentibetico Range (Sierra Nevada) and some small areas in the Central Range which have a dry summer.



The zones which correspond to warm rainy climates (the coldest month has an average between 18 ºC and -3 ºC and the hottest over 10 ºC) can be divided into four. The zone with no dry season and a warm summer corresponds to most of Galicia, Asturias, Cantabria, Rioja, the north of Castilla y Leon, the north of Aragon and Cataluña, zones north of Aragon and the lower part of the Pyrenees Mountains in Cataluña and most of the Iberico Range. The zone with no dry season but with a hot summer would be limited by the northern and southern borders of the Ebro depression, the interior of Girona and a zone to the south of the Iberico Range.

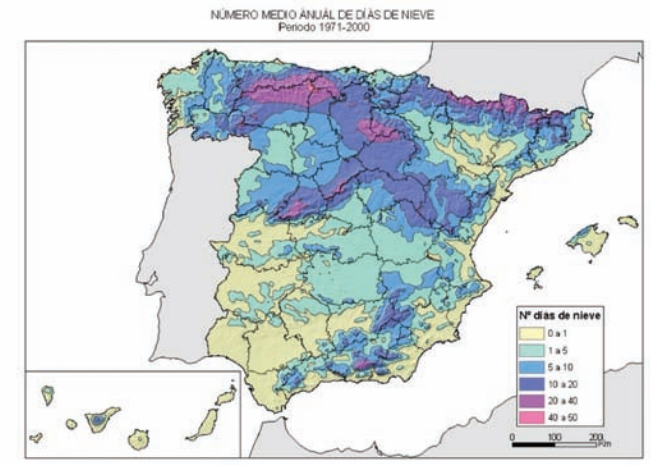
The zone with a dry and warm summer includes some areas in Galicia, most of Castilla y Leon and the Central Range, the southern border of the Central Range, the rest of the mountainous zones of the Penibetico Range and some regions of Cataluña; and also the islands of Palma, Gomera, Hierro, most of the island of Tenerife, and the middle zone of Gran Canaria. Lastly, the zone with a dry and hot summer is the southwest area of Castilla y Leon, Extremadura, most of Andalucia and Castilla la Mancha, Levante, the costal and lower mountainous area of Cataluña, the island of Menorca and most of Ibiza and Mallorca.

The Ebro depression, the Mancha, most of the southeast peninsula and the southern parts of the islands of Mallorca and Ibiza has a dry warm climate (evaporation superior to precipitation and average yearly temperature below 18 ºC). Areas in Almeria, Murcia, the interior of Gran Canaria, Fuenteventura and Lanzarote have a dry hot climate (annual temperature average over 18 ºC). Areas in Almeria, Murcia, and most of Fuenteventura and Lanzarote have a desert climate (evaporation greater than precipitation and a dry season in winter).

WINTER CARACTERISTICS

Winter presents some areas in Spain with abundant below freezing temperatures and snowy days. As you can see in the map below, some areas exist in Spain where it snows annually an average of 40 to 50 days in the reference period (1971 to 2000): areas of the Pyrenees, Cantabrica Range, Central Range, Iberico Range and Sierra Nevada Range. Around these zones extensive areas exist which have an average of 20 to 40 days of snow per year. Areas of note in this zone would be the cities and surrounding areas of Soria, Burgos and Ávila and some of the major highways.

SPAIN

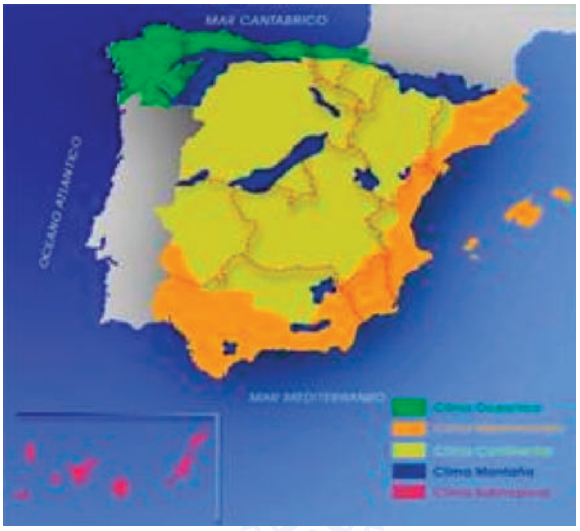


Number of days with snowfall

With respect to the number of days which have temperatures below freezing, the highest elevated zones of the Peninsula have around 150 to 250 in the reference period (1971-2000). In the areas which have between 75 to 150 days of freezing temperatures we can include Soria, Burgos, Avila, Teruel, Valladolid and Salamanca. The areas of Leon, Segovia, Cuenca and Albacete and some major highways have between 50 and 75 days of freezing temperatures. A large part of the principal highway network has sections within all the areas previously noted.

Atlantic Climate: Temperatures are mild all year long (average of 10 ºC to 20 ºC a year), the precipitation is abundant due to the influence of the humid air masses which come from the Atlantic. Galicia and the Cantabrica cornice pertain to this zone.

Continental Climate: Long and cold winters, and a mild summer in the north and warm in the south are characteristic of this climate (temperatures range from 25 ºC to -13 ºC). Precipitation is scarce and occurs during storms in the summer. The plain and the Ebro depression belong to this climate.



Mediterranean climate: Temperatures are high in summer and mild in winter. Precipitation is irregular (especially in Almería and Murcia). The Mediterranean zone, Atlantic Andalucian zone, Baleares, Ceuta and Melilla are part of this climate zone.

Mountain climate: Low temperatures with long and very cold winters, and short and warm summers. Precipitation is abundant and increase with altitude. The Pyrenees, Central and Penibético Ranges, some areas of the Cantabrica Range, Iberico Range and Grazalema are included in this zone.)

Note: Other climate classifications exist that use a classification similar to the one used by the French, but they are not the official classification of the Climatological Atlas. The material distributed by the Education Ministry can be consulted, but that it isn't the system used by the AEMET.

SPAIN

3. Winter Road Management

3.1 Standards and rules

The Directorate General of Roads belonging to Spain's Ministry for Development has powers extending to the technical and operational management of the infrastructure for the State run Road Network. This service is headed by the Subdirectorate General for Operation and Maintenance.

The strategies for executing the winter maintenance work commissioned to the Maintenance Services are stated in documents entitled Operating Plans, which are drawn up for each individual maintenance section and cover the scenarios likely to occur and the means required to tackle each one of them, with a view to achieving the desirable aim of restricting traffic disruption at most to the level corresponding to each road section affected as a function of the Service Level assigned to it.

Three Service Levels have been set up on the State-run Road Network taking into account two parameters: the maximum number of traffic disruptions permitted to occur and their maximum duration.

Service Levels 1, 2 and 3 are assigned to the road categories as described below:

Service level 1 (SL1):

- all toll-free motorways and expressways;
- conventional roads with an ADT of 5,000 vehicles and over, with the exception of mountain passes possessing alternative routes by motorway or expressway, assigned SL2;
- access routes to major skiing resorts;
- all provincial capitals and towns with a population of over 20,000 through which one of the State-run Network roads runs must be connected to the main-road network (assigned Service Level 1) by at least one SL1 road;
- both for this service leve1 and the next, SL2, an attempt will be made to provide the same service level on al1 road sections along the same route so that the level of service does not vary from origin to destination.

At this service level, blocking the road or cutting off circulation to all vehicles due to the existence of snow or ice on the road is not permitted. For this purpose, the actions to be taken will be cutting off circulation to heavy vehicles and restricting the passage to light vehicles with snow chains, when necessary, minimizing restriction time.

The maximum length of time for cutting off heavy weight vehicle traffic or restricting the circulation of light weight vehicles with snow chains will be for the duration of the snowfall plus 2 hours.

Clearing road margins must be done no later than 6 hours after the end of the snowfall.

Service level 2 (SL2):

- conventional roads with an ADT ranking from 1,000 to 5,000 vehicles;
- all access routes to provincial capitals and towns with a population of over 20,000 are assigned at least SL2;
- all towns with a population of over 4,000 through which a State-run Network road runs must be connected to the main-road network (assigned Service Level 1) or to the secondary network (assigned Service Level 2) by at least one SL2 road.

For this service level, one situation of blocking the road and one of cutting off traffic to all vehicles will be admitted annually. For this purpose, cutting off traffic circulation to heavy weight vehicles and restricting circulation to light weight ones with snow chains will be applied when needed, minimizing restriction time.

The maximum period of time for cutting off traffic to heavy weight vehicles or restricting it to light ones with snow chains, will be for the duration of the snowfall plus 4 hours.

Cleaning of roads margins must be done no later than a day after the end of the snowfall.

Service level 3 (SL3):

- The remaining conventional roads, except for mountain passes bridging two provinces or comprising the only link between towns with a population of over 2,000 must be assigned at least SL2.

SPAIN

At this service level, disturbances caused by snow are allowed when, due to the intensity of the snowfall, it is necessary to take actions to assist the needs of the roads with a higher service level.

In any case, in the State Road Network, the existence of ice on the road that causes traffic disturbances is not admitted.

The quality of service is based on the degree of compliance with the Operational Plan. Considering the service conditions established in the conservation contract, the performance of the contract is faulty when the established service levels are not reached in the different roads object of the contract.

Nor have any fixed rules been set in respect of the characteristics of the materials or equipment used as these characteristics are defined in each individual Operating Plan and are adapted to the particular features of each road section.

In general, for the execution of the works assigned to the maintenance of the winter road network, frontal shove snowplows, and in some cases, also side ones, with solid deicer, solid-humid or brine spreads are used. In some mountain areas dynamic snowplows are used. The most commonly used emulsifiers are sodium chloride (salt) and in some cases, mixed with calcium chloride. Nowadays, the most used treatments are brine deicers.

3.2 Organization and operation of winter maintenance

Winter maintenance on Spanish roads is the responsibility of the Road Maintenance Services belonging to the relevant road authority.

In approximately 40% of the Spanish road network, continued interventions are needed for the maintenance of the road network during the winter.

Public-Private partnership

Virtually all of the authorities responsible for roads outsource part of their maintenance tasks to private firms which carry out the maintenance work on the majority of the infrastructural elements involved, generally including winter maintenance tasks.

The road network of the state is currently divided in 168 sectors. The conservation of these areas is contracted with private companies, according to the Technical Specifications Document that gives rise to the contest by which it is awarded, making human and material resources available to carry out the maintenance contract and amongst which all the operations related to the winter road network are found.

On the State run Road Network, management of the resources used to carry out the tasks required to maintain winter serviceability is defined in the so-called Operating Plans covering the procedures for action and the work system for all tasks related to each section's winter maintenance. The Plans are drawn up to comply with the instructions laid down in a Service Note issued by the Spanish Directorate General for Roads.

The Private Companies, in order to the Operating Plans, are in charge of the turnouts and they also play a role in the intervention decision. In fact, there are toll roads fully managed by concessionaires.

These Operating Plans are passed by the management team in charge of each contract and are revised annually, tailored to the new needs arising and ready for application in the following winter season.

A significant part of this annual revision relates to the inclusion of the experiences deemed important for improving the service, such as the application of new technologies or specific improvements to the work techniques employed.

The Operating Plans for each section must at least cover the following information:

- Personnel and machines assigned to the section (snow-clearing trucks, self-propelled snowplows and de-icer spreaders, etc.);
- De-icing agents (barns and deposits existing in the particular section and its vicinity and brine production plants, etc.);
- Policy and procedures for transmitting data (communication systems between bases and vehicles plus weather forecast and other types of data transmission);
- Organization of preventive tasks (itineraries established, schedules and inspections, etc.);
- Organization of corrective tasks (equipment location, itineraries, alternative routes, particular trouble spots and areas for parking vehicles, etc.).

Cooperation with Directorate for Traffic and for Civil protection

Part of the Operating Plans deals with coordination with other government agencies holding powers affecting winter maintenance, which are the Directorate General for Traffic and the Directorate General for Civil Protection, both dependent on the Spanish Ministry of the Interior.

SPAIN

The Directorate General for Traffic plays an extremely important role in winter maintenance as its powers include traffic regulation on roads and motorist enforcement of the current regulations on vehicle circulation. Whenever roads are affected by snow and ice, this agency is responsible for enforcing the traffic restrictions imposed, such as the mandatory use of chains or the mandatory stopping of a particular class of vehicles.

The decision to impose traffic restrictions (cut off traffic or use of snow chains) belongs to both the General Roads Directorate and the Department of Transportation. In case of traffic blocks, attention of affected users corresponds to Civil Protection Services.

To organize coordination between the different Government strata responsible for snow on roads, Provincial Protocols are written that are developed from National Protocols regarding "Coordination of the General State Administration, in case of snowfalls and after extreme weather conditions that can affect the States National Roads network", where the approach to be taken in each situation is defined.

Road weather information

Information on weather forecasting is carried out by the Meteorology State Agency (AEMET) through the issuance of bulletins and a daily prediction of adverse weather when snowfalls that exceed determined thresholds are expected.

The Directorate General for Traffic is installing weather station network in order to know the weather conditions on the roads. This weather information is transferred to motorist by variable message panels and is also available in Internet.

3.3 Traffic safety and information

The Government Delegation or Sub-delegation in each province is responsible for providing information to motorists and the media in the event of snowbound conditions.

Supplying Information to Motorists

The Directorate General for Traffic, dependent on the Ministry of the Interior, is responsible for keeping motorists and road users informed.

At the present time motorists have different sources available for accessing information on the condition of roads.

On the one hand, general information is broadcast on the different radio and TV stations operating and also published in the written press. On the other hand, real-time data specific to a particular road are put out by the Traffic Management Centers on variable message panels located on the actual roads and, finally, provided verbally on the spot by officers of the Spanish Traffic Police Force (*Guardia Civil de Tráfico*) who, as well as regulating the movement of vehicles, set up controls to enforce the use of tire chains in the event of bad weather conditions.

In addition, the Department of Transportation has established 4 levels that determine which is the degree of difficulty that a driver can find traveling on a particular stretch of road that is being affected by snow or ice. In these conditions, traffic has been classified in 4 difficulty levels.

- Green: It begins to snow. This color identifies a road stretch where it has started to snow and traffic is not affected. Speed recommendations are set (100 km/h on motorways and expressways and 80 km/h on other roads). The trucks must move in the right lane and cannot pass other vehicles;
- Yellow: Snow on the road. The road starts to cover with snow. Trucks are not permitted to circulate, and light weight vehicles and buses cannot exceed 60 km/h;
- Red: Road covered with snow. Circulation is only possible using snow chains and not exceeding 30 km/h. Circulation of trucks and buses is prohibited;
- Black: Thick snow or ice on road. The road is impassable to all types of vehicles and there is a high risk of being immobilized for an indefinite period.

Systems for Enhancing Driving Safety

The improvement of driving safety on roads is backed by the maintenance and conservation of the state of the road and in addition by the Traffic Management Centers supplying motorists with information on the state of roads affected by bad weather.

The information supplied is based on obtaining and recording the parameters relating to meteorological conditions and the condition of the roads, modeling them and subsequently issuing the relevant information via the means quoted in the preceding paragraph.

Use of Sensors and Variable Message Panels

Knowledge of the state of a road affected by bad weather conditions is one of the activities under security via the agents commissioned to carry out maintenance and conservation tasks and members of the Traffic Police.

Variable message Panels

As from the year 2000, the first year weather parameter recording sensors (SEVAC) were installed on roads, their use has made it possible to know about, register, assess and model the capacity of the different weather parameters recorded, meaning that the actions carried out and their duration and purpose can be rated and confirmed.

In addition, information on the capacity, location and condition of the roads is publicized in the form of messages on the variable message panels. Almost 600 km of highways and expressways on the general road network plus a further few special kilometers on the regional network are covered by variable message panels.

Motorist Information Technologies

All types of technology are employed, whether based on audiovisual means, Internet or personalized receipt of facts via telephone calls and SMS text messaging. Ad-hoc information points are also available for particular spots on exceptional sections or routes.

4. On-going Research and Studies to Improve Winter Management

4.1 New technologies

As from the year 2000, all the machinery involved in winter maintenance work on the State-run Road Network has gradually been fitted with GPS locating systems which, connected to the control centers by mobile telephone, are used as an aid to fleet management for the snow-clearing machines. In addition to supplying real-time positioning of every vehicle, the system installed comprises several sensors on board the de-icer spreaders and snow-clearing blades to provide precise knowledge of the type of work each machine is performing. The data supplied by the GPS and the different sensors on board the vehicles are stored in a data base thus providing the possibility of creating a large range of reports on the tasks actually carried out.. This system has proved to be extremely useful as it enables the actual episodes experienced to be studied and conclusions drawn with a view to improving the service provided.

In respect of the infrastructure, automatic equipment for spreading liquid de-icing agents has been installed as a system for preventing the formation of ice on roads. The use of these systems has important advantages for those singular points that are affected by extreme temperatures or humidity and require special attention. Today its major drawback is the high cost of deployment and maintenance.

4.2 New management systems

Winter maintenance management is reviewed after each season in order to correct any defects found in the preceding campaign and to propose improvements designed to provide a better service to motorists and road users during forthcoming winter seasons. In recent seasons, it has been proven that the effectiveness to avoid or reduce the number of stretches with traffic restrictions or delays and the length of these, is to block truck circulation in stretches that have difficulties due to heavy snowfall. These restrictions are carried out trying to stop trucks in the less time possible, intensifying the work of snowplows and obtaining better output during the clearing of the snow. Nowadays, the State Road Network is implementing a Plan for the construction of emergency car parks for heavy weight vehicles which considers the construction of 56 car parks where it will be possible to store these vehicles in case of road problems both during the winter season as well as during the rest of the year.

4.3 Trans-national cooperation

Spain participates in the SRTI Project which provides motorist information services, cooperation for cross-frontier traffic management and equipment for data exchange and traffic management, etc. in order to enhance safety and comfort and convenience on the roads linking Germany, France, Spain, Italy, Switzerland and Andorra.

5. References

Data relating the climate has been provided by the Meteorology State Agency (AEMET) of the Ministry of Environmental and Rural and Marine Affairs.

SWEDEN

snow and ice databook 2010

1. Demographics and Roads

Area	Total	410,929 km² Mainly forest Fields 8%, Lakes and rivers 9%, Cities 3%
Population	Total	9.3 million
Road - Length - Vehicle km	Total trafficable by car	420,000 km
	Open to the public	210,000 km
	State Roads Including Motorways	98,400 km, 50 billion vehicle km 1,800 km
	State Cycleways	2,200 km (uncertain)
	Municipal Roads	40,000 km, 25 billion vehicle km
	Municipal Cycleways	11,000 km (uncertain)
	Private Road (Subsidies)	75,000 km
Number of vehicles	Private cars	4.3 million
	All road vehicles	4.8 million
Latitude (capital)	59 º 20' North	Sweden covers almost 55–70° N

2. Climate

All statistical data is calculated from a 30 year period at the Swedish Meteorological and Hydrological Institute (SMHI). The following 15 years are warmer than in the table. Through its elongated form in north-southerly the temperature climate in the south differs considerably from that in the northern parts.

The Gulf Stream makes it much warmer than in other parts of the world on the same latitudes (between 55° and 70° North). In southern Sweden the winter period is about four months and in northern Sweden about seven months.

In climate change scenarios the temperature could increase by 5 °C during winter, in the north coastal areas the increase could be one or some degrees more and in the south coastal areas one or some degrees less.

Winter Climatic Zones

	Snowfall in cm during 1961–1990		
	Daily maximum snowfall	Maximum snow depth	Cumulative depth of snowfall
Kiruna	26	132	243
Luleå	30	111	233
Östersund	31	100	251
Stockholm	27	60	153
Göteborg	28	52	131
Jönköping	27	102	225
Malmö	26	38	113

Daily minimum temperature (°C). Average 1961-1990						
Oct	Nov	Dec	Jan	Feb	Mars	April
-4.6	-12.2	-13.7	-18.8	-17.6	-13.9	-8.0
-0.6	-8.0	-14.3	-17.0	-16.0	-11.2	-4.0
1.2	-4.9	-9.6	-12.8	-11.6	-7.7	-2.7
5.3	0.7	-3.2	-5.0	-5.3	-2.7	1.1
6.5	2.1	-1.4	-3.2	-3.5	-1.0	2.4
3.1	-1.2	-5.1	-6.6	-7.3	-4.6	-1.1
6.7	2.8	-0.8	-2.5	-2.5	-0.5	2.4

3. Winter Road Management

3.1 Standards and rules

Legal obligation

According to the Swedish constitution the Swedish Road Administration (SRA earlier SNRA) is responsible for the road transports system and must work for attaining the objectives of the transport policy. The SRA must especially work for securing that the road transport system is available, accessible and effective and that it contributes to the regional balance. The SRA must also work for adapting and designing the road transport system according to high demands on environment and traffic safety. In one paragraph of the "Road Statute" it is stated that road operation includes the removal of snow and ice and taking actions against slipperiness to such a degree that the road is kept accessible to existing traffic, both vehicles and pedestrians.

Classification of roads according to level of winter serviceability

The winter maintenance on the state roads in Sweden is carried out according to the "*General technical description of road operation service levels during winter. Winter 2003*" (VV Publ 2002:147 and 148).

Definitions

Roadside facility

A roadside facility refers to an auxiliary surface where a vehicle can be parked outside the roadway.

Friction

The friction coefficient shall be determined in accordance with the SNRA Methods Specifications 110:2000, Friction Measurement on Winter Road Surfaces. (Retardation measurements with Coralba or similar).

Unevenness

The unevenness on thick ice or compacted snow roads shall be measured using a 60 cm long straightedge. This applies both in the longitudinal and transversal direction of the road as well as at an adjoining state road. The straightedge shall rest on two ridge points or between a ridge and the road surface, whereupon the measurement is taken at a right angle to the straightedge.

SWEDEN

Snow depth

The snow depth shall be calculated as an average value on an area that is 1.0 x 1.0 meters. Every cm of slush is calculated as 2 cm of loose snow.

Materials De-icing/Anti-icing

NaCl (rock or sea salt) is the only salt used for de-icing/anti-icing. The NaCl should be 97% pure and must not contain more than 100 g of Potassium or Sodium Ferro cyanide per tonne NaCl. A gradation curve is specified and the maximum allowed grain size is about 3–4 mm.

The material normally used for mechanical de-icing is sand, 0-8 mm, mixed with about 3 percent by weight salt. On roads with speed limit above 70 km/h the maximum allowed grain size is 4 mm. The salt is added primarily to facilitate the storage of sand in cold weather and partly to improve its adhesion and durability.

Crushed stone aggregate, usually of 2-5 mm fraction, has been used for several years mostly in urban areas. Crushed stone aggregate, 2 – 4 mm, is used for pedestrian and cycle paths. No addition of salt is needed.

Standard classes

The choice of standard classes for a certain road network is done according to the following recommendations given in the technical description:

Traffic flow, AADT	Winter standard class
≥ 16,000	1
8,000 – 15,999	2
2,000 – 7,999	3
500 – 1,999	4
< 500	5

Standard classes 1–3

Cross-sectional elements	Requirements during precipitation/Action time after precipitation				
	Trigger value		Action time in hours		
	Snowfall	Rain	Standard class		
	Loose Snow depth (cm)	Friction (μ)	1	2	3
Traffic lane	1	0.30	2	3	4
Side shoulder	1	0.25	4	6	8
Roadside facility	1	0.25	4	6	8

Cross-sectional elements	Dry weather requirements when action time after precipitation has expired			
	Road surface temperature			Evenness (cm)
	Warmer than -6 °C friction coefficient	-6 °C to -12 °C friction coefficient	colder than -12 °C friction coefficient	
Traffic lane	Snow and ice-free	0.35	0.25	1.5
Side shoulder	0.25	0.25	0.25	1.5
Roadside facility	0.25	0.25	0.25	1.5

Standard classes 4–5

Cross-sectional element	Dry weather requirements when action time after precipitation has expired							
	Trigger value				Action Time			
	Loose Snow depth (cm)		Friction coeff. (μ)	Eveness (cm)	Snow depth/friction hours		Evenness hours	
	Standard class				Standard class		Standard class	
	4	5			4	5	4	5
Traffic lane	2	3	0.25	1.5	5	6	48	72
Roadside facility	2	3	0.25	1.5	8	8	48	72

Cross-sectional element	Requirements during precipitation/Action time after precipitation				
	Threshold value			Action time in hours	
	Snowfall		Rain		
	Loose Snow depth (cm)		Friction coeff. (μ)		
	Standard class			Standard class	
	4	5		4	5
Traffic lane	2	3	0.25	5	6
Roadside facility	2	4	0.25	8	8

SWEDEN

"High" and "Normal" standard class for pedestrian and cycle paths and prioritized bus stops

Dry weather requirements when action time after precipitation has expired					
Trigger value		Action time/friction hours		Action time/evenness hours	
Friction	Eveness	Standard class		Standard class	
Friction coeff. (μ)	(cm)	High/P	Normal	High/P	Normal
0.30	1	1	2	2	4

Cross-sectional element	Requirements during precipitation/Action time after precipitation			
	Trigger value		Action time in hours	
	Snowfall	Rain		
	Loose Snow depth (cm)	Friction coeff. (μ)	Standard class	
			High/P	Normal
Traffic lane	2	0.30	2	4

A new strategy for reduced use of salt in winter road maintenance since 2004

Environmentally Adapted Winter Road Management shall ensure that the Swedish Road Administration (SRA) maintains high accessibility to the road network and traffic safety while minimizing the use of salt in winter road maintenance in a way that meets the demands of citizens and the business community. The strategy shall be compatible with prevailing environmental standards and SRA's ambition to be an environmentally aware, efficient road manager that puts the customer first.

SRA has worked actively for the last 15 years to limit the use of road salt in winter road maintenance. An investigative committee called "MINSALT" formed in the early 1990s a recommendation that:

- Roads with less than 2000 AADT should not be treated with salt, except during autumn and spring.
- Increased use of brine, especially for preventive actions.
- Improved weather forecasts.
- Improved equipment for snow removal and ice control.

Even if not all findings have been fully applied in all parts of the country the total salt consumption in Sweden may be considered low from an international perspective, but there is still reason to believe it can be further reduced. Examples of other actions taken over the years include physical protection of especially vulnerable water sources.

Objectives

Salt Consumption

The objective is to maintain high accessibility to the road network and traffic safety while minimizing the use of salt. A salt index shall be used to measure accomplishment of the objective. During the 2006/2007 winter season and subsequent years, no operational area shall have an index greater than 1.0 (see 3.3).

Water

The objective is to reduce and eventually eliminate palpable negative impact from road salt on large water sources that supply more than 50 people. This objective shall be met by year-end 2007.

3.2 Organization and operation of winter maintenance

Organization

In 1991, the Swedish Government passed a decision that the design and construction of new roads, as well as all road operation and maintenance works within the state road transportation network, were to be contracted through competitive bidding. This entailed major changes at the SRA. From having been a traditional central government agency, exercising the role of public authority while simultaneously carrying out construction and maintenance works in-house, the SRA was to be divided into a client / contractor organization. In addition, it was stipulated that the contracting arm of the organization was to function like a private contractor, i.e., that it was to be subject to competitive terms on the open market and furthermore required to show a profit for its owner.

Requirements

Co-ordination

The contractor shall plan and co-ordinate his undertakings with those performed in the adjoining areas to ensure continuity in road surface conditions. Contact shall be made with contractors in adjacent areas to co-ordinate snow clearance and skid control measures.

Level of service

The requirements must always be fulfilled, except when weather conditions are so severe that it becomes impossible to meet the action time limits. The client (SRA) shall be notified when such severe weather conditions prevail.

SWEDEN

Operative actions

Sweeping and sand collection shall be carried out so that neither road users nor the surroundings are subjected to dust.

Forms of payment

Form of payment used at present is unit-price payment based on weather data statistics. In order to reduce salt consumption there is a bonus and fine system.

Finance

Twenty-five percent of the SRA appropriation for road maintenance and operations, a total of almost SEK 1.8 billion (US$ 220 million), is spent on snow plowing, skid control and other winter road maintenance works. Of this sum, approximately 50% are fixed costs, i.e., for stand-by, truck stations, storage facilities, etc.

There are 132 maintenance contract areas, covering the state roads, in Sweden. The maintenance contract areas comprise between 600 and 1,000 kilometers of road, centerline. This size has proven sufficient to be financially viable for contractors. In total here is 2,600 plow trucks contracted, which gives an average of 37.7 km per plow truck. In addition there are graders and agricultural (farming) tractors used. Agricultural tractors are used mainly in pedestrian and cycle paths.

Competitive situation

In 1992, the first competitive procurements of basic routine maintenance occurred. Since that year, the competitive procurement of maintenance and operation works has steadily increased and since 1999, 100% of the road network is under competitive bidding. There are basically four contractors that compete for road contracts in Sweden. In beginning of 2009, the division of contractors by km is; Svevia (state owned) 58%, Skanska 10%, NCC 15% and PEAB 14% and others 3%. In the most northerly and southerly parts of Sweden, a couple of smaller contractors have managed to enter the market, having been awarded four areas all in all.

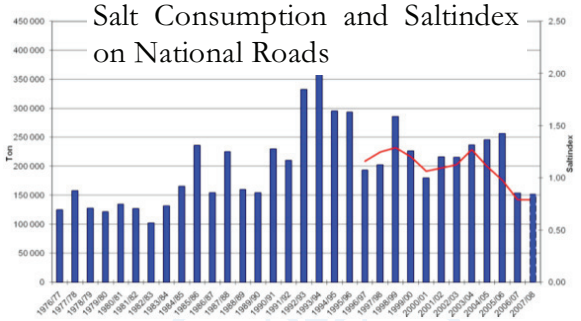
3.3 Assessment of the snow and ice control measures

Winter Indexes

During recent years an experimental work has begun calculating a number of winter indices starting from weather situations. Mean values are calculated for each month and for each county. Representative RWIS stations and MESAN scaled weather data are chosen for each contract and values for SRA region are given.

The weather index describes the number of occasions with slipperiness, snow and snowdrift, respectively.

The salt index describes the actual salt consumption (kg/km) compared to the recommended use of salt (kg/km) for each type of weather situation. A value > 1 means more salt than recommended, and a value < 1 means less salt than recommended.



Training and education

All foremen, i.e., those who take the decisions about winter maintenance actions, must have a certain education and training given by the SRA Road Sector Training and Development Center.

Weather Information provision

RWIS Field stations

Sweden has more than 700 field stations all over the country connected to the RWIS. The stations are equipped with sensors for measuring air and road surface temperature, humidity, amount and type of precipitation, and wind. Dew point temperature is also calculated and delivered for every station. Some stations are also equipped with cameras.

Meteorological information

During the winter season (1st October – 30th April) the Swedish Meteorological and Hydrological Institute (SMHI) delivers radar and satellite information 24 hours a day to the RWIS. Every half-hour, images from the Nordic radar network in different scales are distributed to the RWIS systems central computer.

From the geostationary Meteosat satellite and the orbiting satellite NOAA weather coded images are sent at least every hour to the RWIS system.

Weather maps with comments are updated twice a day, at 01:00 and 13:00 hours. All day and night special cloudiness forecasts are produced for a combined statistical and energy model that every hour predicts the road surface temperature for the next two hours.

Internet

The information from the field stations and from SMHI are collected and compiled at an information center at the head quarters of SRA and can then be obtained via the Internet. (See example from www.vv.se)

Measurements of Efficiency

Internal

Both the SRA and the municipalities follow up the consumption of salt and abrasives.

External

The road user's satisfaction with winter maintenance is surveyed by the SRA every year. The road users are divided into two categories: private and professional drivers.

Road condition

In the most southern region of Sweden the biggest roads have ice and snow condition about 5% of the wintertime (4 months) and the smallest roads 40%. Up in the northern region the corresponding figures are 20% and 70-80% when the winter is 7 month long.

Environmental impact

The main part of the de-icing salt used on the roads will leave the road as run-off or be deposited within some tens of meters but still some amount may be transported further away from the road. The deposition pattern depends on: amount of salt used, intensity, type and speed of traffic, type and amount of precipitation, direction and speed of wind.

The sodium ion participates in ion exchange reactions and is to some extent retarded in soil and groundwater, whereas the chloride ion is conservative and highly soluble. Since the chloride ion is not subjected to retardation or degradation it is a good tracer. If chloride from de-icing salt can be found in a well or in surface water, there is a substantial risk that other pollutants may also be present. Increased chloride concentrations have been observed in both municipal water supplies and in private wells close to roads. Furthermore, the chloride concentration has been observed to increase in lakes in Sweden with concentration peaks during spring. The roadside exposure to de-icing salt may change the species composition of vegetation and also influence the growth conditions and aesthetically appearance of trees.

Other pollutants from the road and traffic related especially to winter-traffic are metals from corrosion of vehicles, wear of road surfaces and tires. The fear about wear-particles has increased the last decade.

3.4 Traffic safety and information

Information to road users

All operation centers have to report at least 3 times a day to the TIC (Traffic Information Center) and also every time there is a change in road condition (e.g., after a turnout). The information is then distributed from the TIC in different ways:

- Radio: Local radio stations get information from the TIC;
- Newspapers;
- Internet: A map showing the present road conditions can be found at the home page of SRA (see example from www.vv.se);
- RDS-TMC for real time road condition data for in-car navigators etc.;
- Road users can also call the TIC to get information.

In some places there are traffic signs showing road surface temperature and air temperature.

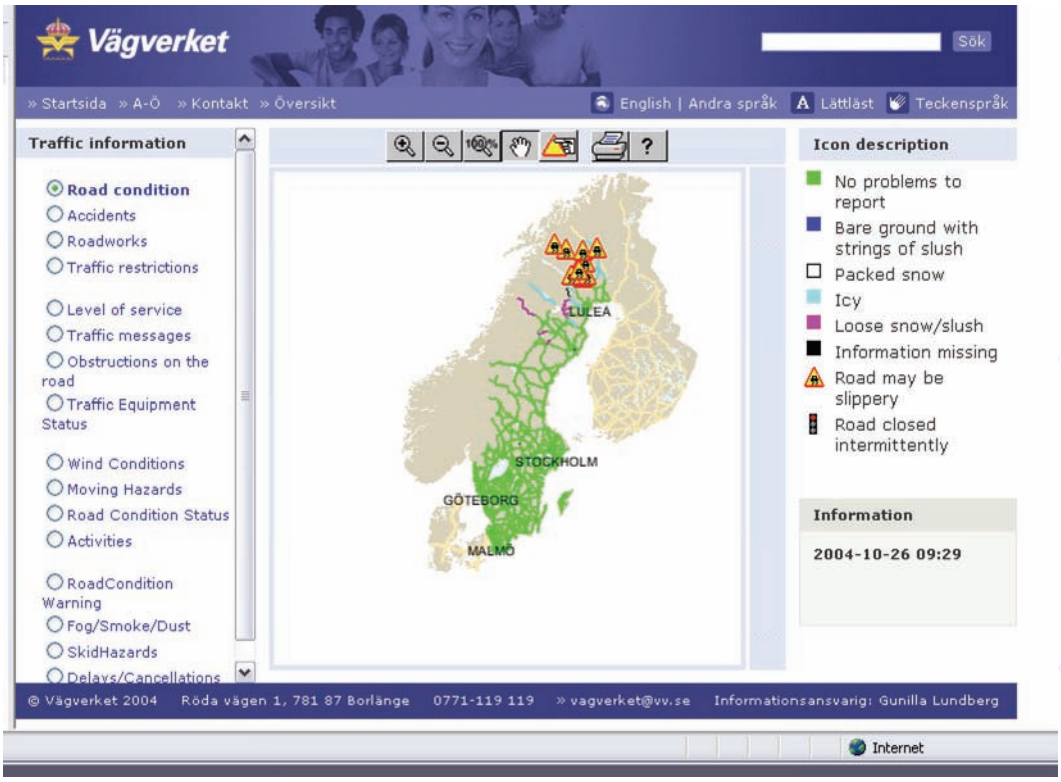
Traffic safety

Speed and speed adaptation play important roles in terms of the accidents that will occur with a particular road condition or friction. To stop a private car in more or less the same distance as on a bare road, the car needs to be travelling at half the speed on roads covered with ice or snow. The adaptation of Swedish drivers to ice and snow conditions is, however, significantly less. With a combination of poor road condition and poor visibility (falling snow) speed reductions are about 25%, but when only ice or snow, speed reduction is often between 10% and 20%.

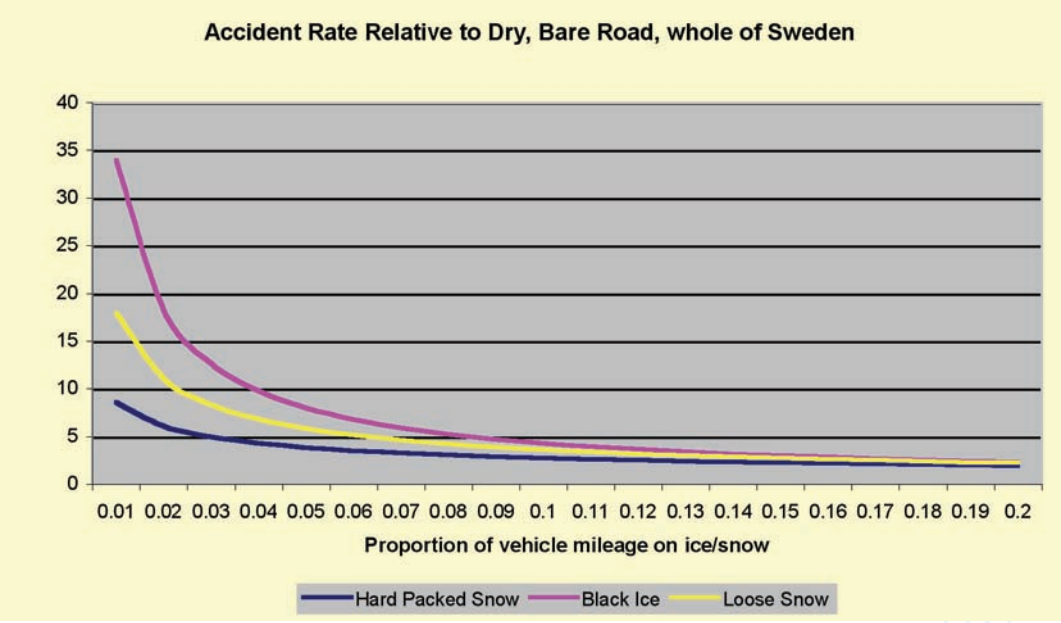
People driving under various road conditions where friction is varied for the various road conditions have shown that it is the appearance of the road and not the road grip which determines the speed that is maintained. This has been observed both in a simulator and on the road. Driving simulator tests have been conducted to determine how best to inform drivers and get the best speed adaption to the friction. Recommended speed display leads to lowest speed and largest headways.

The risk of accidents is estimated as the number of accidents reported by the police per million vehicle kilometers and is known as the accident rate. Accident rates can be calculated either as an absolute value or as a risk relative to a dry bare road in winter. In general, an icy or snowy road condition has about 3-30 times higher accident rate for vehicular traffic than for a dry bare surface. The black ice road condition is the most dangerous. Accident rate can also be calculated as a function of the frequency of occurrence of a given road condition during the winter season.

SWEDEN



Example from www.vv.se on actual road condition



Accident rate versus a dry, bare surface for various proportion of vehicle mileage on ice/snow during one winter

Accident rates for various icy and snowy road conditions have an exponential relationship with the proportion of total vehicle mileage during the winter season carried out on the current road condition (see figure on previous page).

To study the effect of winter road condition frequency more closely, the winter period is divided into short pre-winter and post-winter periods, with a long midwinter in between. The accident rate during pre-winter is not higher than during post-winter. This indicates that it is not the first skid phenomenon during a winter period that causes many accidents, but unusual with an icy or snowy road condition that surprise drivers.

Vehicle Equipment

Since 1999 passenger cars, light trucks and buses with a total weight up to 3.5 tonnes shall have winter tires or equal equipment during the period December 1 – March 31 when winter road conditions (slippery) appear. It is allowed to use studded tires October 1 – April 30.

A follow-up study showed that this requirement led to an 11% – 14% drop in accidents involving seriously injured and fatalities in icy and snowy road conditions. The interval depends on whether it is assumed that the requirement also has an effect on bare surfaces. Over all road conditions during the whole winter period, the reduction was 8%. These reductions are not statistically significant at the 5% risk level.

On the national roads during winter 05/06 there were 1,860 injury accidents under ice/snow conditions. A decrease of passenger cars with studded tires from 70% to 50% will cause an increase in injury accidents of 56 and a decrease to 20% will cause an increase in accidents of 140. A better winter maintenance (one class better) cannot compensate for that.

ABS (anti-lock braking system) and ESC (Electronic Stability Control) systems proportion the acceleration and/or the braking force in such a way that the tire is not blocked and the tangential grip is always used completely to its limit. The accident reduction in Sweden of ESC is for serious and fatal loss-of-control type crashes on roads covered with ice or snow the effectiveness was 49.2 ± 30.2%. It was estimated that for Sweden, with a total of 500 vehicle related deaths annually, that 80–100 fatalities could be saved annually if all cars had ESC.

Pedestrians

The risk of injury is higher to pedestrians than to car drivers when slippery road conditions. When ice/snow is on footways the injury risk is about 8 times higher than when the foot way has bare conditions.

Road furniture

In Sweden it has been quite common with roads with a width of 13 m. When they were built it was with 2 lanes 3.5 m in width and broad shoulders. Those roads had a quite high accident risk and some of them were changed to 2 lanes 5 m in width. But much better results come from the new standard with a guardrail on the road. Often it is 1 lane in one direction and 2 in the other (non-meeting roads with cables). The number of lanes in one direction changes at intersections. This standard resulted in a significant decrease in severe accidents. The fatalities have been reduced to 9 instead of estimated 60 with no cables and severe injuries have had a 50% decrease.

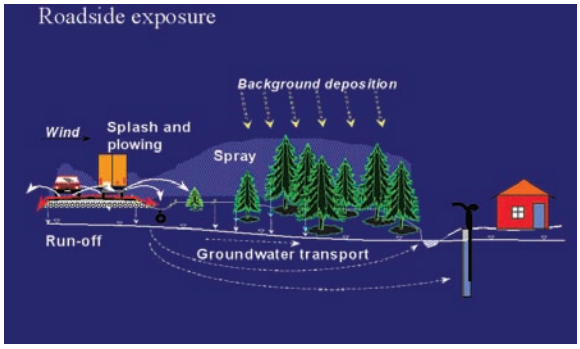
4. On-going Research and Studies to Improve Winter Management

A project has the aim to create a Winter Model (Winter Maintenance Management System = WMMS). It began in year 2001 and the first version of the model will be used by the SRA in 2009. The model incorporates effects of various road conditions on road-users, road maintenance administrators, and society in general. Socio-economic calculations are carried out, and the best possible level of winter road maintenance is proposed.

Road condition is critical in terms of the effects obtained. The road condition model therefore plays a vital role in the Winter Model. What is the impact of weather, traffic, and the various actions on road condition? What effects and costs are involved in various road conditions? There are three steps to creating a road condition model:

Theoretical description starting from physical processes.

- Empirical studies where weather, traffic and actions are related to observations and measurements in the field;
- Model development where the various factors are brought together into a general model;
- Environmental effect.



Effects of exposure to road salt appear first on roadside vegetation and in groundwater

The environmental part of the Winter Model describes, via a number of sub-systems, the relationship between:

- action and exposure;
- exposure and environmental condition;
- environmental condition and consequences;
- consequences and environmental costs.

Other important sub models will give information on accident, travel time and vehicle costs for different winter maintenance and also the costs for the road administration.

5. References

Carl Magnus Berglund. **Tema Vintermodell. Nytta och kostnader för vinterväghållning.** VTI notat 55-2005. Summary in English.

Bergström, A. Tema Vintermodell. Olycksrisker under för-, hög och senvinter. VTI notat 19-2003.

Carlsson, A & Brüde, U: Utvärdering av mötesfri väg: halvårsrapport 2003:1 VTI notat 36-2004

Friction Measurement on Winter Road Surface. SNRA Methods Specifications 110:2000

Ihs, A. **Winter maintenance in Sweden.** Compiled for COST 344. VTI särtryck 351, 2002.

Kircher, Katja. INTRO - Intelligent roads. Deliverable D2.3: Simulator study. Final report. VTI, EU-project report, 2007

Lie,A et al The Effectiveness of Electronic Stability Control (ESC) in Reducing Real Life Crashes and Injuries. Traffic Injury Prevention, 7:38–43, 2006

Möller, S & Wretling, P. Estimate of the distribution of road surface conditions during the 1993/94 to 1996/97 winters. VTI meddelande 848, 1998. Summary in English.

Möller, Staffan. **Tema Vintermodell.Väglagsmodellen.** VTI rapport 529, 2006. Summary in English.

National Environmental Programme 2002-2005. SNRA Publ nr 2001:57

Niska, Anna. Tema Vintermodell. Olycksrisker och konsekvenser för olika olyckstyper på is- och snöväglag. VTI rapport 556, 2006. Summary in English.

TRB. 7th International Symposium on Snow Removal and Ice Control Technology. Transportation Research Board/Circular E-C126. June 16-19, 2008. Indianapolis, USA.

Page 159: Blomqvist, Göran & Gustafsson, Mats. Winter Model: Roadside Salt Exposure Under Diffrent Weather Conditions.

Page 512: Möller, Staffan. Winter Model: **Road Condition Submodel.**

Wallman, Carl-Gustaf. Driver behaviour on winter roads: A driving simulator study. VTI rapport 419A, 1997.

Wallman, Carl-Gustaf. **Tema Vintermodell – Olycksriskmodellen.** VTI notat 60-2001, 2001.

Wallman, **Carl-Gustaf. Hastighet/flöde – väglag.** VTI meddelande 953, 2003. Summary in English.

Wallman, Carl-Gustaf et al. **Tema Vintermodell: Etapp 1.** VTI meddelande 958, 2004. Summary in English.

Wallman, Carl-Gustaf et al. **Tema Vintermodell, etapp 2. Huvudrapport.** VTI rapport 531, 2006. Summary in English.

Wiklund, Mats.Tema Vintermodell. Anpassning av vinterväglagsmodell till empiriska data med censurerade observationer. VTI notat 25-2006. Summary in English.

Winter 2000 General Technical Specifications. Swedish National Road Administration. Unpublished.

Winter 2000 In-house instructions. Head office to regional road administrations. Swedish National Road Administration. Unpublished.

VINTER 2003. Val av vinterväghållnings standard. Swedish National Road Administration VV Publ 2002: 147

VINTER 2003. Allmän teknisk beskrivning. Swedish National Road Administration VV Publ 2002: 148

Öberg, G. **Effect of sanding. Traffic and friction studies.** VTI Rapport 164, 1978. Summary in English.

SWEDEN

Öberg, G. Friction and journey speed on roads with various winter road maintenance. VTI rapport 218, 1981. Summary in English.

Öberg, G; Gustafson, K & Axelson, L. More effective de-icing with less salt. Final report of the MINSALT-project. VTI rapport 369 SA, 1991.

Öberg, G et al. Single accidents among pedestrians and cyclists. VTI meddelande 799A, 1996.

Öberg, G; Wiklund, M & Velin, H. **The effect of the winter tyre law on the use of tires and on accidents.** VTI rapport 479, 2002. Summary in English.

Öberg, Gudrun (editor). PIARC 2006. XII Winter Road Congress 27–30 March 2006, Torino, Italy. VTI notat 19A-2006.

Öberg, Gudrun. Tema Vintermodell. Fordonskorrosion beroende på vintervägsaltning. Kunskapssammanställning. VTI notat 24-2006. Summary in English.

Öberg, Gudrun & Möller, Staffan. Hur påverkas trafiksäkerheten om restiktioner av dubbdäcksanvändning införs? Kan en förbättrad vinterväghållning medföra att trafiksäkerhetsnivån bibehålls? VTI rapport 648, 2009. Summary in English.

From the homepages below most of the reports can be downloaded.

www.vti.se Swedish Road and Transport Research Institute (VTI)

www.vv.se Swedish Road Administration (SRA and in Swedish VV)

www.smhi.se Swedish Meteorological and Hydrological Institute (SMHI)

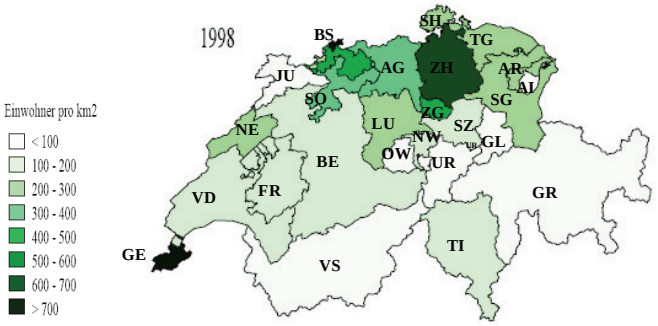
SWITZERLAND

snow and ice databook 2010

1. Demographics and Roads

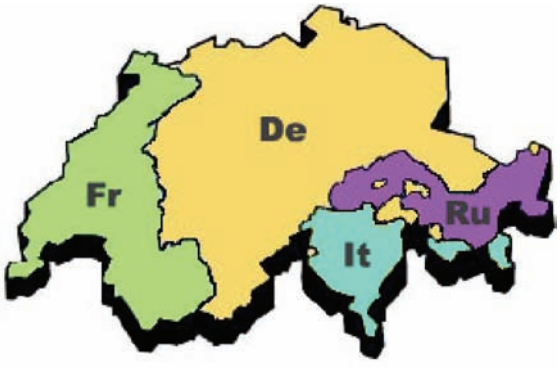
1.1 Information about the country

Switzerland is a small (41,285 km^2), landlocked country in the heart of Europe. Roughly two-thirds of its surface is mountainous. The Midlands between the Alps and the Jura mountain chain is densely populated.



Switzerland is a federal state with 26 cantons. The capital is Berne. Zurich and Geneva are international financial centers. Geneva accommodates the headquarters of several UN organizations as well as other international organizations. Basel is the seat of major pharmaceutical multinationals.

Four cultures or linguistic regions coexist in Switzerland: German: 64% of the population, French: 20%, Italian: 7%, and Romansch (in some alpine valleys): < 1%.



Nine percent (9%) of the population speaks other languages.

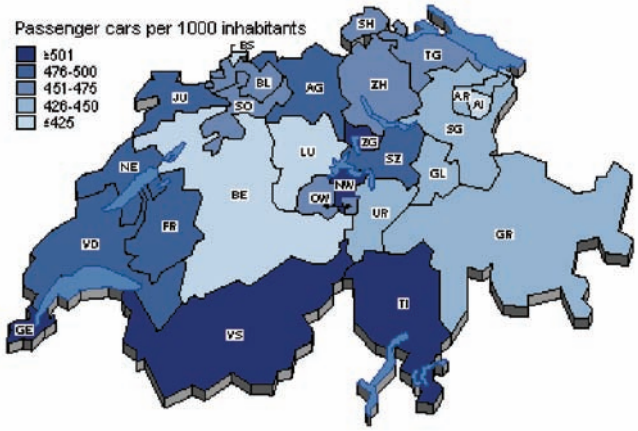
The economy is based on services (71%), industry (25%) and agriculture (4%). Export commodities are: machinery, chemicals, metals, watches, agricultural products.

1.2 Road network and traffic

The Confederation owns the national roads and has full authority over the latter. The network of Swiss national roads, comprising a total length of 1,907 km, was defined as a whole in 1960. Close to 90% built, it will theoretically be completed by 2020. Construction has now made way for adaptation and review of the network.

Roads	National roads	1,700 km
	Cantonal roads	18,000 km
	Communal roads	51,000 km
Vehicles	Utility vehicles	292,329
	Passenger cars	4,147,500

The cantons and communes respectively own the cantonal and communal roads.



The average Swiss travels 11,000 km a year in private cars and 2,100 km by train. The average daily traffic on motorways reaches 100,000 vehicles on certain stretches (3+3 lanes). Road transport accounts for 85% of the total freight tonnage. The economic importance of roads is therefore very high. The federal, cantonal and communal road authorities are responsible for keeping the roads serviceable at all times.

SWITZERLAND

Winter maintenance is in operation between October and April and accounts for 20-25% of the yearly operational cost.

2. Climate

2.1 Overview of climatic areas

About a hundred of Switzerland's mountain peaks are close to or higher than 4,000 meters and there are more than 3,000 square kilometers of glaciers. Forests occupy about a quarter of the country.

The climate varies according to altitude. Four characteristic climate regions can be distinguished:

Jura

The Jura is a mountain chain in the northwestern part of the country. The highest peak reaches 1,300 meters.

High precipitation, accompanied by frequent strong winds, prevails. The winter climate is harsh. Precipitation averages between 120 and 180 cm over 140 to 160 precipitation-days a year. Strong winds reach peak speeds up to 140 km/h and 210 km/h at the mountaintops. In winter, blowing snow is frequent.

Midlands

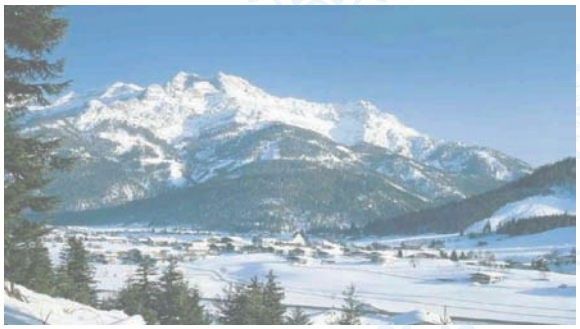
More than two-thirds of the population lives in the region between the Jura and the Alps. All the major cities lie in this region. The altitude varies from 300 to 700 meters.

A well-balanced distribution of precipitation prevails. The quantity of snow varies from winter to winter and fog is a frequent phenomenon.

Precipitation averages between 90 and 140 cm over 120 to 140 precipitation-days a year. Strong winds reach peak speeds of up to 170 km/h.

Alps

The Alps and Pre-Alps cover almost two-thirds of Switzerland's surface. The highest peak stands at 4,500 m. The Alps and Pre-Alps are generally rich in precipitation. Precipitation averages between 140 and 200 cm for 140 to 160 precipitation-days a year. Strong winds with peak speeds of up to 270 km/h are possible in the valleys. Foehn winds (hot and dry) are frequent in north-south oriented valleys.



Southern Alps

Ticino, the sunny part of Switzerland, lies south of the Alps, where palm trees grow. The altitude descends to 200 meters.

High yearly precipitation of up to 220 cm prevails as a result of the rain accumulation on the southern face of the Alps in the spring and autumn. Wind speeds go up to 120 km/h.

2.3 Statistics on temperatures

The table shows the winter characteristics of the various climatic regions.

Climate	Air temp		Precipitation					
	Days where T < 0° C	Frost days	Days with rain	Rain in cm/year	Days with snow fall	Days with snow cover	Max. snow cm/day	Amount of snow cm/year
Jura	121	30	157	140.6	64	123	55	317
Midl	96	22	126	104.2	30	51	22	53
Alps	140	42	138	148.7	59	128	50-90	433
SoA	45	4	107	184.8	14	19	63	43

2.2 Winter indices used in the country

A winter index was developed to show the correlation between winter maintenance costs and various meteorological parameters. It has served as a basis for determining compensation for winter maintenance since 2008.

3. Winter Road Management

3.1 Standards and rules

Legislation differs for national, cantonal and communal roads. A legal obligation to ensure winter maintenance exists for the national roads.

The official codes of practice for roads comprise 18 documents on winter maintenance:

SN 640 750b Bases;

SN 640 751 Avalanche Protection;

SN 640 752b Manpower Training and Requirements;

SN 640 754a Weather Information, Record of Road Conditions;

SN 640 756a Priority, Winter Service Levels, Route Planning and Register and Response Plan;

SN 640 757a Intervention Equipment;

SN 640 760b Snow Characteristics;

SN 640 761a Snow Removal;

SN 640 763 Engines for Snow Removal;

SN 640 764b Attachment for Snowplows;

SN 640 765a Snowplow characteristics;

SN 640 772b Ice Control;

SN 640 774a Requirements for Spreaders;

SN 640 775a Snow Fences;

SN 640 776b Structures for Snow Stabilization;

SN 640 778a Signage, Facilities.

Road classes

For snow removal and ice control, the following classes have been defined:

- Motorways, highways;
- Main arteries, steep roads;
- Roads used by public transportation;
- Roads leading to railway stations, hospitals, etc.;
- Public transportation stations;
- Major pedestrian and bicycle paths, stairs.

Service levels

Level A: bare roads, complete snow removal and ice control;

Level B: prevention of slipperiness, bare roads in the medium term;

Level C: roads practicable without the use of de-icers, white roads;

Level D: no winter maintenance.

Priority levels

Level 1: First snow removal pass completed 3 hrs after mobilization (2 hrs on motorways). First spreading pass completed 2 hrs after mobilization.

Level 2: First snow removal pass completed 4 hrs after mobilization. First spreading pass completed 3 hrs after mobilization.

Level 3: First snow removal pass completed 5 hrs after mobilization. First spreading pass completed 4 hrs after mobilization.

All road authorities are obliged to have route maps covering the entire road network where road classes, service levels and priority levels are indicated.

SWITZERLAND

Regulations for manpower

Maximum driving time is stipulated in a national ordinance. It must not exceed 9 hrs (10 hrs allowed twice a week). Weekly working time is 46 hrs. Maximum weekly overtime is 5 hrs (10 hrs in special cases).

Exceptions are, however, allowed for maintenance services. Conditions vary slightly from canton to canton.

Regulations for equipment and material

The regulations for equipment describe the types, test methods and operational areas of vehicles, snowplows, snow blowers, and spreaders. The main objectives are:

- Highest possible speed for plows/spreaders;
- Complete snow removal through mechanical means (plows, rotary brooms);
- Minimal use of thawing agents.

The codes of practice describe the types and operational areas of de-icing agents (NaCl, $CaCl_2$, $MgCl_2$, Urea, salt solutions, methanol, and glycol) and abrasives.

The dosages prescribed are:

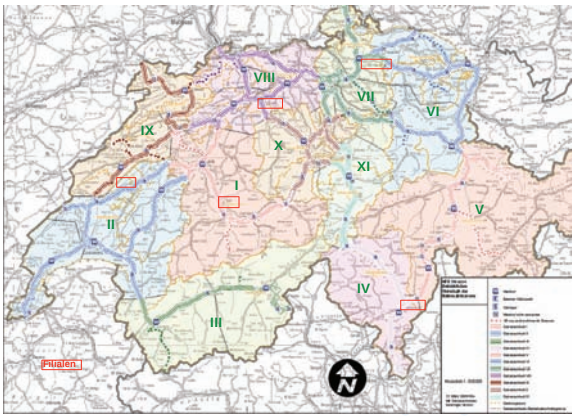
Spreading	Temperatures °C	
	0°C to -8°C	-8°C to -20°C
	g/m²	g/m²
Dry salt Wet salt Brine [in ASI]	7 – 15 7 – 15 5 - 10	10 - 20 10 - 20 5 - 10
Abrasives	≤ 200	≤ 200
Mixing ratio	only NaCl	2/3 NaCl 1/3 CaCl2

Certain surface conditions may require a higher salt dosage.

Progress is being made in the use of the wet salt technique (salt and brine mixed on the spinner). In 2005 this technique was used in 90% of all motorway maintenance centers.

3.2 Organization and operation of winter maintenance

The Confederation is responsible for winter maintenance on the national roads. It awards service contracts to 11 territorial units across Switzerland who perform the winter maintenance.



Winter maintenance on cantonal roads is performed by the cantons, and winter maintenance on communal roads is performed by the communes.

In general, the maintenance centers are responsible for winter maintenance. However private companies are frequently given contracts to do part or, in some cases, all of the winter maintenance. The contracts are established between the cantonal or communal road authorities and the contractor.

Types of contract:

A: The contractor is in charge of a stretch of road for snow plowing and ice control. He works with his own equipment, except plows and spreaders, which are provided by the maintenance center. The call for intervention is in most cases given by the maintenance center.

B: The contractor provides vehicles and drivers, who work together with the maintenance center's crews.

C: The contractor provides vehicles for the winter season.

Payments are based on the number of work hours with a flat rate for providing the vehicles.

National roads

Equipment: The national roads have 45 maintenance centers. The average length of highways serviced by each center is defined by the obligation to do the first round of winter maintenance within 2 hours.

The equipment includes: 2-3 trucks per direction, equipped with plows, 3.5-6.0 m width, detachable spreaders, 4-6 m^3 for salt and 2 m3 brine. One person per truck. On mountainous stretches and on stretches where the snow cannot be pushed to the side, snow blowers are required to load the snow on trucks.

SWITZERLAND

Salt is always stored under shelter, either in barns (up to 4,000 tonnes) or in silos (200 tonnes per silo). The advantage of the silos is the short time needed for loading (2-3 minutes), which can be done by the driver alone. With an appropriate arrangement of the silos, 2-3 spreaders can be loaded at the same time.

Automatic de-icer spraying facilities are in operation on specific stretches with a particular microclimate or which are particularly exposed. Two facilities are on high bridges, one facility (6 km length) on a segment with heavy traffic (80,000 vehicles per day) and a particular microclimate.

Road heating is not used, but for one exception. On a particularly exposed bridge, a solar energy pilot application is in operation since 1995. A heat exchanger tube system embedded in the asphalt layer of a bridge, covering an area of 1,300 m^2, collects heat during the summer and utilizes it during frost periods in the winter to heat the bridge's surface, thus preventing the formation of ice. The liquid is stored in an underground heat store.

Manpower

The maintenance center staff usually consists of:

- One road master responsible for winter maintenance;
- One administrator, responsible for accounting and administration;
- Two to three group leaders;
- Crews, drivers and other professions;
- Two to three mechanics;
- One to four electricians, depending on the number of electromechanical facilities along the highway.

Group leaders are responsible for operational tasks. They decide on interventions, based on the RWIS. Each maintenance center has a standby organization during the whole year. Each employee is obligated to provide temporary standby availability.

The work schedule is set by the head of maintenance operations in each canton. As a rule, the work week is of 42 hrs. Overtime during winter is generally compensated in summer.

Shift working is becoming more common in the maintenance centers as the intensity of the workload increases. Maintenance work in tunnels is mainly done at night and more and more this also applies to other work likely to hinder the flow of traffic.

There are strict safety rules for every type of maintenance work (clothing, tool-handling, equipment, behavior on the road etc.). Every center has a designated safety supervisor.

Training and education

The head of the maintenance center is responsible for crew training.

- Training includes:
- Winter maintenance tasks;
- General organization;
- Vehicles and heavy equipment;
- Response organization;
- Personnel and standby organization;
- Supply of information;
- Instruction on tools;
- Preparation of group leaders;
- Instruction on route planning, service levels and priority levels;
- Application of salt according to RWIS forecasts and residual salt;
- Plowing in teams;
- What should be done in the event of an accident, "risk management";
- Reporting.

At the beginning of winter, courses are given to road operators on basic meteorology, forecasting technology and work on the RWIS and the weather radar.

Other courses cover the handling of ice detection systems.

Methods, equipment and materials for special problems

Special problems are caused by snow drifts, avalanches and porous asphalt. To reduce the amount of snow blown on the road, snow fences are put up where the phenomenon regularly occurs.

SWITZERLAND

In some winters, avalanches cause severe problems for road authorities. In all mountain regions, a special avalanche task force has been organized. Their duty is to observe the characteristics and the amount of snow and to issue warnings, and in some cases to close the road. A special avalanche bulletin and warnings are issued daily by MeteoSwiss and the Swiss Avalanche Research Institute. Automatic warning devices have been installed in certain locations.

Meteorological information

MeteoSwiss provides information for winter maintenance on several levels:

- General road weather forecasts, available to the general public on the Internet and the radio. Free of charge;
- A 24-hr road weather forecast specifically designed for maintenance centers. These forecasts are made separately for more than 20 areas with different local climates;

The information is distributed via telephone lines and the computer network and goes directly to the maintenance center's RWIS computer. The contract is established between MeteoSwiss and the maintenance center. Accuracy is between 86% and 89%;

- Weather forecast warnings are issued for special events or situations, whether general or local, that have not been announced in the general weather forecast. They are delivered directly to the maintenance center's RWIS computer and trigger a warning signal;
- The MeteoSwiss road weather forecasts rely on a network of automatic weather stations (ANETZ) and several forecast models. Verification is usually done with selected road sensors.

RWIS

All maintenance centers for the national roads have a RWIS. The system combines measurements and warnings from road sensors, road weather stations and local weather forecasts. Road sensors and road weather stations generally provide the following parameters: air temperature 2 m aboveground, surface temperature, humidity, dew point, freezing temperature, precipitation, wind: direction and intensity, road conditions: dry or wet, residual salt.

The RWIS local weather forecast is issued every day at 3:00 p.m. and covers 24 hrs. It provides: air temperature 2 m and 5 cm aboveground, humidity and dew point, precipitation: type and quantity, snowfall threshold, wind: direction and intensity, cloud cover, road surface conditions. The forecast is updated if a change occurs in the 24 hrs.

SWITZERLAND

Ice detection system

The national road network is equipped with an ice detection system. In total, about 400 road sensors have been installed and measure the surface temperature and the freezing point by electrically cooling down the sensor surface. The average distance between road sensors is approximately 6 km.

The most widespread system is the Boschung system. In a few cases, the Vaisala and the Micks systems have been installed. The road sensors are generally combined with roadside measuring stations. The location of the sensors was determined by experience or through thermal mapping. Generally, the most dangerous spots were chosen. Additional locations are on bridges, in particularly exposed and shady areas.

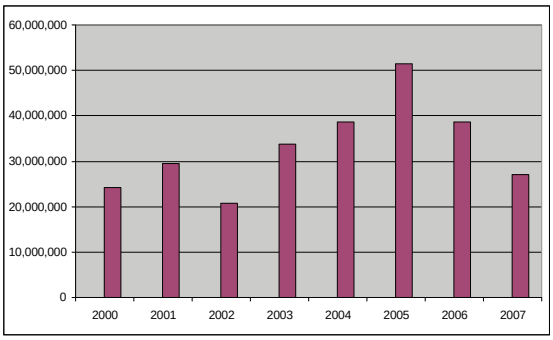
3.3 Assessment of winter maintenance measures

Operating costs on national motorways

Winter maintenance costs can vary between 15% and 25% of total annual operating costs. The following diagram shows the winter maintenance costs in 1,000 CHF per vkm.

(vkm: virtual kilometers, where additional traffic surfaces such as service areas, ramps, braking lanes, etc. are calculated as additional kilometers)

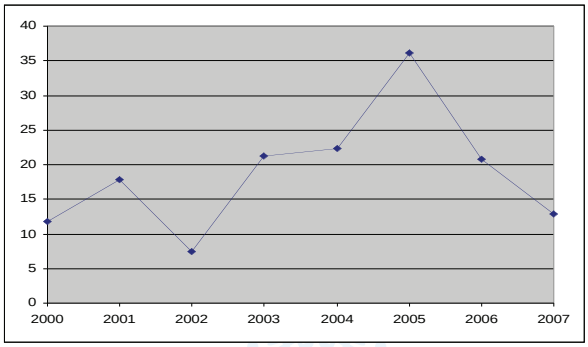
Annual winter maintenance costs



Salt consumption on national motorways

Salt consumption is directly related to the harshness of the winter. Several measures have been introduced in the past years to minimize the use of deicers systems. The annual consumption is shown in tons/km.

History – Annual consumption (t/km)



Measurements of efficiency

Internal

All the maintenance centers for national roads and some for communal roads have a cost accounting system. Therefore the total cost of winter maintenance, as well as the personnel, vehicles/engines, material etc. cost factors are exactly known. Based on this cost accounting, efficiency assessments are made after every winter.

A knowledge exchange project covering all maintenance activities is currently underway. The project objectives are:

- Increasing efficiency;
- Institutionalizing learning programs;
- Reducing costs.

External

The external efficiency can basically be judged by the number of road closures and traffic accidents caused by poorly maintained roads. These occurrences are, however, only summary.

A more detailed method, which will compare activities with the given standards, is actually in the preparatory stage. It will be based on a general road maintenance quality assurance.

Measures aimed at reducing the salt consumption

Besides the approved methods like the wet salt technique, dosage prescriptions according to surface conditions and annual staff education, new procedures and devices are systematically tested for their efficiency.

A test conducted over two winters with an automatic salt dosage system based on "ThermoMat" infrared thermometers has proven that the salt consumption on a motorway can be reduced by 20% to 30% without any reduction of the road safety, providing both environmental and economic benefits in ice control.

3.4 Traffic safety and information

Safety measures

In a large national project called Via Sicura aiming to reduce the number of victims on the road, a number of measures indirectly related to winter maintenance have been defined.

Weather-related information for road users

This kind of information is mainly available by radio. The road administration does not provide any on-site information on road weather or road surface conditions.

However, fixed and variable road signs provide information on closed roads and recommended detours.

International exchange of road information

International information exchanges regard road closures and difficult driving situations. This exchange is ensured by police headquarters.

Traffic management on national roads

There are supraregional offices for traffic management. These traffic guidance centers are responsible for such operations as the collection of data on traffic flow and density, active traffic guidance, the coordination of road maintenance, and information on traffic, the weather, and road conditions.

4. Ongoing Research and Studies to Improve Winter Management

4.1 New technology

Criteria for the implementation of automatic de-icer spraying facilities

This study will provide project evaluation criteria for the use of automatic de-icer spraying facilities in respect of microclimate, traffic, safety and cost/benefit.

4.2 New management approaches

Winter index

The winter index is an empiric formula based on winter maintenance costs and meteorological data. It can be applied to evaluate the theoretical operating costs resulting from the meteorological data from the past winter and thus provide an indication of the efficiency of winter maintenance.

Effectiveness of road winter service

The research will show the traffic flow before and after winter maintenance and thus allow cost/benefit considerations on the propriety and the promptness of winter maintenance operations, including traffic safety, economy and the environmental impact.

Use of modern communication technology in road maintenance to optimize traffic safety

The study will provide the technical and financial criteria for implementing such communications as satellite-based positioning, online data transfers between the base and vehicles, remote-controlled salt dosage, etc.

4.3 Trans-national cooperation

In the area of winter road maintenance, Switzerland collaborates with the following organizations:

- **PIARC** World Road Association, Technical Committee B5 "Winter Maintenance";
- **COST** European Cooperation in Science and Technology, Project 353 "Winter Service Strategies for Increased European Road Safety";

SWITZERLAND

- **SIRWEC** Standing International Road Weather Commission, Executive Committee;
- **CEN** European Committee for Standardization, TC 337 "Winter Maintenance and Road Service Area Maintenance";
- **D-A-CH** Annual seminars organized by the road research associations of Germany, Austria and Switzerland;
- **F-CH** Regular seminars on technical and organizational issues organized by the road research associations of France and Switzerland.

In the past Switzerland has hosted the following international conferences on winter issues:

PIARC VI International Winter Road Congress, Davos, 1982;

SIRWEC 10th International Road Weather Conference, Davos, 2000.

5. References

Swiss Federal Roads Authority

www.astra.admin.ch

Other references

www.swissroads.ch

www.vss.ch

THE NETHERLANDS

snow and ice databook 2010

1. Demographics & Roads

1.1 Information about the country

The Netherlands is a country small in size (41,528 km^2) with a population of 16.5 million inhabitants. That is an average of almost 400 inhabitants per 1 km^2.

The Netherlands is located in Northwestern Europe, and bordered by the North Sea to the north and west, Belgium to the south, and Germany to the east.

The capital is Amsterdam and the seat of government is The Hague. It also has one of the most free market capitalist economies in the world.

The Netherlands is a geographically low-lying country, with about 27% of its area and 60% of its population located below sea level. Significant areas have been gained through land reclamation and preserved through an elaborate system of polders and dikes.

The estuary of three important European rivers, which together with their distributaries form the Rhine-Meuse-Scheldt delta, forms a great part of the Netherlands. Most of the country is very flat, with the exception of foothills of the Ardennes in the far southeast and several low-hill ranges in the central parts created by ice-age glaciers.

1.2 Road network and traffic

Area		41,528 km
Population		16.5 million
Length of road	Motorway	5,050 km
	Regional main roads	7,848 km
	Local Roads	123,237 km
Latitude		51°53' N

The road network comprises 5,050 km of motorways, 7,848 km of regional roads and 123,237 km of local roads, amounting to a total of 136,135 km of paved roads. The national fleet of 10.1 million vehicles includes 7.4 million passenger cars. Transport of freight is of great importance to the Dutch economy. A great deal of this transport takes place at night and in the early morning, particularly commercial traffic.

The economic importance of roads cannot denied, even in winter. As a result, one of the tasks of the road authorities is to keep the road network serviceable at all times, among other things by setting up a full organization for winter maintenance. The winter extends from October to May. The most severe winter conditions take place from the end of December until the beginning of March.

THE NETHERLANDS

2. Climate

2.1 Overview of climatic areas

The Netherlands has a temperate maritime climate influenced by the North Sea and Atlantic Ocean, with cool summers and moderate winters. Daytime temperatures vary from 2 °C – 6 °C in winter and 17 °C – 20 °C in summer. Because the country is small there is little variation in climate from region to region, although the marine influences are less inland. Rainfall is distributed throughout the year with a dryer period from April to September. Especially in fall and winter strong Atlantic low-pressure systems can bring gales and uncomfortable weather. Sometimes easterly winds can cause a more continental type of weather, warm and dry in the summer, but cold and clear in the winter with temperatures sometimes far below zero. The Netherlands is a flat country and has often-breezy conditions, although more in the winter than in the summer, and more among the coastal areas than inland.

2.2 Statistics on temperature

Amount of precipitation (rain)	App. 760 mm/year
Number of days below 0°C	App. 50-60 days/year
Number of days with snowfall[1]	App. 30 days/year
Number of days with freezing rain (black ice)	App. 1 day/year

[1]most of these days the amount of snow is not enough to cause serious traffic problems.

3. Winter Road Management

3.1 Standards and rules

The Dutch authorities are legally obliged to maintain their roads (care obligation as written in the road and civil code). Winter maintenance is part of this obligation.

RWS/Province-level (motorways, primary and regional roads)

RWS/Provinces use the uniform treatment times put up nationwide by CROW.

For national and regional highways and other roads up to a maximum speed of 80 km/h the following treatment times are used:

Pre salting: 2 or 3 hours;

Post salting: 2 hours;

Plowing/post salting: 1.5 hour.

Municipality-level (urban roads)

Municipalities often work by priority of roads. This is put down in a yearly-renewed plan, which is published to inform their inhabitants. First main-/bus routes are spread. Then roads, which enclose quarters and next roads within quarters are treated. Also important social locations like hospitals, schools, shopping centers, and the like, get priority.

There are no standards on manpower.

Equipment

RWS (DVS) has a framework contract for the delivery, installation, maintenance, etc. for demountable spreaders and snowplows. It's of great importance that all equipment works in wintertime. It should be available for 100%. So fixed times are used for reparations and if a machine cannot be fixed the supplier has to supply the authority with one of their own machines.

This framework contract describes:

- Requirements concerning construction and design standard's (EEG, NEN) of spreaders and plows;
- Requirements concerning placing the demountable spreaders on trucks;
- Requirements concerning spread rate, width, distribution, etc.;
- Requirements concerning drive;
- Requirements concerning liquid (brine) tank;
- Requirements concerning operation;
- Requirements concerning mounting the plow on a truck.

Material

RWS (DVS) also has a framework contract for the delivery of road salt (evaporated or rock salt). In this contract minimum requirements are placed, like:

- Composition of the product;
- Grain distribution;
- Presence of moisture;
- Presence of heavy metals;
- Delivery times.

THE NETHERLANDS

3.2 Organization and operation of winter maintenance

Organization of the Dutch Ministry of Transport, Public Works and Water Management, concerning winter maintenance:

level 1: Ministry of Transport, Public Works and Water Management;

level 2: Rijkswaterstaat (RWS);

level 3: Regional Direction;

level 4: Highway Management Center;

level 5: Operation Center.

RWS DVS is the Center for Transport and Navigation of RWS. Concerning winter maintenance, RWS DVS is responsible for:

- The development of RWIS's, consultancy and research concerning winter maintenance (de-icing materials, equipment and methods);
- Central tendering for equipment and road salt;
- Communication about winter maintenance together with traffic information center;
- Coordination in case of calamities (lack of salt; employing of 3 snow blowers/cutters).

The DVS also facilitates the purchase of winter maintenance equipment and does write/provide the "Guideline Winter Maintenance RWS" and consults the Ministry and local management centers.

The local management centers are responsible for operational (winter) maintenance. They consult the RWIS and other weather information sources and decide to start a run (winter maintenance action).

Road Weather Information System

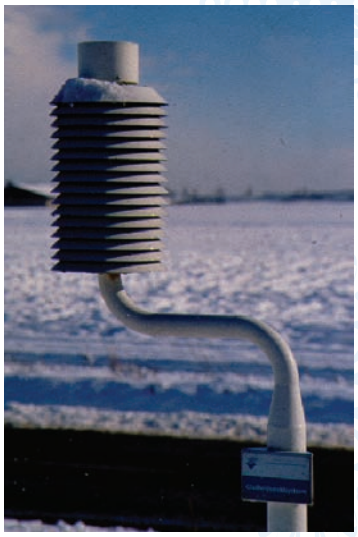
Since the 70's RWS DVS has been experimenting with the RWIS. Traffic safety, cost reductions and a more limited use of salt have been the main starting-points of these experiments. Starting in the end of the 80's, The Netherlands (RWS and Provinces) has placed the RWIS on their roads and bridges (319 measuring stations in the year 2009).

Within winter maintenance the role of the weather bureaus is important, because in the RWIS only a few persons (winter maintenance coordinators) are detached to the winter maintenance night watch. The coordinator has access to weather precipitation radar-image, which is very useful in case of precipitation conditions. Actual local weather-reports for the coordinator specially focused on winter maintenance are accessible. A meteorologist of a weather bureau can be consulted by phone 24 hours and 7 days a week (only if contracted). A weather bureau makes an actual local prediction, which is presented by a user interface or sent to the coordinator by mail. The final decision is always made by the coordinator, based on meteorological predictions, precipitation radar, own experiences, contacts with coordinators from other districts and data of the RWIS.

The coordinator is at home (at night) and will be warned by the RWIS when slipperiness might be expected. Per highway management center a winter maintenance coordinator is stand by during one week (varies per highway management).

The RWIS station measures:

1. Air temperature and relative air humidity (1.5 meter above the earth surface);
2. Presence of precipitation;
3. Road surface temperature measured on the left (fast traffic and coldest) lane;
4. Sub-soil temperature measured under the asphalt layers of the left (fast traffic) lane;
5. Surface condition: dry, presence of moist and/or salty (passive sensors) measured on all lanes.



Part of RWIS station at the roadside

The dew point is calculated from the measured values. Some measuring stations also measure wind speed and wind direction. On critical locations a camera is available for visual inspection of the road surface. The measuring stations are situated on locations which are critical under winter conditions.

THE NETHERLANDS

These locations are not necessarily the coldest, but the combination of moist and low temperature makes the location critical for example roads through woods and near water. Also steel bridges can be critical especially at the start and in the end of the winter season. On most steel bridges a RWIS station is available. Distance between the stations is about 15 km (varies between 5 and 40 km).

In some situations measuring stations are used to start an automatically spraying action on bridges (using brine (NaCl) with a higher purity than the normal used brine).

For finding the most suitable location for a new measuring station, experience of road inspectors and thermal mapping are used.

The user interface is fully Web based and an access to the central server is possible from anywhere with a personal computer or laptop with Internet connection and Internet browser. Measuring stations are wireless (GPRS) linked to a central server. The central server takes care of a large number of functions. It manages the data communication with the measuring stations, and communicate real time with the winter maintenance coordinator. The RWIS send out alarms to the winter maintenance coordinators and can be seen in the user interface. Alarms can also be received on a pager, by voice mail or a mobile phone by SMS.

The information of the measuring stations is stored on the local measuring station for seven weeks. After seven weeks the data is stored for unlimited time on the central server.

When the coordinator is connected to the central server, the computer presents predictions of a weather bureau automatically in the user interface (only if contracted). The weather bureaus have access to the central server and use the actual and historical information of the measuring stations and actual weather information to have input for the predictions. The coordinator can use the output to make a decision.

The coordinator can also use the images of the user interface integrated weather radar (precipitation). It is also possible to consult a meteorologist of a weather bureau. Some weather bureaus offer a "total surveillance". Specialized meteorologists then guards an RWIS (receives alarms) and use the other actual weather information (models, precipitation radar, satellite pictures). When the situation exist that slipperiness is predicted or occurs, he or she will immediately warn the coordinator.

The collected data from the measuring stations are wireless (GPRS) retrieved by the central server.

When the winter maintenance coordinator decides to start a run (spreading- and/or plowing action), a process will start which will take several hours.The process contains:

- Warning involved personal;
- Calling in equipment (commercial trucks from e.g., contractors). Demountable spreaders and salt (in barns) are stored on the property of the local surveillance centers;
- Inform neighborhood road managers;
- Inform police, VCNL (if this is done depends on the agreements).

RWS-level (motorways and primary roads)

Communication between the different levels find place by phone or a message board, which is available in the user interface and accessible for participants in the RWIS.

The alarm coming from the RWIS is connected to a pager or mobile phone used by the winter maintenance coordinator. The time between the calling in the contractor and spreading the last square meter can differ (2 or 3 hours) depending the contract. This concerns a preventive spreading action.

Province-level (regional roads)

Also at Province-level winter maintenance is arranged per region by a winter maintenance coordinator. Most of them use RWIS in combination with meteorological reports and local knowledge of the area. When there is doubt, patrols are carried out.

Municipality-level (urban roads)

Municipalities do sometimes use information from regional weather bureaus like airports and consult meteorological services. Also inspections from local police are important. Sometimes the decisions are made together with the coordinator of the Province. Some of them use RWIS-data.

Equipment

The preparative program before winter activity consists of:

- Equipment checks (checklists and test protocols exist);
- Driver instructions, including test drives on the salt routes;
- Courses for winter maintenance personnel.

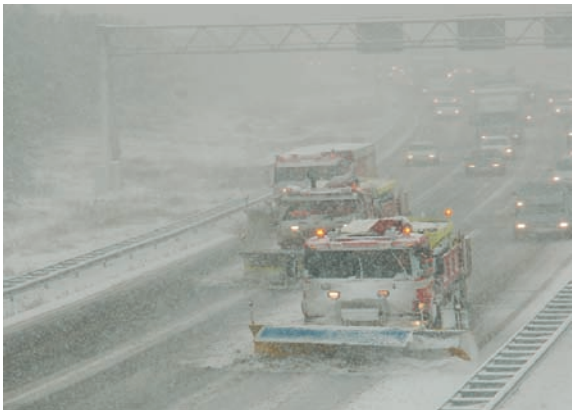
THE NETHERLANDS

Prevention, for example, snow fences, is not used in The Netherlands. The only used prevention is precautionary treatment (preventive salting). The spreaders drive fixed routes (on the basis of: economics, safety, spreader ratio, etc.). Optimizing the salting routes is very complicated and is contracted to a specialized bureau. RWS has developed an application, called SOS (Salting Route Optimizing System), which is used.

A spreading management program is in use to have an optimized administration and to check if the contractor is doing his job well.

Municipalities in The Netherlands own approximately 2,000 spreaders and snowplows. About 30% of the spreaders are used for bicycle roads. The machines for bicycle roads have a capacity up to 1.5 cubic meters and are very often mounted on trailers. Municipalities mostly use their own traction and personal.

The provinces have for about 450 spreaders also in a wide range from 1 cubic meter for bicycle roads up to 9 cubic meters for regional roads. RWS owns circa 550 demountable spreaders (5, 7 or 9 cubic meters), about 850 plows and 3 snow blowers/cutters.



Spreading-width is 4-14 meters

In the Netherlands very often trucks of contractors are used to put on the spreaders and to build on the snowplows. Also the drivers on the trucks come from these contractors. RWS has agreements with contractors. These agreements lay down in a contract for several years (fixed for 3 years and possible to extend for 1 or 2 years). Most local districts have contracted one agent. This agent might have subcontractors. Per district there are several operational centers (2-4) depending on the road area to maintain. Per operational center several spreaders (6-12) and plows (12-18) are present.

The contractor gets a fixed price per season for all preventive spreading actions including a big check of all equipment before the start of the winter. Post salting is done per hour. When the contractor does not react on a call-out, does not salt the route within a certain time period, if slipperiness occurs during the time the contractor actually had to spread salt and when the contractor cannot be reached at all high fines have to be paid.

Materials

In The Netherlands pre-wetted salt is mostly used (the wet component is sodium- or calcium chloride solution; as dry salt (NaCl) evaporated or rock salt is used). The wet component and dry salt are just before spreading mixed on the spreading disk and spread on the road. The ratio between dry salt/fluid is 2.5:1. Fluid means a 20%-NaCl-solution or a 16%-CaCl2-solution.

	rock salt	evaporated salt
NaCl amount	98.5%	99.9%
Grain size (80%) [mm}	0.8 – 3.15	0.20 - 0.45
Grain size (X50) [mm]		0.38
Grain size (max. <)	< 0.16 mm : 4 ± 1%	< 0.16 mm : 5%
Grain size (max. >)	> 3.15 mm : 5 ± 2%	> 1 mm : 1%
Anti-caking	75 ppm	75 ppm
Heavy metals	< 4 ppm	< 1 ppm
Unsolved parts	< 1.5%	< 0.01%
Moisture	0.3%	< 2.5%

Properties NaCl

THE NETHERLANDS

These salts are according the specifications.

- Effectiveness: 12 kg ice per kg 100% pure sodium chloride (NaCl) at -5 ºC;
- Depression of freezing point temperature is - 7 ºC;
- NaCl (dry): summer price circa 46 Euro/ton; winter price about 54 euro/ton;
- Wet-component (16% CaCl2): Approximately 30 Euro/ton.

A tendency is going on to produce the wet-component out of dry salt (NaCl) already present in high volumes in the salt barns.

Salt is stored in barns. These barns are situated on the local surveillance centers or operation centers of RWS (opening of the barn is situated in the southeast direction). RWS has 61 barns with a total capacity of 59,500 tonnes. In last 10 winters an average amount of 68,000 tonnes per winter is used. It varied in between 25,000 and 124,000 tonnes.

In The Netherlands annually circa 36-38 runs are necessary. 75% of the actions are pre-salting (anti-icing) and 25% considers post-salting actions (de-icing)). Using these figures in combination with the road area to be spread the necessary storage facilities of salt can be calculated. For example, when the local highway agency maintain 260 km road lane (medium width of the road lane is 15 meters), 1,440 ton salt is necessary for one winter.

The local agencies can choose the amount of stored salt. An agency can choose to buy salt for the whole winter period or to have salt in storage for, e.g., 5 actions and to refill the barn after every action.

RWS DVS is responsible for the framework contract for salt. The storage capacity of the local surveillance centers is included in this contract. The contractor must be able to deliver a total amount of 3 times the storage capacity in one season (200% delivery guaranty in winter).

Provincial-level

The provinces are dealing with winter maintenance; the use of salt; the spreading actions and times within their road network should be treated in general in the same way as Rijkswaterstaat does.

Municipality-level (urban roads)

Mostly dry salt is used. The use of pre-wetted salt will be used more in the near future.

The RWS and Provincial personnel working with the RWIS, is educated by following an RWIS-course. There is no course for the truck drivers. They learn the job by experienced drivers.

Privatization

In The Netherlands operational winter maintenance on RWS-level is organized by the local highway management centers. Per highway management center one winter maintenance coordinator is in service during one or several week(s). Per highway management center about 3 – 5 coordinators are available. The coordinator uses the winter maintenance facilities and initiates the winter maintenance action when necessary. The decision for a spreading action stays at RWS. In case of preventive spreading no RWS personnel is involved anymore. In case of post salting personnel is available at the local center and for visual road inspections.

RWS only supplies demountable spreaders, snowplows and the salt. The trucks and drivers are contracted (see paragraph 2.4).

Getting information

RWIS

The RWIS contains actual and historical local information. The coordinator will be warned by the RWIS (pager, SMS) if slipperiness is expected in a couple of hours.

Meteorological

A prediction is presented in the user-interface of the RWIS. This information supports the coordinator by making a decision.

Precipitation Radar

The coordinator has access to images from the precipitation radar, which is integrated in the RWIS user interface or available on the internet site of a weather bureau. This is especially useful to start precautionary salting because of, for example, coming snow.

THE NETHERLANDS

Meteorological information

Several times a day, meteorologists, working for the weather bureaus, make an actual local weather-report for the coordinator. This information is specially focused on winter maintenance in the region of the highway surveillance center.

Consults

It is possible to consult a meteorologist at a weather bureau by phone for 24 hours a day, 7 days a week. (only if contracted)

Patrols

Sometimes, if the coordinator thinks it is necessary visual inspections of road conditions are done.

Methods, equipment and materials for snow control

In The Netherlands heavy snowfall is very rare. Nevertheless, RWS can on demand use 3 snow blowers/cutters (Unimog U1750 or U2150 with Schmidt FS 5-Z snow blower/cutter). The snow blowers can also be used to remove large amounts of snow from the hard shoulder.

The concept of white roads does not exist, as prolonged snow on roads is unusual. In case of extreme slipperiness (icy conditions; black ice or snow) the policy can order to reduce the maximum driving speed to 50 km/h. Dynamic road signs show this information. When slippery occurs on porous asphalt roads, traffic can be concentrated on a single lane to have enough wheel passages, which keeps the salt on the surface. These regulations/guidelines are written in the Guideline Winter Maintenance RWS.

Methods, equipment and materials for ice control

Demountable spreaders are used. The driving speed on motorways is circa 70 km/h using pre-wetted salt and 40 km/h using dry salt.

Type of slipperiness	Amount of NaCl (g/m2)	
	dry salt	pre-wetted salt
expected slipperiness (preventive spreading)	-	7 (1)
fog moisture	10	7
icing	15-20	7-10
glazed frost (2)	20	15
snow (after removal) (3)	20	-

(1) : On porous asphalt 14 g/m^2 is used after a very wet period
(2) : When the glazed frost situations stays for several hours, 20-40 g/m^2 dry salt should be used
(3) : Precautionary treatment: 15-20 g/m^2 pre-wetted salt

Recommended average rate of spread

Under specific weather conditions with a lot of salt on the road slipperiness can occur due to salt. It does happen very rarely. Three different kinds of appearances are known. If the problem occurs it can be solved by spraying brine (NaCl or $CaCl_2$).

The equipment (demountable spreaders and plows) is stored at the local surveillance centers and operation centers. Also the salt barns are situated on these terrains.

Methods, equipment and materials for special problems

Porous asphalt will be, under some conditions, treated differently (see table 3.1). The road user will usually not feel or see any difference. Only, when the combination glazed frost & porous asphalt & minimal traffic occurs, it is possible that on the spots where there is a changeover from non-porous asphalt to porous asphalt, there is a difference in slipperiness. This can lead to dangerous situations.

Several bridges in The Netherlands are supplied with a fixed anti icing spray (brine) system connected to a RWIS. The highway management center (road manager) did choose this solution because of economic and safety reasons.

3.3 Assessment of the snow and ice control measures

Some spreaders are equipped with a GPS system. When the trucks return to the RWS terrain a printout of this system is made. This printout contains the route, the spread-width and the used amount of salt. This printout is used to evaluate the run. At the end of every winter season, a survey is done about salt-use, personnel, equipment etc.

3.4 Traffic safety and information

The information of drivers is given by the ANWB. The ANWB gets this information from the VCNL.

Ways of possible dissemination:

1] radio;

2] journals (radio and TV);

3] teletext;

4] telephone;

5] Internet.

Information on the roads (signs) is possible; if necessary a speed reduction is put on the signs. In worst cases lanes can be closed by putting a red cross on the road signs above the road lane.

THE NETHERLANDS

Education/information to drivers about driving in winter conditions etc. is a task of the headquarters of RWS. Technical questions can be asked to RWS DVS.

4. On-going Research and Studies to Improve Winter Management

Co-operations between road operators and administrators

It's growing concern to uniform winter maintenance on different roads of different operators/administrators. On national level guidelines are made to categorize roads in means to treat them uniform.

There is also co-operation in the field of tendering. For instance one tender (4 provinces and RWS) is put on the market to buy salt. In several regions RWS and provinces together use a contract for the actual winter maintenance.

Training course personnel

In most contracts are put demands for capable personnel working in winter maintenance. Two courses are set up. One course especially for winter coordinators and another course for truck drivers of contractors or own organization. Content of last course consider aspects as: forms of slipperiness, using equipment (spreader and snowplow) and spreading management system, weather conditions, dosage of salt, driving aspects under winter conditions (slippery course), etc. In the end an exam is giving. In case of sufficient result, a driver is given a certificate, which allows him to do his job in winter maintenance.

Research on right decision spreading action

Matching information out of the RWIS and the spreading management system makes it possible to check if a decision for a spreading action was made in the right way. Background of this study is to support the coordinator in a better way, uniform the process to make a decision, save costs and environment.

RWIS

Research on several sensors of a road weather information system with the idea to diminish sensors in the road surface. Road sensors and the road itself need to be maintained. Under the severe Dutch traffic conditions a reduction of road works/closures is of great significance.

Also information out of the RWIS in combination with weather information is used to predict if every part of the spreading route has to be treated with the same amount of salt. It's research done under the name of "dynamic spreading".

Salt

Research is set up to measure the effectiveness of spreading different kind of salts on different kind of road surfaces for instance bicycle roads.

5. References

Literature list

[1] : Standardization of Salt Spreaders

[2] : Preparation, Organization and execution of Winter Maintenance

[3] : Winter, Weather and Roads

[4] : Guideline Winter Maintenance Code RWS

Terminology

RWS: Ministry of Transport, Public Works and Water Management; Directorate-General of Public Works and Water Management. RWS is responsible for (winter) maintenance on all motorways and primary roads.

DVS: Center for Transport and Navigation.

Province: The Netherlands are divided in 12 provinces. A Province is responsible for (winter) maintenance on regional and local roads.

Municipality: Is responsible for urban roads (town).

ANWB: Dutch Automobile Administration.

VCNL: Traffic Information Center.

RWIS: Road Weather Information System.

CROW: Information and Technology Platform for Infrastructure, Traffic, Transport and Public Space.

UNITED KINGDOM

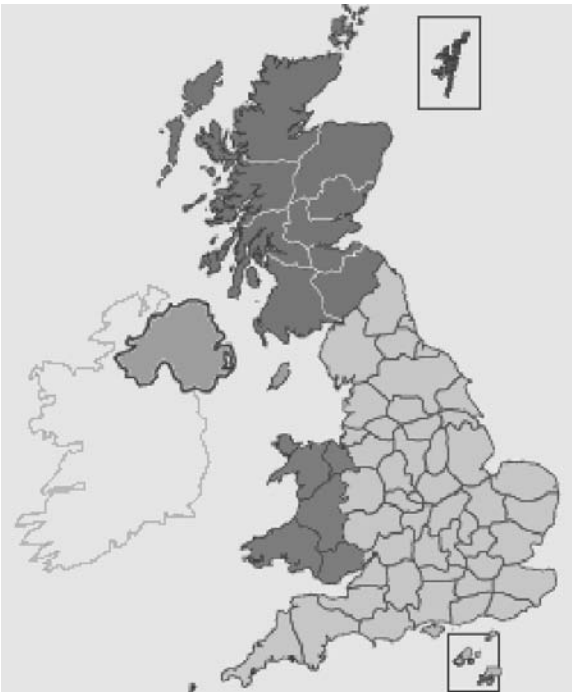
snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

The United Kingdom is made up of four countries, namely England, Northern Ireland, Scotland and Wales. The total area of the United Kingdom is 243,800 km^2, split up as follows:

- England – 130,400 km^2;
- Northern Ireland – 13,800 km^2;
- Scotland – 78,800 km^2;
- Wales – 20,800 km^2.



The physical geography of the UK varies greatly. It includes the chalk cliffs of the south coast, the rolling hills and fields of southeast England, the granite cliffs of the southwest peninsula, the mountains of Wales, the lakes and mountains of northern England, the Scottish lowlands, highlands and islands, and the fields, lakes and mountains of Northern Ireland. The 61 million population in the UK is rather unequally distributed among the four countries: 51 million in England, 2 million in Northern Ireland, 5 million in Scotland, and 3 million in Wales.

1.2 Road network and traffic

The road network in the United Kingdom comprises 14,568 km of motorway and trunk roads and 405,473 km local roads.[1] Road traffic on this network is 490 billion vehicle kilometers per year (excluding Northern Ireland).[2] Each country within the United Kingdom uses a different approach to network management.

England – The English network consists 7,300 km of motorway and trunk roads and 294,000 km of local roads. The Department of Transport delivers transport through a number of executive agencies with responsibility for the various modes of transport: The Highways Agency has responsibility for managing most of the motorway and trunk road network. Local authorities, usually County Councils, have the responsibility for managing local roads. Transport for London is responsible for all forms of public transport in London, including all roads.

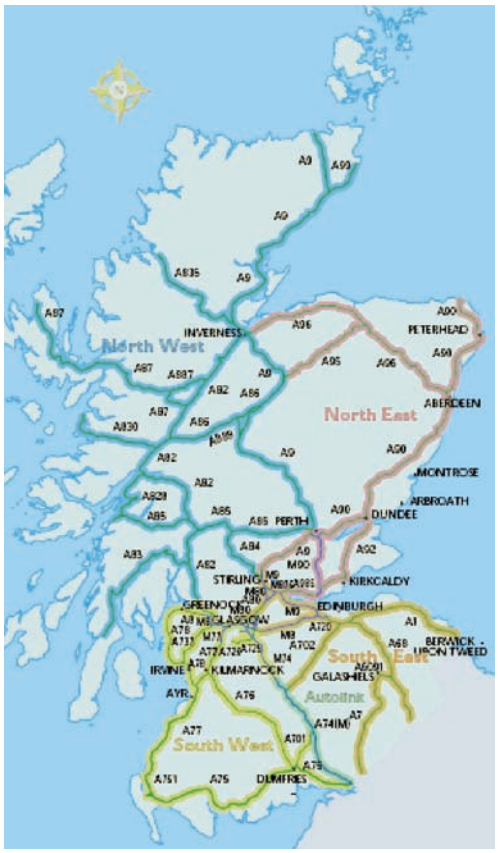
Highways Agency's Trunk Road Network (Source: Highways Agency)

UNITED KINGDOM

Northern Ireland – The Northern Ireland network comprises 2,380 km of trunk roads and 22,500 km of local roads. The Roads Service is responsible for all roads in Northern Ireland.

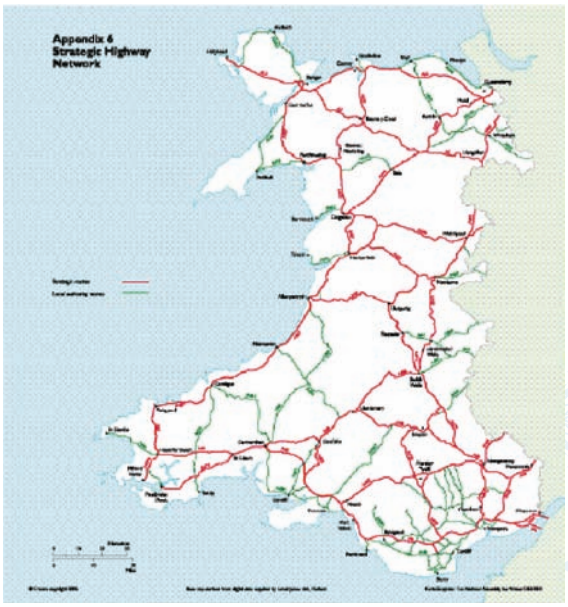
Main Salting Routes in Northern Ireland (Source: Roads Service)

Scotland – The Scottish road network comprises 3,200 km of trunk roads and 56,000 km of local roads. The Scottish Executive has the responsibility for managing major roads. The 32 local authorities have the responsibility for managing local roads.



Scottish Trunk Road Network (Source: Scottish Executive)

Wales – The Welsh road network comprises 1688 km of trunk roads and 32,173 km of local roads. The National Assembly for Wales has the responsibility for managing major roads, which comprises trunk roads, including motorways. Local unitary authorities have statutory powers and obligations for all public highways, which are not trunk roads or motorways.



Welsh Strategic Highway Network (Source: National Assembly for Wales)

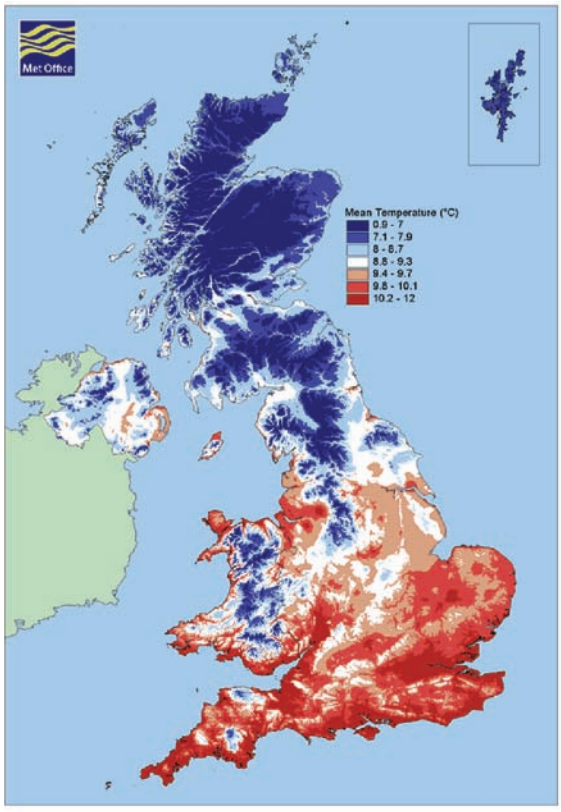
In England and Scotland management and maintenance of trunk and motorways are procured on the basis of competitively tendered contracts. Service providers are appointed to operate specific geographical areas for a period of five to seven years. In Wales this service is predominantly managed and delivered through local authority based agents. Roads Service is responsible for all roads in Northern Ireland.

2. Climate

2.1 Overview of climatic areas

The climate of the United Kingdom is classified as temperate, with warm summers, cool winters and plentiful precipitation throughout the year. The principle factors of influence on the climate include the UK's northerly latitude (which ranges from 50° to 60° N), its close proximity to the Atlantic Ocean and, especially, the warming of the waters around the British Isles by the North Atlantic Drift together with the effects of the Gulf Stream. The weather can be notoriously changeable from one day to the next but temperature variations throughout the year are small.

UNITED KINGDOM



Mean Temperature (°C)
Annual Average
1971-2000

2.2 Statistics on temperature, icing and precipitation days

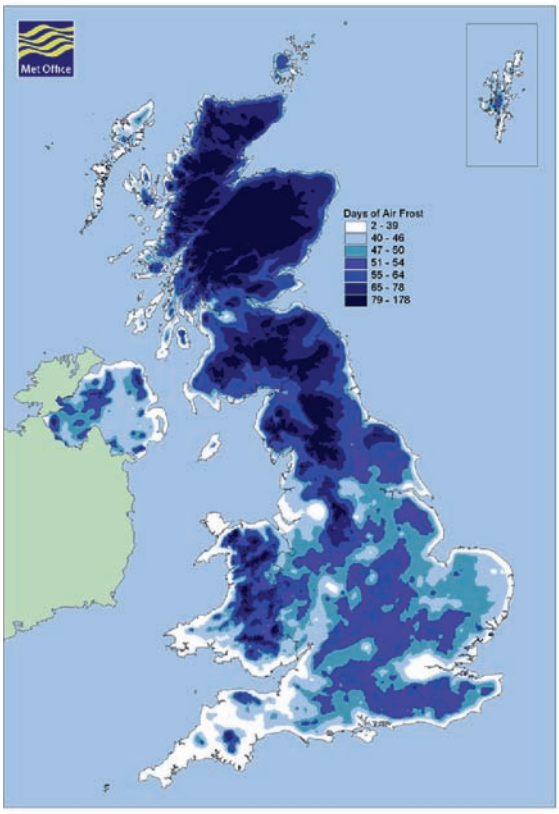
The UK is at the boundary of convergence between the warm tropical air to the south and the cold polar air to the north. In this area, the large temperature variation creates instability and this is a major factor that influences the changeable and often unsettled weather the UK experiences, where many or all types of weather can be experienced in a single day.

	Max Temp [deg C]	Min Temp [deg C]	Days of Frost [days]	Rainfall [mm]
England	13,1	5,6	49,9	838
N. Ireland	12,2	5,2	45,1	1112
Scotland	10,5	4,0	68,9	1520
Wales	12,3	5,5	49,1	1434

1971-2000 Averages (Source: Met Office)

Winter in the UK is generally a cool, wet and windy season. Temperatures at night rarely drop below -10 °C and in the day rarely rise above 15 °C. Precipitation is plentiful throughout the season with occasional snow.

Towards the end of the winter season the weather usually stabilizes with less wind, precipitation and lower temperatures. This change is particularly pronounced near the coasts mainly due to the fact that the Atlantic Ocean is often at its coldest during this time after being cooled throughout the autumn and the winter.



Days of Air Frost
Annual Average
1971-2000

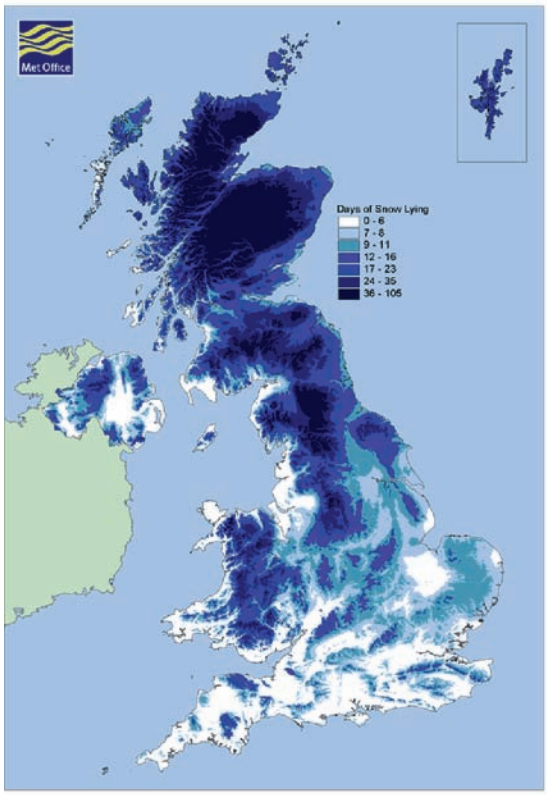
2.3 Winter indexes used in the country

In England, Northern Ireland and Scotland, the Met Office makes use of the Meteorological Office Open Road Index (MOORI). This index reports weather conditions and is typically presented in (i) long term averages of the nights of salting actions, (ii) month-by-month differences from the average, and (iii) whole winter differences from the averages, for each weather station. In addition, graphs are produced to illustrate long-term trends.

Typically in the UK there are three winter maintenance periods for normal operational purposes: (i) High Period (typically December, January and February), when severe conditions might reasonably be expected; (ii) Low Period (November and March), when severe conditions may occur; and (iii) Marginal Period (mid-September, October and April), when severe conditions are generally not expected.

UNITED KINGDOM

Local highways/roads authorities throughout the UK make use of similar classifications. These periods have an impact on the winter service cover imposed on the service providers.



Days of Snow Lying
Annual Average
1971-2000

3. Winter Road Management

3.1 Standards and rules

Highways/roads authorities in the UK have a statutory duty to maintain highways/roads with effective winter service being one element of that responsibility. The statutory basis for winter maintenance differs throughout the countries.

Highways Authorities in England and Wales have a statutory duty to "ensure, so far as is reasonably practicable, that safe passage along a highway is not endangered by snow or ice".[3] In addition, the Highways Act 1980 also imposes a duty upon authorities to remove obstructions of the highway resulting from "accumulation of snow or from falling down of banks on the side of the highway, or from any other cause".[4]

In Northern Ireland, Roads (Northern Ireland) Order 1993 requires the highway authority to remove snow and take such action, as it considers reasonable to prevent snow or ice interfering with the safe passage of persons and vehicles using the road.

In Scotland roads authorities[5] have a statutory obligation to take "such steps as it considers reasonable to prevent snow and ice endangering the safe passage over public roads."[6]

The Highways Agency in England aims to provide a winter service, which as far as possible, allows the safe movement of traffic on motorways and all-purpose trunk roads in England, and keeps delays and accidents caused by adverse weather to a minimum. The winter maintenance procedures in England are set out in the Network Management Manual and the Routine and Winter Service Code, including the requirements and advice for winter service on the trunk road network.

The Welsh Assembly Government Trunk Road Maintenance Manual; Part 4: Winter Maintenance sets out the requirements and the advice of the National Assembly for Wales [Transport Wales] for winter service activities on motorways and all-purpose trunk roads which are within the responsibility of the Assembly, whereby top priority is given to the motorways and the more important all-purpose trunk roads.

3.2 Organization and operation of winter maintenance

The budget for winter service on roads in the United Kingdom is an estimated £150 million per annum. Wales spends approximately £4 million on motorways and trunk roads winter service during an average winter, while Scotland's £5 million expenditure on winter service which represents around 4% of overall spend on their network. Approximately £5 million is spent on the winter service operation each year in Northern Ireland.

Both the English and Welsh trunk road maintenance manuals outline roles, responsibilities, operational purpose and techniques, application of salt and alternative de-icers, use of maintenance plant and equipment, liaison and communication.

Roles and Responsibilities

The Highways Agency (England), the Roads Service (Northern Ireland), the Scottish Executive and the National Assembly for Wales [Transport Wales] are responsible for setting the overall policy on the provision of winter services on the motorway and trunk road network. The service providers and maintenance agents normally undertake the operational management of the service and provide the necessary labor, plant and materials except for the specialized motorway plant provided to them (except Scotland).

UNITED KINGDOM

Service providers and highways/roads authorities throughout the UK typically prepare a severe weather/winter service plan updated annually, which describes the policy, objectives, procedures and operational arrangements. This document is often made widely available so that local residents, transport firms and local industries may be informed of the level of service to be expected. In addition, the document details unique local conditions and how a satisfactory level of service will be provided, while at the same time complying with local, regional or national specific legislation.

Operational Purpose and Techniques

The operational arrangements within the severe weather/winter service plan define the precautionary pre-treatment network, the preparation, the dedicated spreading and snow-clearance plant, strategically sited stocks of de-icing agents, ice/snow prediction and monitoring, action/operational procedures for the treatment of ice and snow, defined procedures for public information/media coverage, and monitoring the effectiveness of action.

Pre-treatment is undertaken on all the major routes of the network and provides the most effective way of ensuring the safety of these routes where the majority of vehicle movements take place. The definitions and criteria applied to determine the precautionary pre-treatment network vary considerably between countries and highways/roads authorities. The precautionary pre-treatment network will typically comprise a maintenance category priority order as indicated in the following table.

Maintenance category	Road type	Function
1	Motorways	Major road
2	Primary national trunk	Major road
3	National primary	Major road
4	Primary county	Interurban and
5	Secondary county	through routes

In addition to defining the network on a maintenance category basis, consideration is given to the criteria such as traffic flows, settlement population, emergency premises, adjoining highway authority salting networks with respect to lower road categories and important facilities for cycling and walking.

Treatment route optimization exercises are carried out to maximize efficiency and ensure coordination with other routes. This exercise improves the targeting of pre-treatment operations and minimizes inappropriate treatment on marginal weather forecasts by determining action on a route-by-route basis. The precautionary pre-treatment network is typically denoted on a map. In addition, route cards and maps are produced for each precautionary spreading route and copies retained in the assigned spreading vehicles at all times. The precautionary spreading network is reviewed annually to reflect developments, improvements and changes in traffic patterns.

Highways/roads authorities and service providers define the planned winter service operations by late summer. The issues typically discussed at the winter preparation operations and pre-winter meetings are preparation of winter service plant and equipment, calibration of road weather sensors, plant and equipment, certification of plant operatives, preparation of winter service cover, de-icing agents stocks, contact/stand-by systems and rotas.

The Application of Salt

The management of the salt stock and its replenishment is an essential element of effective winter service. Minimum holdings are specified for each depot, which can be varied over the winter period. The salt stock levels are generally based on historical information and are sufficient to cope with an average winter and are topped up should extreme weather conditions occur.

The use of salt barns, which is becoming more widespread across the UK, ensures that salt is maintained with low moisture content, preventing leaching and allowing easier handling of the salt.

The quality, chemical composition and uniformity of salt are important to ensure control of the rate of spread. Rock salt is used by most organizations in preference to vacuum and marine salt, mainly on the basis of cost. Generally, a fine grading of rock salt is used for precautionary salting due to reduced vehicle damage and a more uniform spread on the carriageway together with minimizing overspread and contamination of adjacent vegetation.

UNITED KINGDOM

Type and grade		BS410 test sieve	% passing
Rock salt	Coarse	10 mm 6.3 mm 2.36 mm 300 µm	100 75-95 30-70 0-20
	Fine	6.3 mm 2.36 mm 300µm	100 30-80 0-20
Vacuum salt and marine salt	Coarse	10 mm 1.18 mm 150 µm	100 0-80 0-10
	Fine	1.18 mm 150 µm	100 0-30

Grading of Salt (BS3247)

In 2008 the Highways Agency in England began a four year procurement of a fleet of new winter vehicles capable of spreading pre-wetted salt. Tanks fitted to the sides of the bodies on the new vehicles carry brine, which during treatments, is mixed with dry salt in measured proportions, to create the optimum blend (typically a 70:30 ratio, dry salt to brine). This pre-wetted salt is spread onto the surface of the road in a similar manner as if carrying out purely dry treatments.

The Use of Maintenance Plant and Equipment – The serviceability of the winter service plant is crucial to the effectiveness of operations. It is therefore essential to operate a well-maintained fleet of spreading vehicles.

There is a vast selection of plant and transport available for highways/roads authorities with which to discharge their winter service responsibilities. The topography and needs of each country and area is unique and it follows that this will create the need for a particular range of equipment in order to fulfill its function and the requirements. The choice in size and type of vehicle used depends on the character of the road network and length of salting route.

The new Highways Agency vehicles were procured through two companies: Romaquip and Schmidt. The Romaquip spreader body is constructed almost entirely from stainless steel. The benefits of this construction include reduced maintenance and increased operational life. The Schmidt vehicle is equipped with a Stratos modular hopper with a powder-coated finish (electrostatic spraying and baking) which is an advantage for work in the harsh winter environment. Both vehicles are currently on MAN Euro IV chassis. As the procurement of the new spreaders continues into 2011, new chassis will operate on Euro V engines.

Careful consideration is given in regard to resources requirements to react to heavy snowfalls. Purpose built four or six wheel drive spreading plant is assigned to high ground or routes with significant gradients where increased traction and pushing power are essential in the event of heavy snowfall. Provisions are made for reserve snowplows to be available to provide support and give cover in the event of damage to front-line equipment.

Where precautionary treatment shall be insufficient to prevent ice or snow remaining on the trunk road, further treatment including salting, plowing and/or snow blowing is carried out to restore all roads to a safe condition and expose the original surface as soon as reasonably practicable. Snow is plowed when the snow depth exceeds 30 mm. Each pass of the plow is supplemented by salt spread generally in accordance with the table below.

ROAD SURFACE CONDITION	AIR TEMP	TREATMENT			
		Spreading (grams/metres²)		Ploughing	Blowing
		Salt			
Ice formed	Below minus 5°C and stable	20 to 40		No	No
Snow covering exceeds 30mm	Below minus 5°C and stable	10		Yes	No
Snow covering exceeds 30mm	Below minus 5°C and dropping	10 to 40		Yes	No
Snow accumulations due to prolonged falls	Below minus 5°C and stable	20 to 40		Yes (continuous)	Where applicable
Hard packed snow/ice less than 20mm thick	Above minus 5°C	20 to 40 (successive)		No	No

Ice and Snow Clearance Treatment Rates (Source: Scottish Executive)

In severe snow situations highways/roads authorities also make use of snow blowers, which are either self-propelled or de-mountable units. In Scotland where heavy snowfalls are a regular occurrence each year the self-propelled units are essential. The modern blower is powerful and capable of moving a high volume of snow.

Calibration is essential to providing an efficient winter service operation and attention is given to the tests ensuring that each vehicle is achieving the correct spread rate and width of spread within defined parameters. The calibration of equipment is carried out in advance of the expected first frost.

UNITED KINGDOM

Road Weather Information Systems

All highways/roads authorities throughout the United Kingdom make use of road weather information systems.

For example, on the English Trunk Road Network, the weather forecasting and ice prediction are provided through two separate contracts: weather forecasting is procured by individual service providers and ice prediction services are procured centrally by the Highways Agency. There are over 200 weather stations on the Highways Agency's network gathering weather data every 20 minutes throughout the winter months. This data is fed via a bureau service to the forecasting organizations that combine the current condition data with their own forecast models to provide detailed site-specific forecasts. The service providers use this information to determine their treatment method and more importantly the timing.

Vaisala – Road Weather Systems

Accurate prediction of ice and snow is a key factor in facilitating efficient winter service operations, minimizing abortive salting works while keeping the network as safe as possible. Highways/roads authorities make considerable investment in the very latest technology to provide the means for accurate prediction so that appropriate winter action is taken.

Prediction of freezing temperatures and snow is typically made by interpreting information from:

Weather Forecasts

There are two basic types of weather forecasts, area and site specific. Area road weather forecasts are plain text forecasts, which cover the whole area of operation of that particular highways/roads authority/Service Provider. The information is similar to a traditional type of weather forecast, such as seen in a newspaper or on the Internet, with the exception that all weather described is related to conditions on the road network. Site-specific weather forecasts are for a single point on the road surface. Site-specific forecasts are normally provided for locations where a road sensor exists. This means easier monitoring and verification than traditional weather forecasts.

Thermal Mapping

Thermal mapping of a road network identifies temperature profiles and particular problem areas, different climatic zones and helps inform the location of ice prediction sensors. A thermal map can be used to extrapolate information from specific sensors to the whole network.

Road surface temperature varies in both space and time. It is dependent on certain fixed factors such as altitude, topography, road construction and sky-view factor and on variable factors such as traffic density and weather conditions. Since thermal mapping is expensive it is important to consider the benefits. Consideration is being given to moving to a dynamic thermal map to take better account of the variables.

Predictive Radar (when and where available)

Weather satellite information is useful to determine the movement of weather systems in the assessment of a possible extended period of adverse weather and determination of cloud cover, which is highly relevant when forecasts are marginal. While, in its basic form, weather radar will only indicate precipitation (rainfall) intensity, other recently developed composite systems will provide a forecast of precipitation type. Radar can also help to define treatment time.

3.3 Assessment of the snow & ice control measures

Snow & ice control measures are typically included within the winter service plan. Local highways/roads authorities within the United Kingdom work to a Best Value business principle. A range of performance indicators (PI) are used to monitor winter maintenance.

Examples of performance indicators are:

Objective: PI:	Compliance with response time for leaving the depot Number of late departures; 100% compliance expected.
Objective: PI:	Compliance with response times for completing the routes. Number of late arrivals; 100% compliance expected.
Objective: PI:	Receipt of the service provider's diary. Number of diary entries received after the agreed time limit as a percentage of total winter service diary entries.
Objective: PI:	Receipt of the winter service order. Number of orders received after the agreed time limit as a percentage of total winter service orders.
Objective: PI:	Average cost to salt per kilometer. Cost per winter service season.

Auditing the service can be undertaken in two different and separate forms. The first is by desktop, through analyzing written records such as tachographs, computer printouts (possibly involving GPS), salt diaries, confirmation of call-out, driver training records, quality assurance operating procedure/winter service manual, and salt management records for the individual salting routes. The second is on-site, by carrying out random inspections to check that salt is being placed on the network at the correct time and in the right manner. A comprehensive record must be kept for each audit.

An important part of road weather information systems is to record base data in order to be able to assess the value of the forecasts. In general, it can be said that a road weather forecast has value if a correct decision is taken which prevents the formation of ice or snow accumulation on roads and/or a correct decision is taken which prevents the use of unnecessary de-icer applications. However, assessing value is complicated by external factors such as the residual de-icing chemical on the road and political considerations, which can bring about unnecessary treatments.

In order to judge the value in a forecast it is best to look at forecasts of road frost. This is usually done using a 2x2 contingency table, which compares the forecast against the actual.

Two by two contingency table

	Frost forecast	No frost forecast
Frost occurred	Protection cost: (F/F)s	Damage cost: (NF/F)s
No frost occurred	Protection costs: (F/NF)	Correct rejection: (NF/NF)

By assigning financial values to these contingencies it is possible to derive a measure of value from the forecast. Using the contingency table there are a number of derived variables which can be produced:

- Percentage correct;
- Probability of detection;
- False alarm rate;
- Frost frequency.

The Highways Agency in England makes use of the following winter service measures:

- Gritting run performance, which measures response times;
- Occurrence of frost;
- Performance Audit Method Salt (PAMSALT), which is concerned with the proactive and reactive salting of the roads and the relative decision making performance of service providers.

3.4 Traffic safety and information

Contact through the media is important as a means of keeping the road user informed of adverse conditions and promoting safety on the highway.

Through this contact with the community and road users, the operations are more effective, better understood and promote a positive interchange of views with the public. Highway/roads authorities therefore make use of several means of communication which include:

- Leaflets on ways motorists can help to improve road safety;
- A plan of the spreading network;
- Press releases relating to winter service and particular highway incidents;

- Press articles;
- Press/radio/television interviews;
- Information passed through motoring organizations and local radio stations.

For the English Trunk Road Network, weather and road condition information is distributed to the media and our customers from the Highways Agency's National Traffic Control Centre (NTCC) in Birmingham. During the winter months weather forecasters are stationed in the NTCC to ensure that we can provide early warning of severe weather and give targeted advice about safe driving and road conditions regionally or nationally as appropriate.

Highways Agency's National Traffic Control Centre

In the 2003/2004 winter season the Highways Agency introduced a web-based winter reporting system in England, which provides the Highways Agency management team, Ministers and the Press Office with information on the state of the network and weather-related incidents. The winter reporting system also ensures that adjacent service providers, local authorities, Police, and Highways Agency area teams are aware of winter service decisions. The service providers have a minimum requirement to report on the state of the network and treatment decisions at 8:30am and 3:00 pm each day. In addition, the service providers are to give an assessment of the weather forecast and their intended winter service action for the weekend before 3.00 pm on Friday.

In Northern Ireland, information on salting activities is relayed electronically to the broadcast media to ensure that the latest news on road conditions is available to motorists prior to peak travel periods.

In Scotland, the Scottish Executive operates the National Driver, Information and Control System (NADICS) from the National Network Control Centre in Glasgow. The principle functions of the system are to monitor, control and inform. A weather bulletin board is included on the NADICS website which details the conditions on the trunk road and where known the local road network.

The information on the bulletin board is populated by the 8 Police Forces in Scotland, the trunk road maintaining organizations and the NADICS operator. In addition, the NADICS operator receives weather forecast information direct to the Control Centre which allows him to make informed decisions with regard to strategic Variable Message Sign (VMS) legend setting and advise motorists in-trip of severe weather warnings that may affect their journeys.

In Wales, the National Assembly for Wales promotes the service providers to develop effective liaison and communications with Police, media, emergency services, public transport operators, freight transport, and haulage and automobile associations directly in order to avoid extended chains of information.

4. On-going Research and Studies to Improve Winter Management

4.1 Advances in spreader technology

Since the mid-1990s organizations throughout the United Kingdom have been seeking to reduce salt usage through the integration of new technologies, such as global positioning system (GPS), geographical information systems (GIS), digital radio communications and forecast thermal mapping. Experimentation through recent research and development projects in the United Kingdom has demonstrated that selective salting is both possible and desirable. The possibility to start and stop gritting also provides the possibility of varying the spread rate along the route in accordance with the forecast thermal map temperatures. The next logical step would be to provide real-time weather data captured by the vehicle as it travels along the route and this is now possible through the spreaders reading and recording road surface temperatures whilst carrying out their route.

The Highways Agency's new winter fleet in England is equipped with a data logging capability which provides a facility for real time data capture. The amount of salt spread, spread width, material type, time taken to complete the route, and, fuel usage are examples of some of the elements that data logging can capture. The use of data logging further aids the Highways Agency and its Service Providers to monitor salt usage and spreader driver behavior, thus improving the sustainability of the winter service provided.

UNITED KINGDOM

4.2 Alternative materials

During the 2008/2009 winter season the Highways Agency has carried out trials on its network using pre-wetted salt with nominal dry salt size of 6.3 mm in order to compare the levels of residual salt for each material. Further trials are to be carried out to assess the effectiveness of salt treated with an agricultural by-product (ABPs) when compared to untreated rock salt.

As part of the drive to reduce salt usage the Highways Agency is looking at the suitability of brine only treatments. Brine is particularly suitable for precautionary treatments on marginal nights which can be typical due to the weather patterns in much of the United Kingdom. The economical and social impact of winter treatments is being assessed by trials to measure the corrosive effect of various de-icers on highway assets. In addition, work into the environmental effects of winter treatments also continues.

4.3 Road weather information systems

Following a review of the procurement of the existing road weather information system, in England the Highways Agency has identified a need to review the existing arrangements for the provision of all year round weather information. Work is currently ongoing to establish the make-up of a new system, presently called the Highways Agency Weather Information Service (HAWIS) which will build upon the successful current system.

During 2008 an extensive stakeholder communication exercise, with a wide range of users, took place in order to establish what the new system should include. It is proposed that the new contracts will be designed to enhance competition in all areas of the system and provide a best value solution. In the longer term there is the potential for other weather related information to be included as part of HAWIS. In it envisaged that the first phase of the new service will be in operation by October 2010.

4.4 Residual salt measurement

Within the United Kingdom research is ongoing into measuring residual salt on the road surface. Currently road inspections confirm whether there is sufficient residual salt on the road to deal with the current conditions. There is a great possibility in the future that the measurement of residual salt on road surfaces might take place through intelligent systems.

---

1 Transport Statistics for Great Britain (TSGB) 2004; 3

2 Northern Ireland Transport Statistics 2003-2004; Transport Statistics Scotland 2003

3 Section 41 (1A) of the Highways Act, 1980; Section 111 of the Railways and Transport Act 2003; Section 150 of the Highways Act 1980

4 Section 150 of the Highways Act 1980

5 In Scotland, the terminology used is 'road' instead of 'highway'.

6 Section 34 of the Roads (Scotland) Act 1984

UNITED STATES

snow and ice databook 2010

1. Demographics and Roads

1.1 Information about the country

The United States of America is a federal system with 50 states, the District of Columbia, and numerous local governments within each state. The Federal Highway Administration (FHWA), within the national executive branch, neither operates nor builds highways, but administers over $26 billion per year of federal-aid highway funds to states and localities, primarily for capital expenditures. The total expenditure for highways is over $118.3 billion per year, mostly funded by state and local governments (3).

The total area of the United States is over 9.1 million square km. More than 81% of this land (or 7.4 million square km) is in snowy regions, which receive more than 13 cm of average snowfall per year. The population of the United States exceeds 304 million people (17). Nearly 71% of Americans (or more than 215 million people) live in snowy regions.

1.2 Road network and traffic

The road network consists of more than 6.4 million km of highways. Over 262,000 km of the road network are part of the National Highway System, which is comprised of interstate expressways and primary roads. There are over 1.3 million km of other federal-aid highways and more than 4.9 million km of non-federal-aid highways. On average, each vehicle travels more than 19,300 km each year. Nearly 235 million passenger vehicles (cars and light trucks) use U.S. highways to commute to work, for personal business, or for recreational travel (3). More than 3 million commercial vehicles use the highways, with about 1.1 million being long-distance freight haulers (10).

Area	Total	9,161,979 km^2
	Snowy regions	7,447,614 km^2
Population	Total	304.06 million
	Snowy regions	215.79 million
Road Length	National Highway System	262,809 km
		Snowy regions 195,626 km
	Other Federal-Aid Hwys	1,320,998 km
		Snowy regions 958,957 km
	Non Federal-Aid Hwys	4,900,125 km
		Snowy regions 3,678,426 km
	Total	6,483,932 km
		Snowy regions 4,833,010 km
Latitude (capital)		39°N

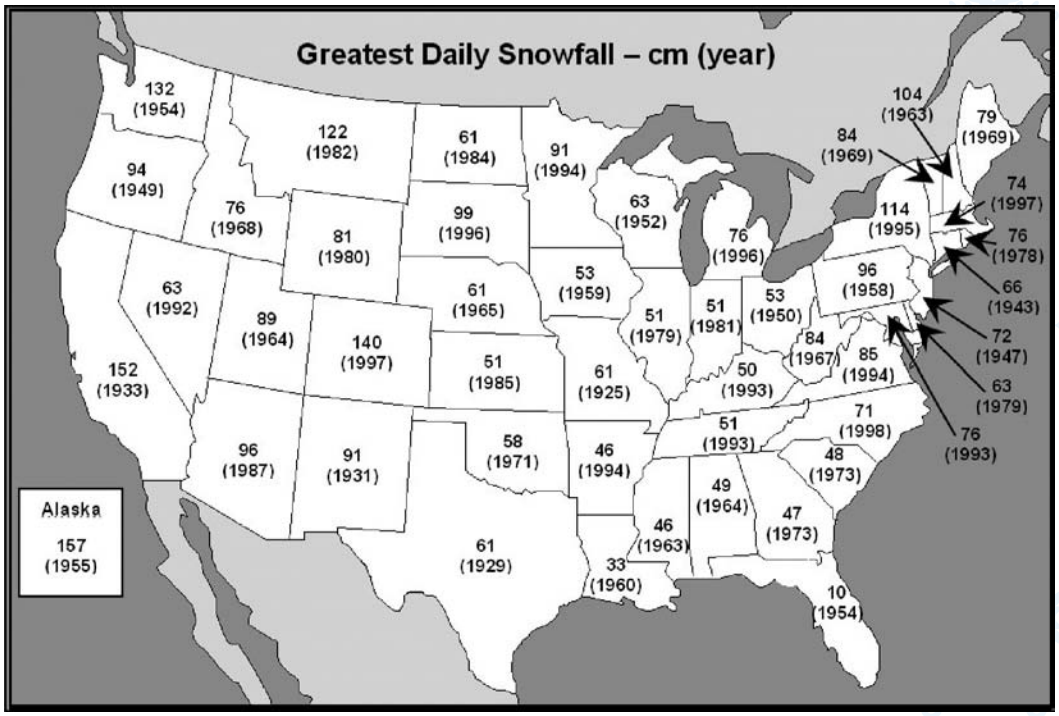
Winter weather has a significant affect on traffic flow, road safety, and agency productivity. It has been estimated that 23% of the non-recurrent delay on highways across the nation is due to snow, ice, and fog. This amounts to an estimated 544 million vehicle-hours of delay per year. Snow-covered and icy pavement also caused significant delay. Each year, approximately 2,200 people are killed in crashes during snowfall and sleet or in crashes on pavement covered with snow, slush, or ice. Approximately 192,500 people are injured in these crashes annually. Winter road maintenance accounts for roughly 20% of state transportation agency maintenance budgets. Each year, state and local agencies spend more than $2.3 billion on snow and ice control operations (2).

UNITED STATES

2. Climate

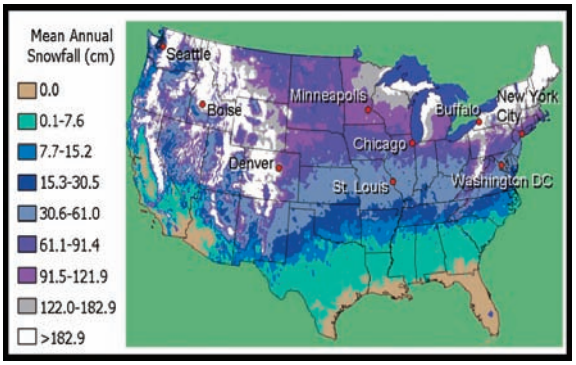
2.1 Overview of climatic areas

The United States has a variety of climates due to significant terrain differences, its proximity to large water bodies and a large land area between its northern border and the Polar regions that allows arctic air to migrate south in the winter with minimal moderation. The 48 contiguous United States (CONUS) are climatically different from the northern State of Alaska, and the semi-tropical State of Hawaii in the Pacific Ocean. The snow extremes in the CONUS, depicted in the Greatest Daily Snowfall map, are primarily in mountainous areas with low population densities and few roads, but with many critical mountain passes. There are large metropolitan areas in all regions. However, the Northeast and Midwest have both large populations and considerable snowfall due to lake effect snow and coastal cyclones.

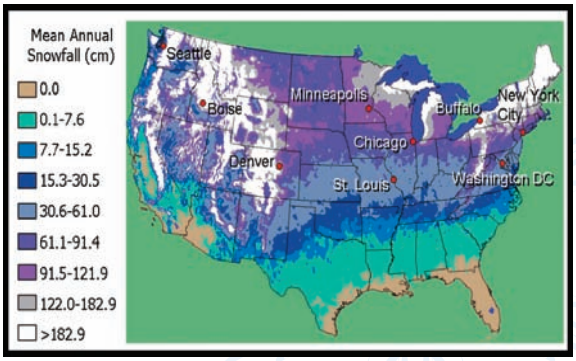


Greatest Daily Snowfall Map

As shown in the Mean Annual Snowfall maps, geographical factors create large differences in average snowfall. Most states experience significant snowfall. The exceptions are located along the southern tier of the CONUS along the Gulf coast, the southwestern deserts, the Pacific coast and Hawaii. Ice without snow can also form on roads, especially in more temperate and coastal areas.



CONUS Mean Annual Snowfall Map



Alaska Mean Annual Snowfall Map

UNITED STATES

2.2 Statistics on temperature and precipitation

Table 1 lists temperature and precipitation statistics for the 10 U.S. cities depicted on the Mean Annual Snowfall maps (9).

Location	Normal Daily Minimum Temperature (Degrees C)				Normal Monthly Snowfall (cm)				Normal Annual Snowfall (cm)	Normal No. of Days: Snowfall >2.5 cm	Max. Snowfall in 24 hours (cm)	Max. Snow Depth (cm)
	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar				
New York, NY	-0,2	-3,2	-2,2	1,7	6,6	20,6	19,3	8,1	56,9	6	67,1	55,9
Buffalo, NY	-4,7	-7,9	-7,4	-3,3	64,8	66,3	45,2	9,1	246,4	27	96,3	111,8
Washington, DC	0,0	-2,6	-1,3	2,9	3,8	15,7	13,2	4,1	38,6	4	47,5	55,9
Chicago, IL	-6,4	-9,8	-7,1	-1,9	22,1	28,7	21,1	15,2	96,5	12	47,2	71,1
Minneapolis, MN	-11,7	-15,4	-11,2	-4,7	25,4	34,3	20,8	26,4	142,0	17	53,3	96,5
Saint Louis, MO	-3,4	-6,0	-3,1	2,3	12,4	18,8	12,2	8,4	57,2	6	35,3	50,8
Denver, CO	-8,7	-9,3	-7,2	-3,7	22,6	19,6	16,0	29,5	154,9	18	59,9	158,0
Boise, ID	-4,4	-4,7	-1,8	1,1	16,3	12,4	8,4	3,8	49,5	7	33,0	33,0
Seattle, WA	2,2	2,2	2,9	3,9	6,4	6,1	3,3	1,5	20,6	3	54,4	53,3
Anchorage, AK	-11,4	-12,6	-7,7	-1,8	37,8	22,9	27,9	26,2	176,5	20	55,9	2,301,2

Table 1 – Temperature and Precipitation Statistics for 10 U.S. Cities

2.3 Winter indexes used in the country

Several state Departments of Transportation (DOTs) have developed or adopted winter indexes (15). The Indiana DOT has developed a winter index for each of four winter climatic zones in the state. They have also developed a state-wide index. Indiana's indexes use seven weather factors including frost day, freezing rain, drifting snow, amount of snowfall, snow depth, storm intensity (or duration), and average temperature during the event. Indiana DOT plans to use the indexes to analyze winter severity and compare snow and ice control efforts in different climatic zones.

$$WI = 0.71839 * Frost + 16.87634 * FreezingRain + 12.90112 * Drifting - 0.32281 * Snow + 25.72981 * SnowDepth + 3.23541 * Hour - 2.80668 * AverageTemperature$$

The Washington State DOT uses a frost index, which is a winter index without a snowfall factor. The frost index is related to performance measures for snow and ice control strategies. When the winter road maintenance budget is exceeded, the DOT plans to use the frost index to help justify requests for additional funding.

The Wisconsin DOT uses a winter index with five weather factors including snow events (SE), freezing rain events (FR), snow amount (AMT), storm duration (DUR), and incidents (INC) such as drifting, cleanup, and frost runs. The Wisconsin winter index is used to classify the type of winter and to evaluate expenditures and performance.

$$WI = 10 * \frac{SE}{63} + 5.9 * \frac{FR}{21} + 8.5 * \frac{AMT}{314} + 9.4 * \frac{DUR}{1125} + 9.2 * \frac{INC}{50}$$

The Kansas DOT and the Minnesota DOT have adopted a winter index developed by the Strategic Highway Research Program (SHRP). Weather factors in the SHRP index include mean daily snowfall (S), proportion of days with air frosts (N) (that is, days with maximum air temperature at or below 0 °C), temperature range (R), and an average daily temperature index (TI). The temperature index is 0 if minimum air temperature is above 0 °C, 1 if maximum air temperature is above 0 °C while minimum air temperature is at or below 0 °C, and 2 if the maximum air temperature is at or below 0 °C.

$$WI = a(TI)^{0.5} + b\ln\left(\frac{S}{10} + 1\right) + c\frac{(N)^{0.5}}{R + 10} + d$$

UNITED STATES

3 Winter Road Management

3.1 Standards and rules

Because of the allocation of maintenance to state and local governments, there is no national policy for winter road maintenance in the U.S. State and local governments may operate their own maintenance equipment, hire contract services, and establish their own Level of Service (LOS) goals. Level of Service may be based on pavement condition goals, traffic levels, or customer satisfaction. Winter road maintenance efforts vary based on climatic conditions, agency resources, and roadway characteristics. Higher classes of highways generally receive more attention. Routes on the National Highway System are typically cleared more completely and quickly. Critical areas like mountain passes may have snow-chain requirements for vehicle tires, and many local streets are designated "snow emergency routes" that must be cleared of parked cars during snow events.

In the United States, winter road maintenance involves controlling snow and ice through mobile techniques or fixed systems. Mobile snow and ice treatment strategies include plowing snow, spreading abrasives (such as sand, ash, and crushed stone) to improve vehicle traction, and dispensing anti-icing/deicing chemicals to lower the pavement freezing point and minimize bonding of snow and ice to pavement surfaces. These strategies are often used in combination. In regions with heavy snowfall, maintenance managers may also erect snow fences adjacent to roads to reduce blowing and drifting snow. (13)

Surveys by the American Association of State Highway and Transportation Officials (AASHTO) Lead States Program have found that nearly 40 states use anti-icing strategies. In addition to mobile anti-icing/deicing operations, 23 states have deployed fixed anti-icing/deicing systems on bridges, sharp curves, and other locations prone to icing (15). These fixed systems typically consist of a controller, tanks, pumps, conduits, and nozzles that dispense anti-icing chemicals on a predetermined area of pavement. Chemical applications can be activated manually or automatically based on Environmental Sensor Station (ESS) data.

Fixed Anti-Icing Spray System
(Photo courtesy of CRYOTECH Deicing)

Several types of snow and ice control materials are used in the U.S. including solid chemicals (dry and prewetted), liquid chemicals, abrasives, as well as abrasive and chemical mixtures. Chemicals used include sodium chloride, calcium chloride, magnesium chloride, calcium magnesium acetate, potassium acetate, calcium acetate, and magnesium acetate; with sodium chloride being the most prevalent. Snow and ice control material application rates depend on conditions (such as weather, pavement, and traffic) at the time of treatment and on how conditions are expected to change prior to the next treatment (15). Abrasive application rates range from roughly 140 kg to 419 kg per lane km with the average being approximately 224 kg per lane km. Application rates for solid and liquid chemicals vary based on pavement temperature ranges, dilution potential, and ice-pavement bonding. The National Cooperative Highway Research Program (NCHRP) has developed general guidelines on the use of treatment materials and application rates (7).

Solid treatment materials are often applied to roads by maintenance vehicles equipped with spreaders, which typically dispense free-flowing granular materials across a width ranging from of one to twelve meters. In many cases spreader operation is automatically adjusted based on vehicle speed. Liquid treatment chemicals are usually applied with vehicle-mounted spinners or spray nozzles. Different types of hydraulic snowplows are used including one-way front plows, reversible plows, deformable mouldboard plows, underbody plows, side wings, and plows designed specifically for slush removal. (15)

UNITED STATES

Several states have demonstrated and tested advanced winter maintenance vehicles and new maintenance vehicle management systems (15). Snowplows equipped with environmental sensors, as well as Automated Vehicle Location (AVL) and Global Positioning System (GPS) technologies are being used to monitor air and pavement temperatures, observe pavement conditions, track vehicle locations, monitor vehicle systems (such as plow position, material application rate), and monitor road treatment activities. Central computers provide map-based displays for managers who can plan treatment strategies, monitor winter maintenance operations, or conduct post-event analyses. Central managers can also communicate with plow drivers via in-vehicle devices with integrated display and communications capabilities. Thirteen state agencies equip a portion of their snowplow fleet with AVL/GPS technologies and sensors to track distribution of chemical treatments (18).

Highway Maintenance Concept Vehicle

Other advanced snowplow technologies include heads-up displays that delineate the roadway when visibility is reduced by fog or blowing snow. These technologies can help snowplow drivers determine their lane position, warn of objects and obstacles in front of and behind the vehicle, and increase safety by reducing the frequency of snowplow-related crashes. (15)

3.2 Organization and operation of winter maintenance

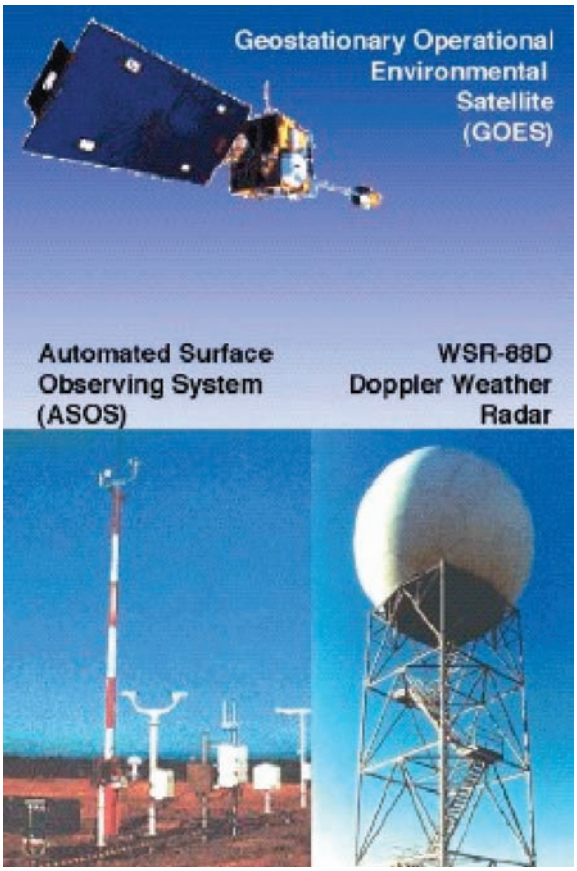
In the United States, winter maintenance is decentralized since roads are owned and operated by state and local agencies. State and local governments fund and perform snow removal and ice control activities or contract with private entities for these services. State and local capital expenditures for roads are more than $57.5 billion annually. Maintenance and operations are over $31.8 billion, of which costs for winter road maintenance are over $2.7 billion per year (3). One third of winter road maintenance expenditures are for treatment materials (10).

Regional differences between average and extreme snowfall create differences in how road maintenance agencies respond to winter weather, from continual and routine treatment to occasional and emergency response for infrequent events. In some states, maintenance agencies coordinate with traffic management agencies to close roads during snow and ice control operations, impose lower speed limits during inclement weather, or restrict travel to vehicles with snow tires or chains (13).

The 50 states coordinate through AASHTO's Snow and Ice Cooperative Program (SICOP) for implementation of advancements and training. SICOP has developed an interactive Road Weather Information System (RWIS)/Anti-Icing training program. This computer-based program consists of seven lessons including Introduction to Anti-Icing and Winter Maintenance, Winter Road Maintenance Management, Winter Roadway Hazards and Principles of Overcoming Them, Weather Basics, Weather and Roadway Monitoring for Anti-Icing Decisions, Computer Access to Road Weather Information, and Anti-icing Practice in Winter Maintenance Operations. The national training program is being used by 90% of Snow Belt states, the Association of Public Works Association (APWA) and the National Association of County Engineers (NACE). In April 2003, both generic and customized versions of the computer-based training program were distributed to users. Customized versions are tailored to the specific methods, equipment, policies and procedures, and chemicals used in a specific state. (15)

Maintenance personnel use road weather information to assess the nature and magnitude of environmental threats, make decisions about road treatment strategies, and manage resources (that is, staff, equipment, and materials) (13). State and local agencies use various sources to obtain road weather observations and forecasts including the National Weather Service (NWS), private sector meteorological service providers, RWIS, and thermal mapping. The NWS is a federal agency operated under the National Oceanographic and Atmospheric Administration (NOAA). The NWS is chartered with weather forecasting; issuing storm warnings; disseminating weather and flood warnings for the benefit of agriculture, commerce and navigation; and taking meteorological observations to record the climatic conditions of the United States. In practice, the NWS provides general weather information and warnings for public safety. NWS products include observations from surface sensors (such as ASOS), Doppler radars, geostationary and polar satellites; national forecasts and numerical model guidance from the National Centers for Environmental Prediction (NCEP); as well as regional forecasts and warnings from 125 Weather Forecast Offices and 13 River Forecast Centers.

UNITED STATES

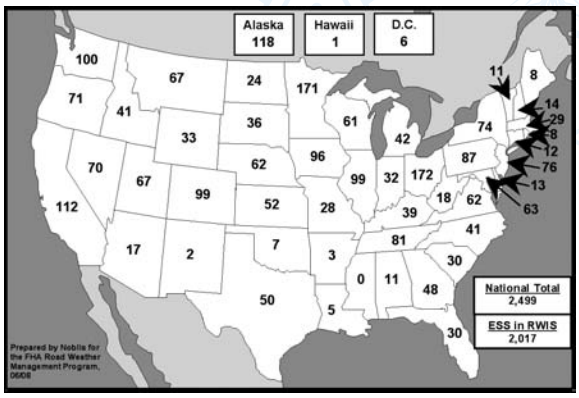


Environmental Observing Technologies

Generally, the observations provided by the NWS are inadequate for characterizing details of the road environment such as pavement conditions and localized visibility conditions. Because it is not the mission of the NWS to provide customized forecasts to support operational decision making, tailored road weather information is typically provided by private VAMS who are contracted for route-specific "nowcasting" and forecasting services.

NOAA has embraced surface transportation weather by establishing a Surface Weather Program in its Commerce & Transportation Goal Team, a component of the agency's budgeting process. Additionally, NOAA has added Surface Transportation Weather to its strategic plan. Under this goal, NOAA is partnering with the FHWA Road Weather Management Program to improve safety and make more efficient the movement of people and goods on the Nation's highways. In 2007, NOAA and FHWA conducted the 3rd National Surface Transportation Weather Symposium to provide a forum for members of the surface transportation operations, research, and user communities to work together to enhance collaboration and partnerships to improve surface transportation weather products and services for those individuals who use, operate, and manage the United States' surface transportation infrastructure (11).

The FHWA has been active in trying to integrate observations from state-owned Environmental Sensor Stations (ESS) with NWS surface observations. ESS are deployed along roadways and other transportation facilities to provide their agencies with observations of surface weather and pavement conditions. Most ESS are deployed as the field components of RWIS (16). RWIS has been widely used in the United States since the late 1980s. Currently, there are nearly 2,500 ESS in the U.S. Over 2,000 of these are part of state-owned RWIS. Central RWIS hardware and software collect field data from numerous ESS, process data to support various operational applications, and display or disseminate road weather data in a format that can be easily interpreted by a decision-maker. (2)



ESS owned by State Transportation Agencies

Maintenance personnel can also use thermal mapping to obtain information on pavement temperatures. Thermal mapping involves use of infrared sensors (hand-held, vehicle-mounted or satellite-based) to create thermal profiles of road surfaces. Measurements are taken under various environmental conditions. Several states, including Washington, Nevada, and Minnesota, have created thermal maps of highway segments. Thermal mapping data have been used to optimize siting of ESS, predict pavement temperatures in locations without ESS, and plan winter road treatment strategies. (4)

UNITED STATES

3.3 Assessment of the snow and ice control measures

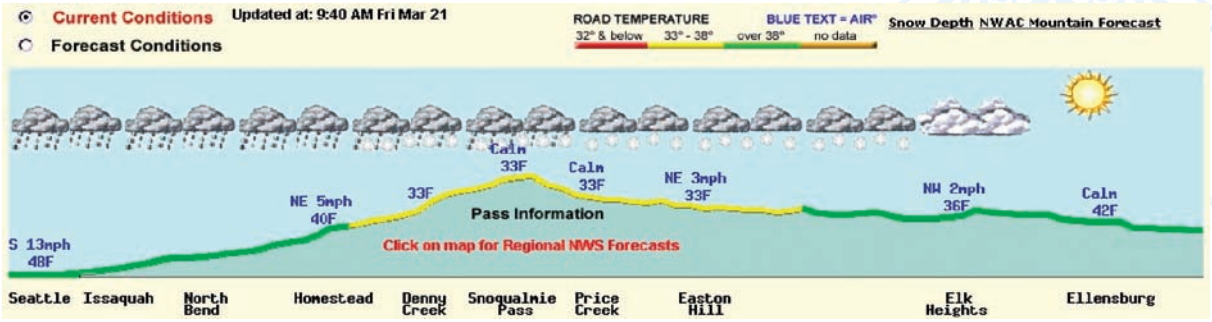
Some states have embraced the concept of performance standards to assess winter maintenance activities (12). Some agencies conduct post-storm evaluations of treatment effectiveness (such as pavement friction measurements) to identify modifications or improvements in treatment strategies (4). Post-season assessments can be used to modify routing and determine changes in personnel and training procedures or equipment and material needs. As part of a project to develop Guidelines for Snow and Ice Control Materials and Methods, the NCHRP developed a pavement snow and ice condition index to evaluate the effectiveness of winter maintenance strategies. The index was used to evaluate the Level of Service achieved by treatments during and after winter storms (7). Different performance measures have been used across the United States with varying degrees of success. There are no widely accepted measures applicable to different roadway classifications and storm characteristics. The NCHRP plans to conduct additional research to evaluate potential performance measures and identify or develop appropriate measures of performance for all roadway classifications and storm characteristics (9).

Some benefits of snow and ice control operations have been quantified. Winter maintenance activities have improved safety by reducing crash frequency and minimizing risks to field personnel and motorists. Roadway mobility is improved when accumulated snow and ice are removed and the number of road closures is minimized. U.S. maintenance managers indicate that effective anti-icing and pre-wetting strategies reduce sanding applications by 20% to 30%, decrease chemical applications by 10%, and reduce chloride and sediment runoff in local waterways. Evaluation data show that anti-icing programs can lower snow and ice control costs by 10% to 50% and reduce crash rates by 7% to 83%. Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found crash reductions from 25% to 100%. With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety; benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1 (18).

3.4 Traffic safety and information

In addition to supporting winter maintenance decisions, ESS data are used by traffic managers to modify traffic signal timing, activate automated motorist warning systems, vary speed limits, close roads, and disseminate traveler information (13). Almost half of all states (i.e., 24) use ITS technologies to manage traffic diversions in response to road closures due to weather events. The same number of states use ESS to determine the need to implement temporary restrictions on vehicles. Eight states use variable speed limits to respond to weather conditions (17). Traffic managers provide travelers with road weather information through dynamic message signs, highway advisory radio, Web sites, and 511—the national traveler information telephone number. The Internet is the medium most commonly used by state agencies to disseminate roadway conditions and weather forecasts on a statewide basis; 37 distribute weather information via Web sites and 35 distribute it via 511 (1). Twenty-nine states distribute weather information on dynamic message signs and 20 states use highway advisory radio. According to a 2006 survey of the country's 108 largest metropolitan areas, 49 metropolitan areas reported using DMS to disseminate weather advisories (18). The Washington State DOT has an advanced web site that includes integrated displays of weather and pavement conditions.

Road weather information is more important to travelers than construction information, traffic conditions, travel times, public transit information, or incident information. A public opinion survey found that weather-related and road surface conditions were most frequently identified as important elements for a 511 service. Forty percent of respondents identified weather and road conditions as most critical (10). Evaluation data show that 80% to 94% of motorists who use traveler information Web sites think road weather information enhances their safety and prepares them for adverse road weather conditions (18).



Weather and Pavement Temperature Information on Washington State DOT Web Site

4. On-going Research and Studies to Improve Winter Management

4.1 New technologies

Since 2000, the FHWA Road Weather Management Program (www.fhwa.dot.gov/weather) has sponsored the development of a guidance tool for winter road maintenance decision makers. The tool, known as the Maintenance Decision Support System (MDSS) prototype, was created by a consortium of U.S. national laboratories with significant input and feedback from numerous state DOTs and commercial weather information providers. The MDSS prototype capitalizes on existing road weather data sources, fuses data to present integrated road weather observations and predictions, and generates recommendations on road treatment strategies with anticipated consequences of action or inaction. Treatment recommendations are based on standard practices for effective winter road maintenance (such as anti-icing, de-icing, plowing, sanding), which are tailored to the procedures of the local agency. The MDSS prototype was field tested during the winters of 2003 and 2004 in the state of Iowa. The FHWA has cultivated relationships with private vendors to foster integration of prototype modules into their product lines and development of applications tailored to the needs of state DOTs. Currently, MDSS technologies are being incorporated into the product generation routines of several private sector companies. (6)

By 2004, MDSS technologies were mature enough for private sector companies to incorporate MDSS capabilities into their product lines for State DOT clients. By 2007, 21 state transportation agencies were using or developing MDSS tools. Thirteen states have joined the MDSS Pooled Fund Study led by the South Dakota DOT to develop an enhanced version based on the federal MDSS prototype, while others are in the process of procuring the software or have contracted with private vendors for maintenance decision support capabilities. In 2008, the FHWA released an MDSS Deployment Guide (http://www.itsdocs.fhwa.dot.gov/JPODOCS//REPTS_TE/14439.htm). From 2007 to 2009, the FHWA conducted evaluations of operational MDSS applications being used by the pooled fund states, the Maine DOT, and the City and County of Denver, Colorado (2).

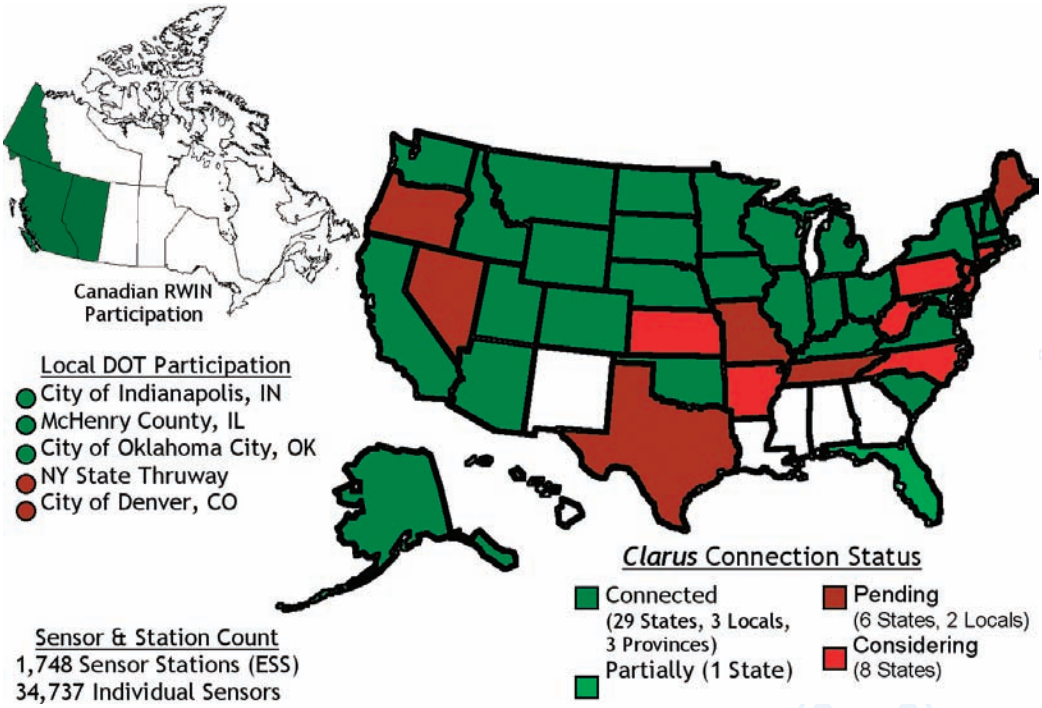
4.2 New management and organization approaches

The FHWA Road Weather Management Program was formed in 1999, for coordination of snow and ice programs, among federal agencies and with the state and local constituencies. The program seeks to better understand the impacts of weather on roadways, and promote strategies and tools to mitigate those impacts. Envisioned is a system that provides "Anytime, Anywhere Road Weather Information" for road operating agencies and road users, as well as a robust, competitive market for road weather services. Program goals are to enhance observing capabilities, facilitate training and information dissemination, advance the state-of-the practice, and promote coordinated research.

In late 2004, the Road Weather Management Program began a new multi-year initiative called *Clarus*. The *Clarus* Initiative is an effort to develop and demonstrate an integrated surface transportation weather observation data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System (2). The vision of *Clarus* is to reduce the impact of adverse weather for all road and transit users and operators. Implementation of the *Clarus* system has demonstrated how an open and integrated approach to observational data management can be used to overcome deficiencies in road weather information products. *Clarus* has enabled public agencies to more accurately assess the state of their operations as they are affected by weather events. Such knowledge is critical for evaluating the effectiveness of winter road maintenance activities.

From 2004 to 2006, the U.S. DOT developed the *Clarus* advanced data management system that assimilates all ESS observations across the United States and provides quality checked road weather observations for any user. The *Clarus* System can be accessed at www.clarus-system.com. The system is an experimental product that is being used for evaluation and demonstration purposes. The transition of *Clarus* System functionality to the NWS operational system is expected to take place in 2011 (16).

UNITED STATES



Status of State, Local, and Provincial Agencies Connected to the Clarus System

The U.S. DOT has also initiated the IntelliDrive[SM] program (www.intellidriveusa.org) to develop an enabling communication infrastructure to support both vehicle-to-vehicle and vehicle-to-infrastructure communications in support of both safety and mobility applications. Safety applications will have an emphasis on crash avoidance. Mobility applications will allow access to better information for roadway system management and operations. This includes the potential to observe and infer both driver-level weather and pavement conditions. Several studies are planned to determine how best to process the potentially large amounts of data for the benefit of the surface transportation weather community (16).

The FHWA Road Weather Management Program has also sponsored foundational research on the characteristics and the feasibility of using vehicles as meteorological sensor platforms. Vehicles were equipped with air temperature sensors in the front bumper, near the engine air intake cowling, and in the rear bumper. The primary research areas included temperature bias vs. vehicle speed, mobile temperatures vs. in situ observations, importance of sensor placement, thermal characteristics of similar vehicles, and effects of external phenomena on mobile temperatures. Researchers also conducted a feasibility study to explore and assess the utility of using data from vehicles to improve surface transportation weather observations and predictions and road condition hazard analyses and predictions (2).

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program partnered with the Aurora Pooled Fund Program, and the AASHTO Snow and Ice Cooperative Program to develop siting guidelines for ESS in the roadway environment. The RWIS ESS Siting Guidelines, released in April 2005, provide a set of recommendations to support uniform siting of sensor stations that collect road and weather observations for RWIS. In 2006, the Road Weather Management Program initiated a project to implement and evaluate the guidelines in a field environment to ensure that the recommendations are realistic and that the contents are credible, understandable, and useful to the deployers. The results of this study are being used to refine the guidelines. As transportation agencies continue to invest in RWIS sensing technologies by installing new stations or adding sensors to existing stations, the refined guidelines will become a valuable tool to aid in their placement (2).

The Road Weather Management Program aims to promote a systematic approach to the significant challenge of managing traffic during adverse weather. Weather-responsive traffic management strategies view weather events and their impacts as predictable, non-recurring incidents that contribute to roadway congestion. In 2004, the program identified research needs to advance weather-responsive traffic management and began a study to examine use of weather information in Traffic Management Centers. In 2005 and 2006, the program quantified the impacts of various weather events on arterial and freeway traffic. Results from these empirical studies on traffic flow in inclement weather will support the development of guidance for state agencies and the incorporation of weather effects into traffic simulation models. In 2007, the program initiated a project to conduct a microscopic analysis of traffic flow in inclement weather. This project focuses on how weather events and associated road conditions affect driver behavior. The results will be a methodology for identifying and modeling microscopic traffic parameters that are influenced by poor road weather conditions and recommended procedures for incorporating findings into existing traffic microsimulation models.

The Road Weather Management Program also sponsored a research project to study how weather information is integrated into operations at 38 Traffic Management Centers (TMCs). In general, very limited integration and application of weather information for TMC operations were observed. Clearly there was a need to advance the state of the practice and help agencies overcome the challenges associated with weather integration in TMCs. To address these challenges, the Road Weather Management Program initiated a project to develop a self-assessment guide to help TMCs evaluate their weather information integration needs and assist them in creating a plan to meet those needs. The FHWA is working with two TMCs to conduct a self-assessment using the guide and develop a weather integration plan.

5. References

1. AASHTO, "511 Deployment Coalition," www.deploy511.org/.
2. FHWA, "Road Weather Management Program Web Site," Office of Operations, www.ops.fhwa.dot.gov/weather/.
3. FHWA, "Highway Statistics Publications," Office of Highway Policy Information, www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm.
4. FHWA, "Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel," Publication No. FHWA-RD-95-202, June 1996, www.fhwa.dot.gov/reports/mopeap/eapcov.htm.
5. Goodwin, L., "Weather-Related Crashes on U.S. Highways in 2001," prepared for the FHWA Road Weather Management Program by Mitretek Systems, December 2003.
6. National Center for Atmospheric Research (NCAR), "Maintenance Decision Support System (MDSS) Web Site," Research Applications Programs, www.rap.ucar.edu/projects/rdwx_mdss/.
7. NCHRP, "Guidelines for Snow and Ice Control Materials and Methods," Description for Project 6-13, Transportation Research Board, October 2004, www4.trb.org/trb/crp.nsf/0/02c3a2b01547add785256748005619f5?OpenDocument.
8. NCHRP, "Performance Measures for Snow and Ice Control Operations," Research Project Statement for Project 6-17, Transportation Research Board, September 2004, www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/e852202779bb7dd685256f100053441f?OpenDocument.
9. NOAA, "Local Climatological Data," National Climatic Data Center, www.ncdc.noaa.gov.
10. OFCM, "Weather Information for Surface Transportation: National Needs Assessment Report," FCM-R18-2002, December 2002, www.ofcm.gov/wist_report/wist-report.htm.

11. OFCM, "3rd National Surface Transportation Weather Symposium Summary Report," August 2007, www.ofcm.gov/wist/3NSTWSP-Summary-Report-Final.pdf.

12. Pletan, R. and Stapp, D., "Best Practices of Outsourcing Winter Maintenance Services," www.sicop.net/Best_Practices.pdf.

13. Pisano, P., et al, "Surface Transportation Safety and Operations: The Impacts of Weather within the Context of Climate Change," presented at the Potential Impacts of Climate Change on Transportation Workshop, October 2002, http://climate.volpe.dot.gov/workshop1002/pisano.pdf.

14. SICOP, "Automatic Vehicle Location (AVL) Applications to Winter Road Maintenance Operations," December 2002, http://www.sicop.net/avl%20matrix.pdf.

15. Transportation Research Board, "Sixth International Symposium on Snow and Ice Control Technology," Transportation Research Circular E-C063, June 2004, http://trb.org/publications/circulars/ec063.pdf.

16. Transportation Research Board, "Surface Transportation Weather and Snow Removal and Ice Control Technology," Transportation Research Circular Number E-C126, June 2008, http://onlinepubs.trb.org/onlinepubs/circulars/ec126.pdf.

17. U.S. Department of Commerce, "U.S. Census Bureau Web Site," www.census.gov.

18. U.S. Department of Transportation, "Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned: 2008 Update," Intelligent Transportation Systems Joint Program Office, September 2008, www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_te/14412.HTM.

AUTHORS AND CONTACTS LIST

ANDORRA

Mr. **Jordi Garcia Llevet**
Ministry of Territorial Ordering,
Urbanism and Environment
jordi_garcia@govern.ad

Mr. **David PALMITJAVILA DUEDRA**
Ministry of Territorial Ordering,
Urbanism and Environment
david_palmitjavila@govern.ad

Mr. **Rafel CERVOS ISERN**
Ministry of Territorial Ordering, Urbanism and
Environment
rafel_cervos@govern.ad

AUSTRIA

Mr. **Manfred Skerlan**
Municipal Department 48
Waste Management, City Cleaning and Motor Pool
City of Vienna
manfred.skerlan@wien.gv.at

BELGIUM

Mr. **Xavier Cocu**
Belgian Road Research Centre
x.cocu@brrc.be

Mr. **Thierry Decoux**
Directorate-General Roads and
Buildings Walloon Ministry
thierry.decoux@spw.wallonie.be

Mr. **Marcel Hoefmans**
Directorate of Road Management
Ministry of Brussels-Capital
mhoefmans@mrbc.irisnet.be

Mr. **Tom Roelants**
Roads and Traffic Administration
(Ministry of Flanders)
tomjj.roelants@mow.vlaanderen.be

CANADA

Mr. **Miguel Tremblay**
Meteorological Service of Canada
Environnement Canada
miguel.tremblay@ec.gc.ca

AUTHORS AND CONTACTS LIST

CANADA – QUÉBEC

Mr. **Michel Brown**
Direction du soutien aux opérations
Ministère des Transports du Québec
michel.brown@mtq.gouv.qc.ca

Mr. **Richard Charpentier**
Director
Direction de la Chaudière-Appalaches
Ministère des Transports du Québec
richard.charpentier@mtq.gouv.qc.ca

CZECH REPUBLIC

Ms. **Radomíra Plíšková**
Road department
Ministry of Transport – Czech Republic
radomira.pliskova@mdcr.cz

DENMARK

Mr. **Michel M. Eram**
Danish Road Directorate
me5@vd.dk

Mr. **Freddy Knudsen**
Danish Road Directorate
fek@vd.dk

ESTONIA

Mr. **Kuno Männik**
Regional Director of
Estonian Road Administation
kuno.mannik@mnt.ee

Mr. **Rain Hallimäe**
Head of the Road Maintenance
Department of Estonian Road Administration
rain.hallimae@mnt.ee

Mr. **Tõnu Asandi**
Chief specialist of the Road Maintenance
Department of Estonian Road Administration
tonu.asandi@mnt.ee

FINLAND

Mrs. **Anne Leppānen**
Finnish Road Administration
anne.leppanen@tiehallinto.fi

Mr. **Jukka Karjalainen**
Finnish Road Administration
jukka.karjalainen@tiehallinto.fi

FRANCE

Mr. **Didier Giloppé**
Winter Service Expert
DESGI CETE Normandie Centre
didier.giloppe@equipement.gouv.fr

GERMANY

Mr. **Horst Hanke**
Road Authority of German State Saarland
h.hanke@saarhafen.de

ICELAND

Mr. **Bjorn Olafsson**
Head of Service Department
Public Roads Administration
bjorn.olafsson@vegagerdin.is

Mr. **Einar Pálsson**
Chief of Technical Department
Service Department
Icelandic Road Administration
einar.palsson@vegagerdin.is

Mr. **Skuli Thordarson**
Senior Researcher
Vegsyn Consult
skuli@vegsyn.is

ITALY

Mr. **Roberto Giannetti**
ANAS S.p.A.
r.giannetti@stradeanas.it

JAPAN

Mr. **Masaru Matsuzawa** Ph. D.
Cold Region Road Research Group
Civil Engineering Research Institute
for Cold Region, PWRI
masaru@ceri.go.jp

LATVIA

Mr. **Jānis Kastanovskis**
State Joint-Company
Latvian State Road
janis.kastanovskis@lvceli.lv

Mr. **Boriss Jelisejevs**
State Joint-Company
Latvian State Road
boriss.jelisejevs@lvceli.lv

AUTHORS AND CONTACTS LIST

LITHUANIA

Mrs. **Inesa Seskauskiene**
Lithuanian Road Administration
inesa.seskauskiene@lra.lt

MOROCCO

Mr. **Abdelhamid Janati Idrissi**
Head of the Division of Maintenance
and Winter Service
Roads Division - Morocco
janati@mtpnet.gov.ma

NETHERLANDS

Mr. **Rinse Nieuwsma**
Ministry of Transport
Centre for Transport and Navigation
rinse.nieuwsma@rws.nl

Mr. **Bert Verkaik**
Ministry of Transport
Centre for Transport and Navigation
bert.verkaik@rws.nl

NORWAY

Mr. **Dystein Larsen**
Technology Department
Directorate of Roads
Norwegian Public Roads Administration
dystein.larsen@vegvesen.no

SLOVENIA

Mr. **Svit Cerne**
DDC Consulting & Engineering Ltd.
svit.cerne@ddc.si

SPAIN

Mr. **Luis Azcue**
Main directorate of Highways
Ministry of Public Works and Transport
lazcue@mfom.es

Mr. **José del Pino**
Madrid Calle 30
delpinoaj@mc30.es

Mr. **Jorge Lucas**
Ministry of Public Works and Transport
jlucas@fomento.es

SWEDEN

Mrs. **Gudrun Oberg**
Swedish National Road and
Transport Research Institute (VTI)
gudrun.oberg@vti.se

Mr. **Jan Olander**
Swedish Road Administration
Head Office
jan.olander@vv.se

SWITZERLAND

Mrs. **Anne Gillardin**
Federal Roads Office
anne.gillardin@astra.admin.ch

UNITED KINGDOM

Mr. **Martin Hobbs**
Head of Severe Weather Strategy
Highways Agency
martin.hobbs@highways.gsi.gov.uk

U.S.A.

Mr. **Paul Pisano**
Federal Highway Administration
Road Weather Management Program
paul.pisano@dot.gov