Interim Report

Snow & Ice Databook

Austria
Belgium
Canada
Canada-Québec
Estonia
Finland
France
Germany
Italy
Norway
Japan
Slovenia
Sweden
Switzerland
U.S.A

2002 AIPCR PIARC SAPPORO

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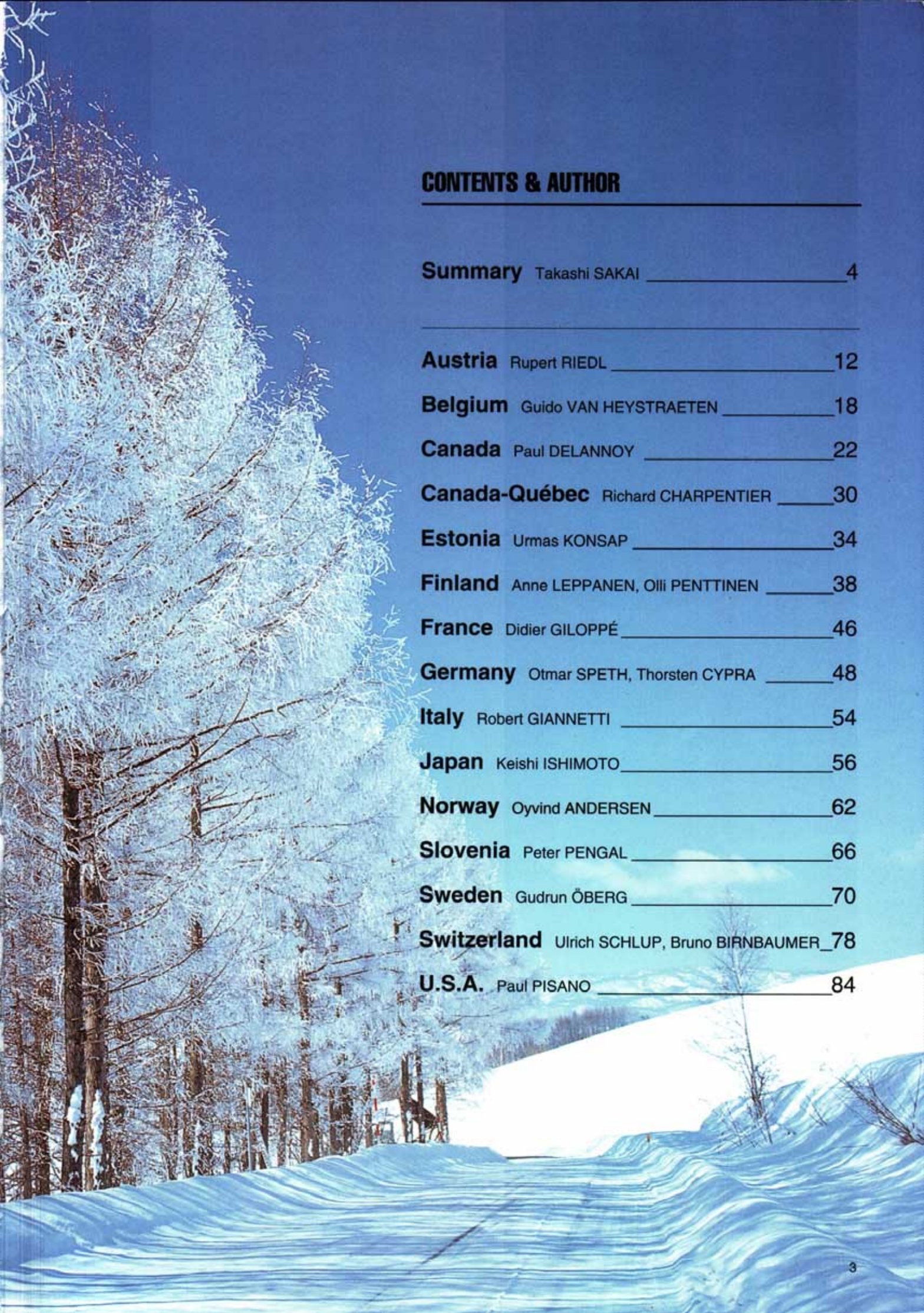
Chairman, PIARC Technical Committee on Winter Maintenance (C17)

The Snow and Ice Databook will be published in commemoration of the XIth International Winter Road Congress, 2002, Sapporo, Japan. Snow- and ice-control measures vary by region or country, depending climate, geology, and other natural conditions, road traffic, and socioeconomic circumstances.

To discuss snow- and ice-control measures from a global viewpoint, it is vital to identify the circumstances of roads in individual regions and countries. The Snow and Ice Databook is the first issuance of such data in united format. It is meaningful that this book compiles information from all of 15 countries. We have included photos, figures, and tables, which we hope will make it easy to understand despite the limited number of pages.

I would like to extend my great appreciation to the members of PIARC Technical Committee C17 and others concerned who have cooperated in offering their country's data.

The Snow and Ice Databook has been published under the auspices of the Japanese Organizing Committee for the XIth International Winter Road Congress. I believe it will be an ideal reference material for readers of the Proceedings of the XIth International Winter Road Congress and that it will contribute to improved understanding of international snow- and ice-control measures.



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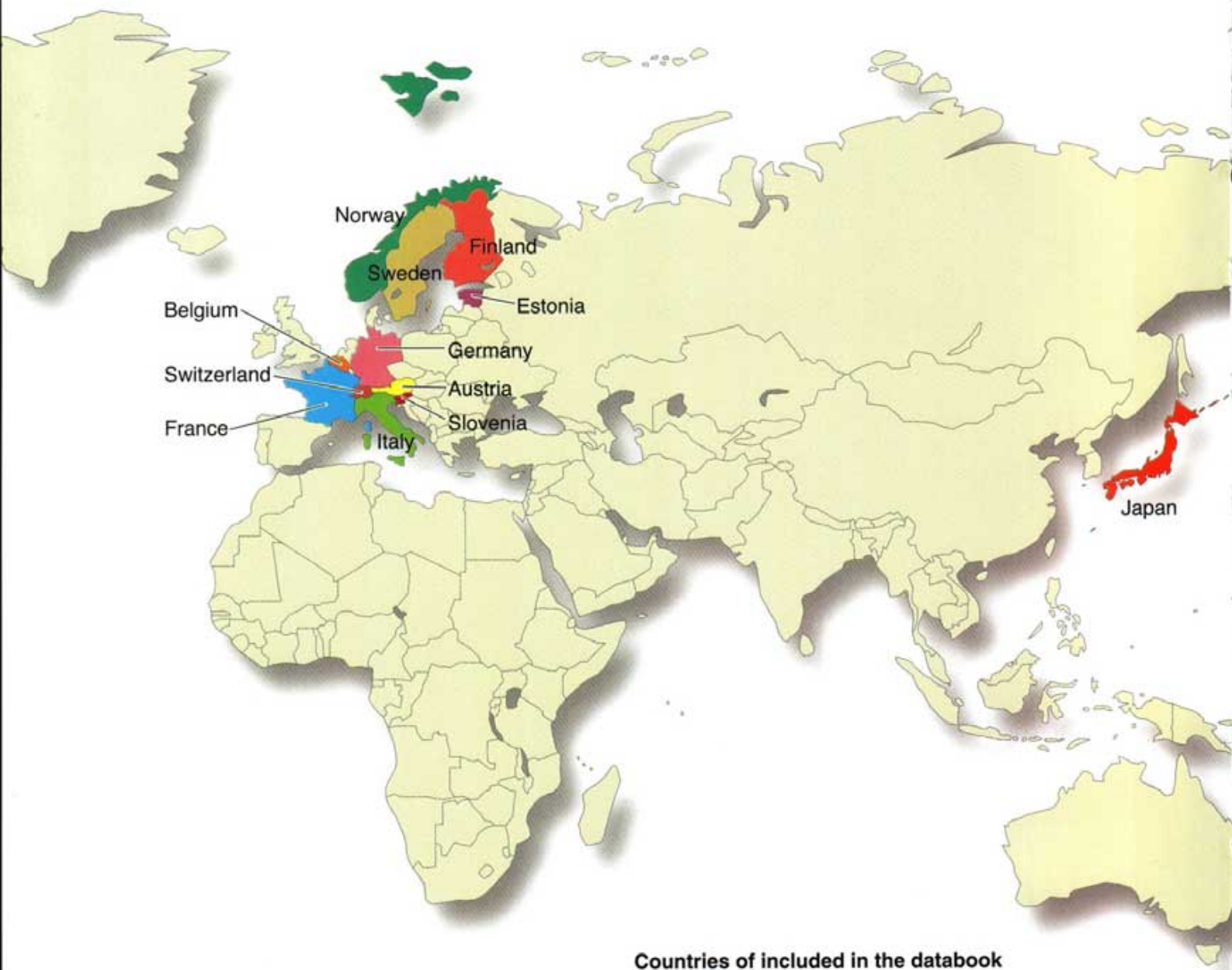
Summary

Introduction

This Snow and Ice Databook compiles investigations led by Japan in a project of the C17, the PIARC committee in charge of winter road maintenance. Data were collected from C17 member countries regarding road conditions, climatic and geographical features, levels of snow and ice control, maintenance technology, winter road maintenance budgets, and measurements of the effectiveness of winter road measures.

Winter weather conditions, history and the public awareness of winter road maintenance differ by country, and snow- and ice-control measures originate from these different backgrounds. When introducing the snow and ice technology of another country, it is essential to make innovations and improvements after understanding the source country's circumstances and recognizing its differences from the destination country. This is what has motivated us to compile the Snow and Ice Databook.

This publication should be regarded as an interim report on the findings of the investigation. Ideally, a final report would be issued after comprehensive collection and exacting analysis of data from each country, which would take quite some time. However, even an incomplete report should prove valuable to attendees of the PIARC 2002 Sapporo Congress. Therefore we, the Japanese Organizing Committee, have decided to distribute this at the Congress as an interim report.



Countries of included in the databook

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For this reason, the Snow and Ice Databook contains reports from each country just as they were submitted. There are certain places where questions may come to mind, such as regarding the appropriateness of units or the sufficiency of the English translation, but we ask you to understand that the materials are printed as they were reported. We recommend that readers who require greater detail contact each country directly, at the addresses listed herein.

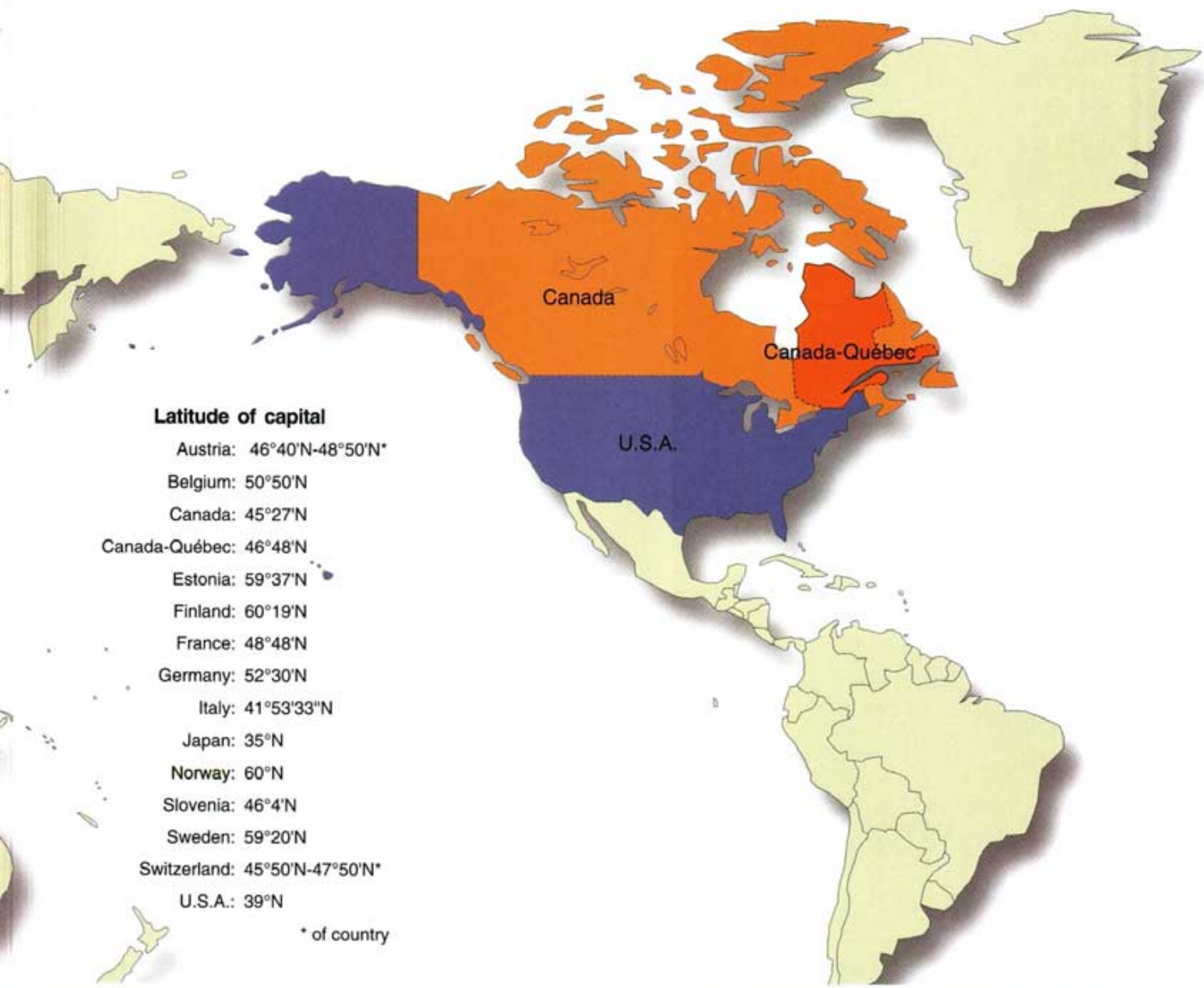
This summary of the interim report addresses the three aspects of population density, weather conditions, road networks and snow- and ice-control policies for them. For snow- and ice-control technology and other information, please refer to each country's report.

Summary of the investigation

Participation was obtained from 15 countries or regions, whose areas, populations, latitudes, lengths of road and other information are summarized in Table 1.

(1) Population density

The area of cold/snowy regions (Table 1) was reported by Austria, Finland, France, Japan, Norway and the U.S. The definition of cold/snowy region, however, varies by country. France considers such areas as those that see snowfall on at least 30 days of the year. The United States defines them as areas whose annual snowfall averages 13 cm or more. Japan defines snowy regions as those whose maximum



Summary

snow depth averages 50 cm or more. (It also recognizes less snowy "cold regions," as those whose temperature in January averages 0 °C or below.) No records pertinent to this subject have been received from the other countries.

Herein, snowy regions are considered to be areas annually averaging several centimeters of snowfall. Several countries do not specify snowy regions, but their report makes it obvious that virtually their entire area is snowy. Table 1 assumes these (Canada, Québec Canada, Estonia, Germany, Switzerland, Sweden) to be 100% snowy regions, and it is on this assumption that the population and population density of their snowy regions have been calculated.

Many of the 15 participating countries and regions are entirely covered with snow. Exceptions are France, Italy, Slovenia, Japan and the U.S., which have snowy regions and snow-free regions.

Figure 1 shows the population density of each country calculated from the area and population, and the population density of each country's snowy regions. The population density is high in Western Europe and Japan, and low in Northern Europe and North America. However, as the high latitudes of Canada and Northern European countries are very sparsely populated, their southern regions are considered to have relatively high population density.

Among France, Italy, Slovenia, Japan, and the U.S., which have snowy and snow-free regions, only Japan and the U.S. reported the population and area of their snowy regions. These regions account for 62% of Japan's area and 22% of its population. These regions account for 80% of the U.S.'s area and 69% of its population. Thus, in Japan and the U.S., the area of snowy regions is roughly the same (as a percent of the whole), but a much greater share of the U.S. population lives in these areas.

Nevertheless, the formulation of policies for snow and ice management on roads is a challenge common to countries with both snowy and snow-free regions, as they must always be sensitive about relations between these regions, and the background of policy formulation differs from that of countries that are entirely snowy.

(2) Weather conditions

Here we briefly summarize weather conditions in each country.

Norway's mountainous regions account for 75% of its land area, and its west coast is deeply incised with fiords and dotted with islands. Because of this, the climate varies greatly over small distances. The winter lasts 150 to 200 days, the average temperature in January is between 0 and -8 °C, and the snow depth ranges from 40 to 70 cm.

Sweden stretches long from north to south, and the difference in temperature between the north and south is

Country	Area			Population		Population density		Length of road				
	Overall (A)	Cold/snowy regions (B)	(B)/(A)	Overall	Cold/snowy regions	Overall	Cold/snowy regions	Overall (C)	(C)/(A)	Trunk road (D)	(D)/(A)	Other road
	km²	km²	%	mill. people	mill. people	people/km²	people/km²	km	km/km²	km	km/km²	km
Austria	83,858	83,858	100%	8.00		95.4	95.4	35,100	0.419	12,000	0.143	23,100
Belgium	30,500			10.20		334.4		145,700	4.777	14,700	0.482	131,000
Canada	9,093,507	9,093,507	100%	31.09		3.4	3.4	1,427,000	0.157	205,500	0.023	1,221,500
Canada Qu bec	1,667,926	1,667,926	100%	7.29		4.4	4.4	123,140	0.074	27,778	0.017	95,362
Estonia	45,227	45,227	100%	1.44		31.8	31.8	49,486	1.094	16,430	0.363	33,056
Finland	338,145	338,145	100%	5.20		15.4	15.4	402,000	1.189	78,000	0.231	324,000
France	551,000	64,000	12%	60.00		108.9		978,000	1.775	37,000	0.067	941,000
Germany	357,000	357,000	100%	82.00		229.7	229.7	645,800	1.809	53,000	0.148	592,800
Italy	301,302			57.00		189.2		451,679	1.499	26,128	0.087	425,551
Japan	377,737	232,553	62%	123.61	27.51	327.2	118.3	1,100,000	2.912	46,661	0.124	1,053,339
Norway	385,000	385,000	100%	4.50	4.50	11.7	11.7	92,500	0.240	27,000	0.070	65,500
Slovenia	20,256			1.98		97.7		6,170	0.305	1,403	0.069	4,767
Sweden	410,929	410,929	100%	8.90		21.7	21.7	212,073	0.516	98,049	0.239	114,024
Swizerland	41,284	41,284	100%	7.10		171.9	171.9	71,000	1.720	1,710	0.041	69,290
United States	9,159,117	7,285,900	80%	272.69	186.88	29.8	25.6	6,352,861	0.694	255,910	0.028	6,096,951

Table 1. Natural environment and social circumstances of each country

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great. Winter lasts for about 4 months in the south, whereas it extends to almost 7 months in the north. The average temperature in January is around -2 to -18 °C and the maximum snow depth is between 40 and 110 cm.

In Finland, the average temperature in January in the south is around -5 °C and about -15 °C in the north. Winter lasts for 5 to 7 months, and all the road networks are affected by snowfall and freezing.

In Estonia, days with the daily average temperature below 0 °C averaged 127 (September to May) for the years from 1992 to 1999. The whole country is covered with 20 to 30 cm of snow, and its capital, Tallinn, sees 31 days of snowfall a winter.

The climate in Slovenia can be divided into three types, alpine, Mediterranean and continental. The annual precipitation is 800 to 3000 mm, the average temperature in January is 0 to 2 °C in the central part and 2 to 4 °C on the coast. The average annual snowfall is 100 to 300 cm in the uplands and 100 cm in the lowlands.

Austria lies in the transition zone between oceanic and continental climate. The Alps occupy a considerable area of the country and they and their environs see heavy snowfall. Snow control measures are required throughout the country. Winter road maintenance is generally carried out from November to early April, and the temperature during this period ranges from +10 °C to below -20 °C.

Switzerland, can be divided into four climatic regions; the Jura mountains, the Mittelland, the Alps region and the region south of the Alps. Winters in the Jura mountains and the Alps region are severe, with ice days exceeding 30. The region south of the Alps is relatively mild, with four ice days, and snowfall days number 14.

The climate in Germany is relatively temperate, but is characterized by frequent weather changes. From the lowlands in the northwest to the southeastern regions, the climate shifts from oceanic to continental. The southeastern part has frequent cold winds and snowstorms from Eastern Europe. The average temperature in January is 1.5 °C to -0.5 °C in the lowlands, and in the alpine region it can drop below -6 °C, depending on the altitude.

Italy can be divided into the cold north and the mild south. Since the whole country is mountainous, the climate differs greatly by region, and caution for local snowfall is needed even in the south. The snow in the north is powdery and light; in the south it is damp and heavy.

Belgium has an oceanic climate and is relatively wet, with the annual precipitation of 700 to 1500 mm. Yearly snowfall days number from 14 to 63, and the capital, Brussels, has 59 days of frost annually.

In France, winter severity is indicated by the number of snowfall days, the number of days when black ice forms with precipitation and the number of days when black ice forms without precipitation. Budgets for winter road maintenance are planned based on the winter severity. The weather conditions are particularly severe in the mountainous area from east to south; winters from north to west are relatively mild.

Canada is generally covered with snow from mid December through late March. Annual snowfall ranges from lows of 1 m on the central prairies to more than 3 m in southern Québec and over 4 m on the Atlantic Coast.

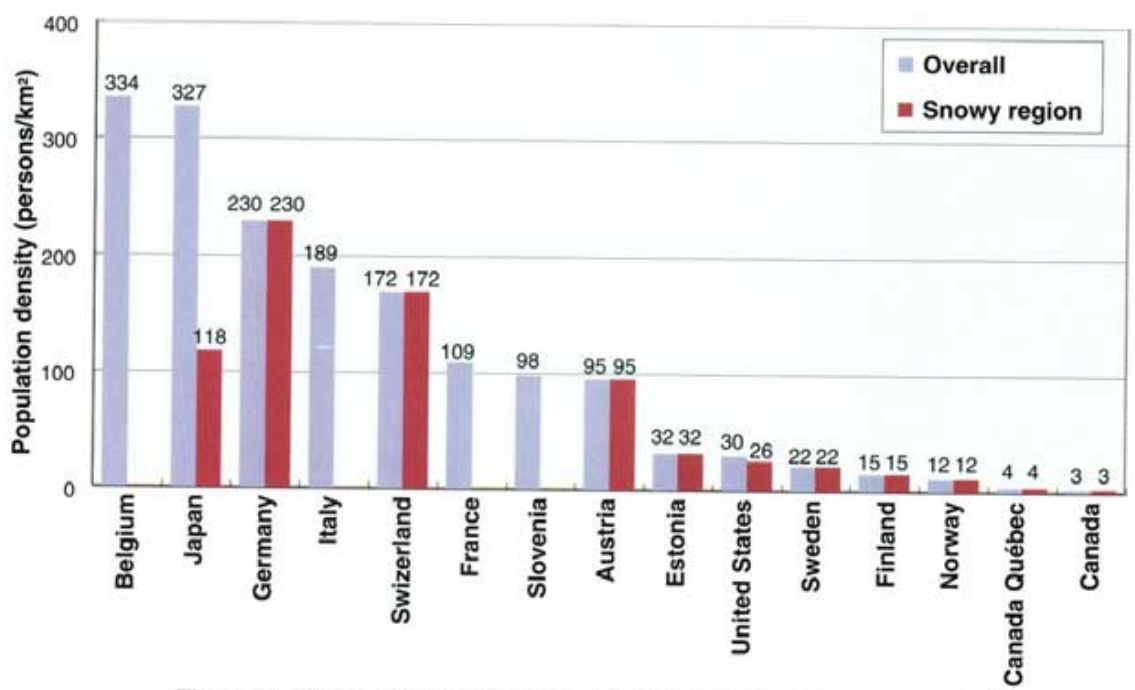

Figure 1. Population density by country (Overall and snowy region)

Summary

The only exception is the area around Vancouver Island, where the winters are wet.

The U.S. is a vast land of diverse climates, but snow falls regularly in every state, excluding the southern tier of the contiguous U.S. around the Gulf of Mexico, deserts in the Southwest, and Hawaii. Snowfall is particularly heavy on the eastern shore of the Great Lakes, due to the lake effect.

Japan is an archipelago extending from northeast to southwest, partitioned lengthwise by the mountain ranges that run along the middle. Heavy snow clouds form in winter when cold air masses arrive from the continent after picking up water vapor from the Sea of Japan. These cause heavy snowfall west of the mountains. Northwestern Japan has among the heaviest snowfall in the world.

We have received information from Japan, the U.S., Québec Canada and Sweden on snowfall and the temperature in January in major cities. The relationship between temperature and snowfall in major cities is shown in Figure 2.

It is evident that winter weather conditions in each city differ greatly even in the same country. While differences in temperature are more remarkable than differences in snowfall in cities of the U.S., Québec Canada and Sweden, for Japanese cities it is the differences in snowfall that are large. Annual snowfall in Aomori and Sapporo is particularly high, and Fukui and Nagaoka have much snowfall even though the temperature in January is around 0 °C. This is characteristic of Japan, a snowy country whose cities are situated in very snowy areas.

The above findings have given us a renewed appreciation of the challenges facing winter road maintenance, in light of the fact that winter weather conditions vary not only between countries but also between regions of the same country. The Winter Index, a factor that expresses the harshness of winter, was reported by France, Canada and other countries, and similar attempts are being made in other countries. All such efforts, however, remain in the trial stages, a situation that calls for research on a universally applicable Winter Index.

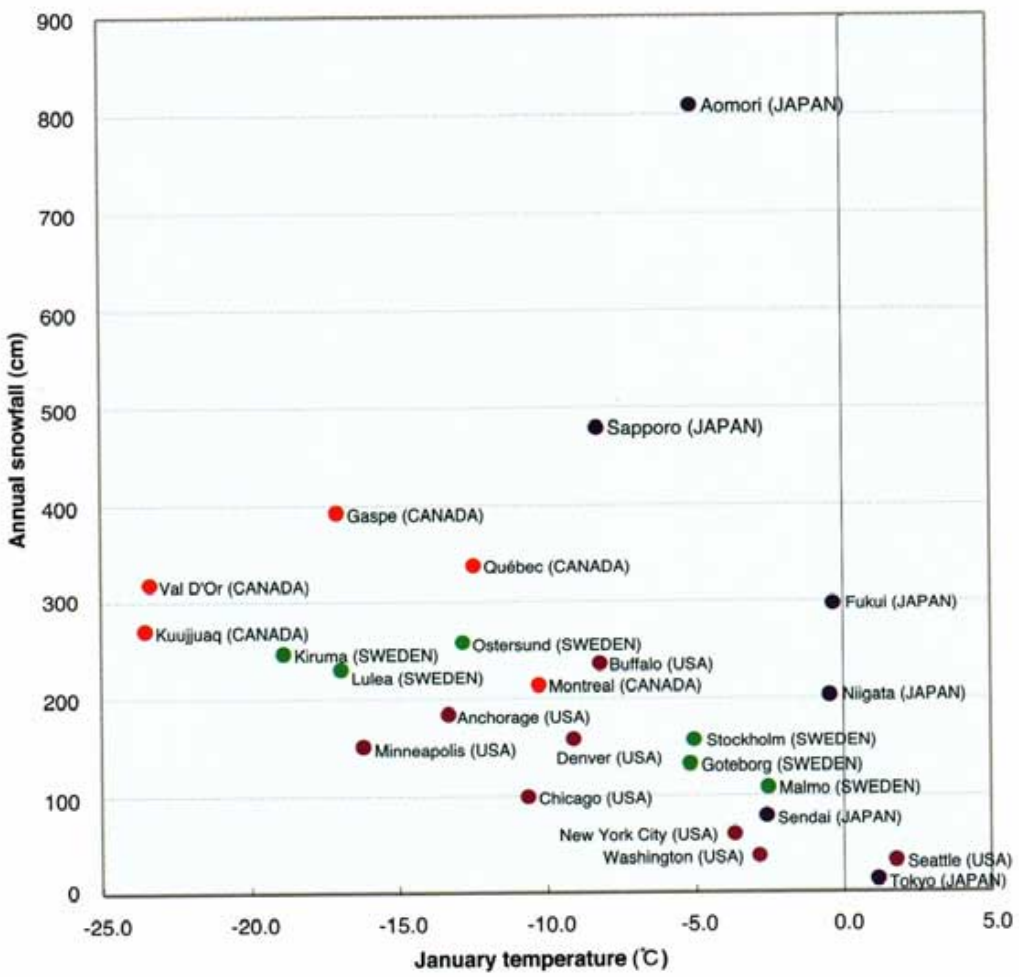

Figure 2. Snowfall vs. temperature for various cities

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(3) Road networks and snow- and ice-management policies

The diversity of road classifications makes it difficult to compare data between countries. Therefore, I define expressways, toll roads, national highways, interstates, and the like herein as "trunk roads" and all others as "other roads" (including prefectural roads and municipal roads).

Figure 3 shows values obtained by dividing the total length of all roads and the total length of trunk roads by each country's land area. Belgium, Germany, France, Switzerland and Japan, which have a small land area and a large population, have high values. The rate of trunk roads is high in Belgium, Estonia, Finland and Sweden. The U.S. and Canada should be distinguished from Europe and Japan, because the small values of those two countries are due to vast, very sparsely populated areas.

The winter road management of such road networks is carried out based on the management policy of each country. Outlines of the snow and ice management policies and the management standards of each country are described below.

In Japan, a five-year program is implemented based on the Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas and snow and ice are controlled according to this program. Service levels of snow and ice control are set by each area or local government, because weather conditions vary. In general, management levels of about three grades are set as standards for the deployment of machinery, according to the amount of snowfall. With the pervasion of studless tires, attempts to specify road conditions have been seen recently.

In the United States, policies on maintenance and management are determined individually by each state or municipality. A high service level is set for roads connecting states, such as interstates.

In Canada, the management and operation of highways and road networks are conducted by provinces, cities, towns and villages, and this is also true for winter road management. In the Province of Ontario, the northern part and the southern part differ greatly. In each part, five-grade road classifications are set based on the traffic volume, and the road condition to be secured and time required for this are specified for each road classification. Basically, management follows a "bare pavement policy" that calls for the exposure of black road surfaces. Each operational standard of salt spraying, snow removal and sand spreading and time of operational cycle is also specified.


1963 Heavy snowfall, Muikamati (Japan)


Québec (Canada)


Luleå (Sweden)


Sapporo (Japan)


Helsinki (Finland)


Washington, D.C. (U.S.A.)

Summary

In Québec, Canada, winter road service levels are determined according to the daily mean traffic volume in winter and road categories (highway, national highway, local road, sub-trunk road, resource development road). The levels are three: road surface with no snow cover, road surface with partial snow cover and road surface with compacted snow. Basically, roads with heavy traffic must have surfaces without snow cover.

In Norway, roads are managed in winter by dividing them into those covered with snow/ice and those whose surfaces are exposed. For roads on which snow cover is permitted, the quality of snow is divided into dry snow and wet snow for every traffic volume and the snow depths of four levels each are specified. Roads must be managed so that the snow depth meets the standard. The number of days to complete each work operation and the coefficient of friction to be secured by sand spreading are also set. For roads whose surfaces must be exposed, similar standards are set. As road surfaces must be exposed, as a basic policy, a high value is set for the coefficient of friction, and the time from snow removal until the specified coefficient of friction is secured is also specified.

In Sweden, four service levels are set for roads whose surfaces must be exposed, two service levels for roads where snow cover is permitted and three service levels are set for pedestrian paths and cycling lanes. These service levels are set separately for national highways and regional roads for every traffic volume. For each service level, the snow depth on roads, the minimum temperature of road surfaces, time to secure a certain road surface condition, the coefficient of friction to be secured and time to secure it, and the like are determined in detail.

In Finland, in addition to specifying service levels, the "quality" standards are set for each service level, and contractors maintain and manage roads in accordance with the contracted quality standards. Service levels are specified with five grades of road surfaces to be maintained. A service level is determined for each road, based on the traffic volume, the grade in terms of road category and the weather condition. For quality standards, the coefficient of friction, the snow depth on the road surface, the operational cycle time and the evenness of the road surface are

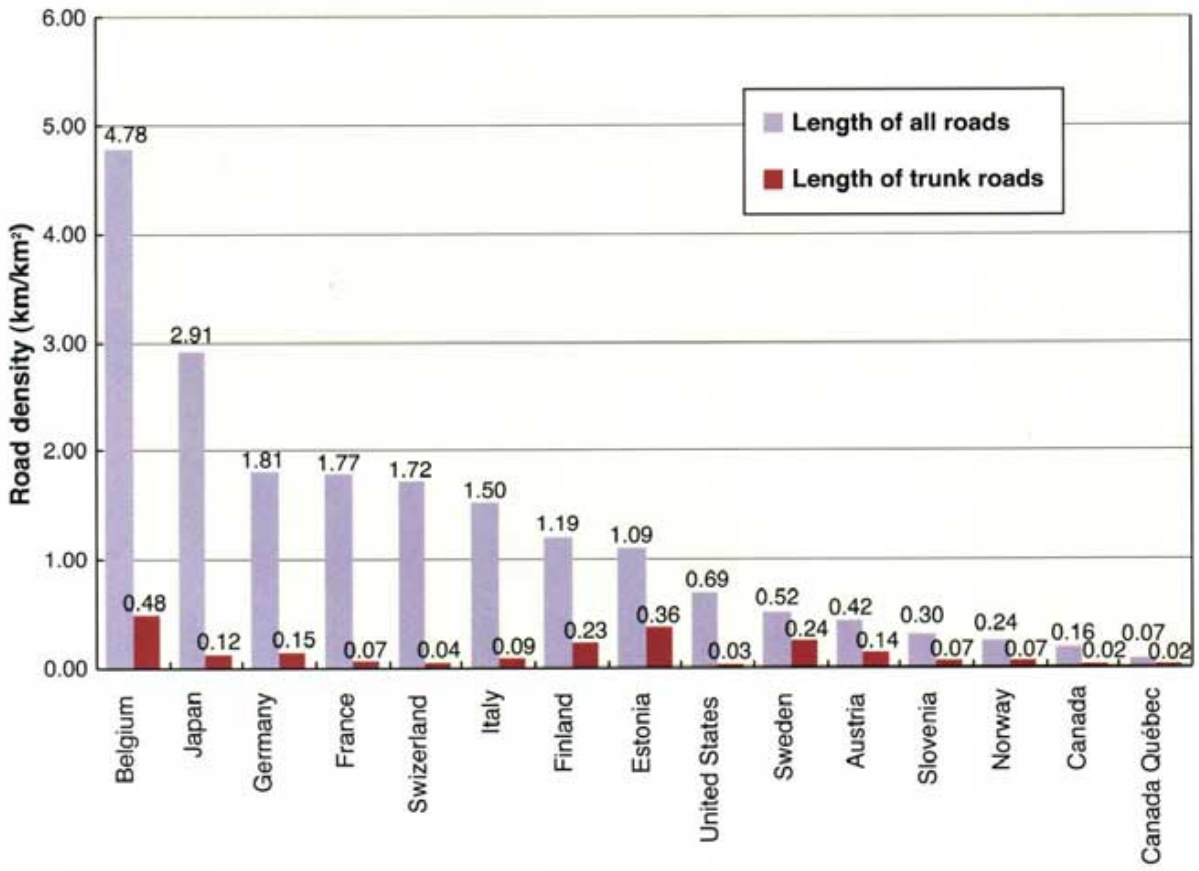

Figure 3. Road density by country (km of road per km² of land area)

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specified in detail for each service level. Contractors conduct operations to keep these standards.

In Estonia, roads are classified into four functional categories. Each of these road categories is divided into five groups according to the traffic volume, to set a service level. The operational cycle time of each winter road maintenance work (snow removal, freezing prevention, sidewalk snow removal, etc.) is set for each service level of the four functional categories.

In Slovenia, six operational indexes are set for each functional category. They consist of the number of lanes to be secured and permissible duration of traffic suspension.

In Austria, roads are maintained and managed by dividing them into four levels based on the traffic volume. Time to manage snow and ice is specified for each level. Autobahns, expressways connecting each province, are at the highest level and they are maintained and managed around the clock.

In Switzerland, winter road management standards comprise road classifications, service levels and priorities, and they are set for each road. The four service levels are shown by road surface conditions and content of work, while priorities are shown by the permissible time to complete snow removal or anti-freezing agent spreading.

In Belgium, each winter road management operation is specified for each of 8 kinds of winter weather forecasts provided by the weather forecast department of the air force. On the basis of these, winter road administrators of each district carry out work adding local information from road patrols and the like.

In Germany, the road bureau of each state takes charge of the winter road management of expressways, major roads and major state roads. Winter road management standards are classified into 8 kinds by road category and each category specifies a maximum permissible period of time to carry out winter road maintenance and management. Road conditions to be secured under especially severe weather conditions are also specified for each road category.

In France, three winter road service levels are set for each time period for maintenance and management work, and a level is determined for each road, considering weather, traffic volume, importance, and the like. Road traffic conditions are divided into four levels: normal traveling condition, condition with potential danger, condition with likely danger and condition under which traveling is impossible. Although the basic condition is "normal traveling condition," the time required to recover from black ice or snow cover to normal is specified for each service level. In addition, standards are established even for when road traffic conditions deteriorate.

Winter road management standards vary by country, and it is thought that they have been devised according to regional weather and history. One commonality is that service levels are determined on the basis of the traffic volume and road classifications. The content of each service level is roughly divided according to the country into work standards and conditions to be secured. Countries that specify conditions to be secured in particular detail are Sweden, Norway and Finland in Northern Europe. In these countries, the coefficient of friction serves as both a numerical target and a performance indicator, which is not seen in other countries. It should be mentioned that Finland has introduced quality standards into contracts. It was ordinary in former contracts for contractors to be paid according to hours of operation of snow removal equipment or kilometers of snow removal. Today in Finland, however, road conditions to be secured are numerically indexed (e.g., snow depth, coefficient of friction, evenness) and contractors carry out work to secure those indexed values. This is interesting as a world-leading attempt to maintain road performance by specifying the content of the contract regardless of the number of work hours.

Conclusion

Two major development themes were seen regarding snow and ice technologies. One is an attempt to use information technologies for efficient management and for avoidance of danger by providing information to road users. Another is an attempt to decrease the application amount of anti-freezing salts while maintaining the service level. Concrete measures include the development of a method of proper spraying according to a detailed understanding of road surface information, improvements in spraying machines, use of wet salt and technical improvements of operators. Some technological developments that show regional characteristics are snow disposal techniques in Japan and measures against avalanches in Switzerland.

Future technical challenges include understanding the influences on the surrounding environment and developing measures against these influences, and achieving a decision-making system to support work and a method to measure its effects, including cost and benefit.

This investigation outline is an interim report, as mentioned above. Reports from each country will be revised and edited in the C17 committee for compilation in a final report. Therefore, I would like you to understand that the final report may differ somewhat in content.

This investigation impressed on me the idea that "winter" is a season of great variety that is not the same in any two regions. At the same time, I came to recognize anew that, in promoting exchanges of technology and technical information, it is important to understand the snow and ice technology of each country together with its natural environment and social circumstances, which have fostered such technologies. I hope these movements will expand to countries that are in need of technology transfer, and it is my wish that life in these places will be stabilized or improved by the securing of smooth road traffic even in winter.

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Demographics and Roads

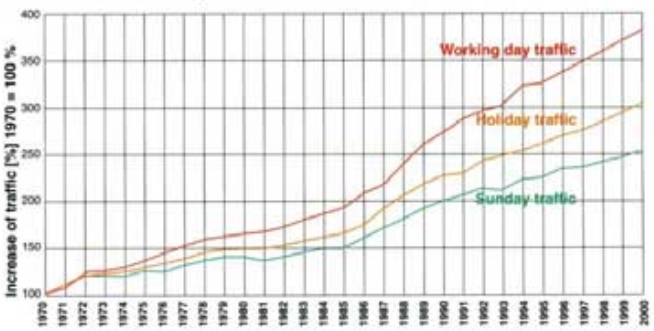
Area	Total	83,858 km²
	Snowy regions	83,858 km²
Population	8 million	
Length of road	Federal roads	Interstate highways (Autobahnen) 1,600 km (40 maintenance bases)
		Highways 10,400 km (193 maintenance bases)
	Provincial roads	23,100 km
Latitude		46°40'N to 48°50'N

Austria is a federal state, consisting of the independent province of Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tyrol, Vorarlberg and Vienna.

Capital: Vienna (Wien); population 2 million

In view of topographical conditions prevailing in Austria, the high-order roads in particular require a large number of engineering structures: the network comprises more than 10,000 bridges and a total tunnelling length of some 180 km.

Traffic development of the Austrian road network



The volume of average daily traffic in Austria has nearly quadrupled in the last 30 years.

In Austria different speed limits exist, corresponding to the Highway Code:

Autobahnen	130 km/h
Federal and provincial roads	100 km/h
Urban areas	50 km/h

According to accident statistics, issued by Kuratorium für Verkehrssicherheit, in 2000, less than 1,000 people were fatally injured. In the same way less pedestrians were affected, but one fatally injured pedestrian in two was 65 years or older.

In contrast to all other types of vehicles, it is noted that an increasing number of fatalities are motorcycle riders.

1) Accident rate 1996 - 2000

	Accidents	Injured persons	Fatalities
1996	38,253	49,673	1,027
1997	39,694	51,590	1,105
1998	39,225	51,077	963
1999	42,348	54,967	1,079
2000	42,126	54,929	976

2) Accidents classified by road

Traffic	Accidents	Injured persons	Fatalities
Local traffic			
Federal roads	8,342	10,672	87
Provincial roads	3,830	4,674	44
Other roads	13,216	15,670	82
Total	25,388	31,016	213
Long-distance traffic			
Autobahnen	2,659	4,253	150
Federal roads	6,822	10,154	325
Provincial roads	5,030	6,710	219
Other roads	2,227	2,796	69
Total	16,738	23,913	763
Total	42,126	54,929	976

Salzburg Province

Area	Total	7,154.2 km² (8.5% of Austria)	
	Snowy regions	7,154 km²	
Population	509 thousand		
Length of road	Federal roads	Interstate highways (Autobahnen) 145 km (4 maintenance bases)	
		Highways 690 km	5 maintenance bases
	Provincial roads	675 km	
Number of vehicles	300 thousand		

Many of Salzburg's main roads are situated in alpine areas and therefore 42 km tunnels have to be maintained. Half of these tunnels serve Autobahnen, and have separated tubes for each direction - with the exceptions of Tauerntunnel (6.4 km) and Katschbergtunnel (5.4 km).

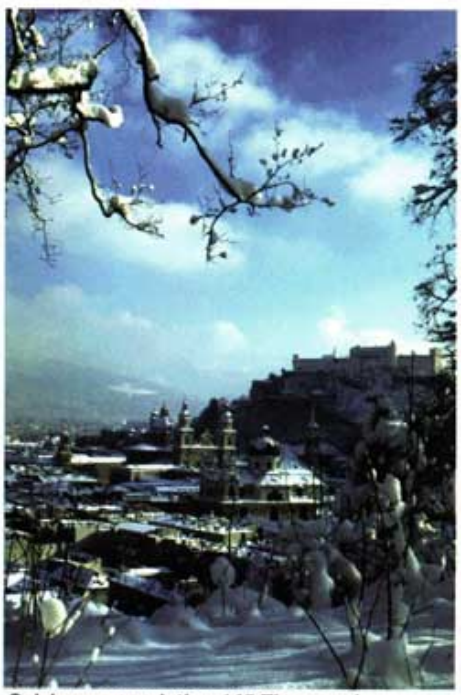
Salzburg, the capital of the federal state of that name, lies on the river Salzach, at 1395 ft. Traffic density on the A1 West-Autobahn, in the vicinity of Salzburg, is the highest in the province with 64,000 vehicles / 24 hours.

1) Accident rate 1996 - 2000

	Accidents	Injured persons	Fatalities
1996	2,644	3,465	66
1997	2,711	3,544	77
1998	2,778	3,580	73
1999	2,809	3,619	100
2000	2,830	3,652	59

2) Accidents classified by roads

Traffic	Accidents	Injured persons	Fatalities
Local traffic			
Federal roads	671	817	7
Provincial roads	176	206	0
Other roads	853	994	0
Total	1,700	2,017	7
Long-distance traffic			
Autobahnen	244	389	9
Federal roads	505	753	29
Provincial roads	216	291	8
Other roads	165	202	6
Total	1,130	1,653	52
Total	2,830	3,652	59



Salzburg; population 145 Thousand

Maintenance Base Obertauern (Altitude 5,700 ft)

AUSTRIA

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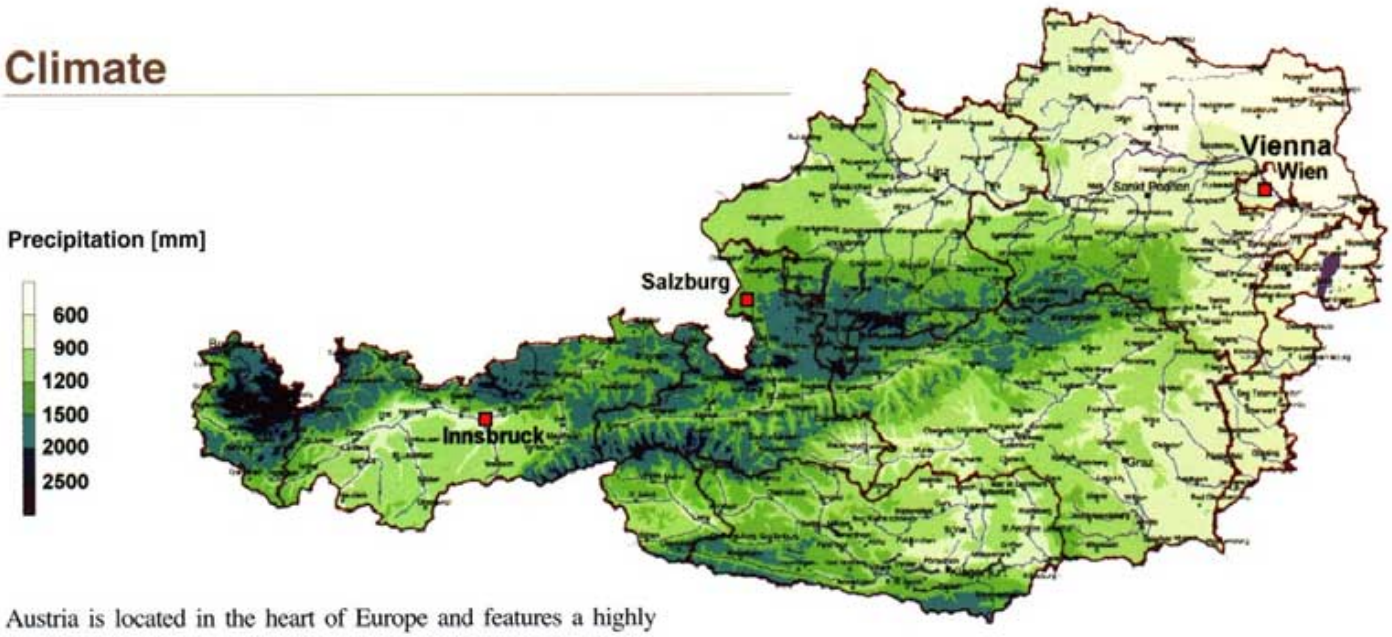
Climate



Austria is located in the heart of Europe and features a highly complex topography. As the Alps cover large parts of the territory, these regions are affected by heavy snowfall. Heavy snowfall also hits the lowlands around eastern Austria and the Danube valley. Austria lies in a transition zone, between maritime and continental climate.

Ice and snow control is necessary in the entire country. Winter road service starts usually at November and ends at the beginning of April. During this period the temperatures varies from + 10°C to - 20°C and lower. Precipitation is generally smallest in low-laying northern, eastern, and south-eastern parts of the country and in some intra-alpine dry zones. Highest rain and snow amounts are measured due to orographic effects in the vicinity of the Alpine north rim.

Road Weather Information

The "Zentralanstalt für Meteorologie und Geodynamik" provides a general weather forecast, which is broadcast via radio. A special designed weather prediction is given for maintenance centres and the region they are working for. The maintenance centres also set road sensors, which are located on the most dangerous spots, like bridges, shady stretches, steep runs. About 20 sensors were set up in Salzburg Province, they give information on precipitation (rain or snow), humidity, air temperature, surface temperature, freezing temperature and in combination with computer software a 2 hour forecast of aforesaid parameters is provided and monitored.

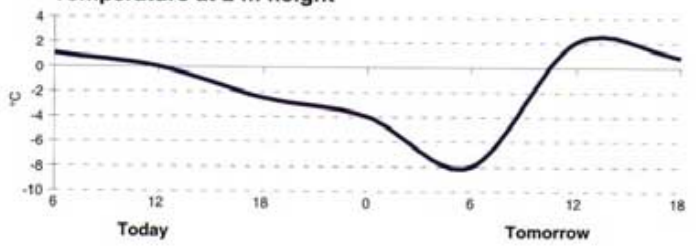
The local weather information centre of Salzburg provides a specific sheet, like the example right, to give weather forecasts for remote areas without ice control technology to the maintenance base, at 2 p.m. every day. Knowledge about the micro-climate, the rise and drop in temperature over the next twelve hours, is a valuable information for the operating team during winter time.

Heavy multiple - day snowfalls

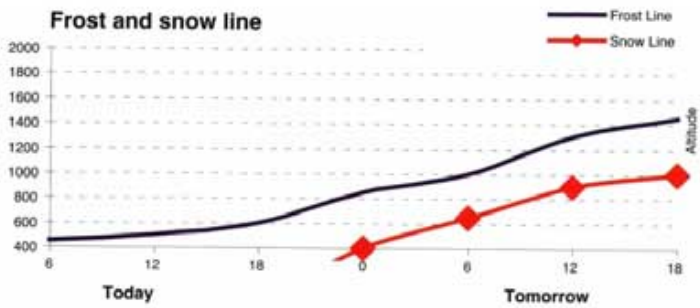
Station	Altitude (m)	1d-Max (cm)	2d-Max (cm)	3d-Max (cm)
Bregenz	424	40	45	47
Brenner	1,450	100	107	114
Graz (airport)	340	30	49	57
Innsbruck	578	36	43	55
Klagenfurt	447	47	47	55
Linz	263	22	27	31
Salzburg	434	33	52	63
Obertauern	1,740	60	95	120
Zell am See	750	53	55	60
St. Pölten	272	43	53	58
Vienna	226	31	56	75

1d-Max. = maximum one day accumulation of fresh snow
2d-Max. = maximum two-day fresh snow
3d-Max. = maximum three-day fresh snow

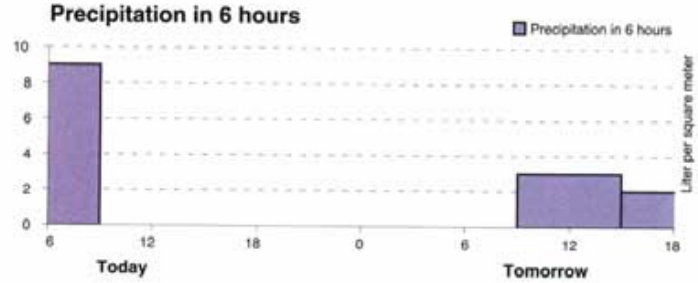
Temperature at 2 m height



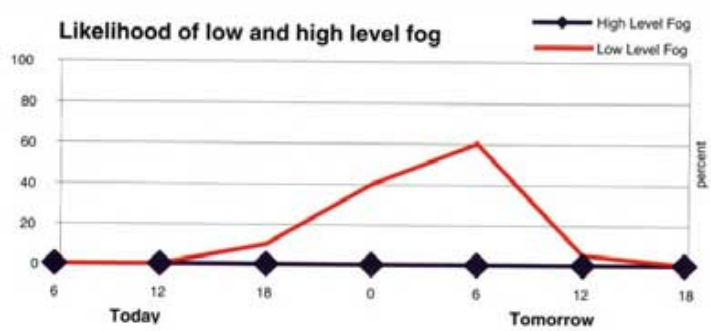
Frost and snow line



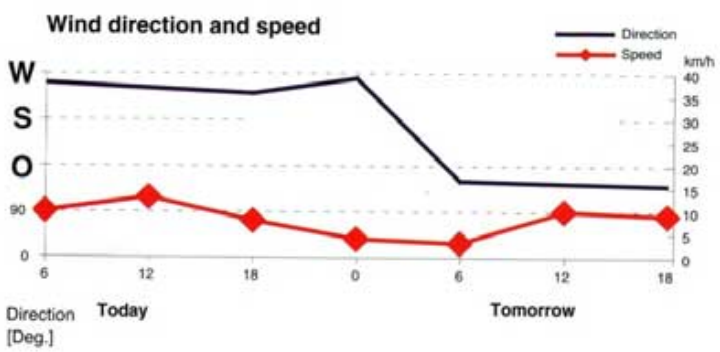
Precipitation in 6 hours



Likelihood of low and high level fog



Wind direction and speed



Road weather
ABTENAU / LAMMERTAL

Prepared by the weather service
Salzburg on Jan. 9 2001

Weather situation:

The cloudiness decreases during the next few hours, the NIGHT will be clear and cold. Local fog patches are likely along the Lammer river and in the Abtenauer Becken. TOMORROW morning it will be partly sunny with some high clouds. In the course of the day cloudiness increases and in the afternoon light rain is likely.

Warnings:

Snowfall

	POSSIBLE	LIKELY	EXPECTED
Snowfall < 10 cm			
Snowfall > 10 cm			
Heavy snowfall (even temporary one)			

Snow drift

	POSSIBLE	LIKELY	EXPECTED
Mild or moderately			
Strong snow drifting			

Ice

	POSSIBLE	LIKELY	EXPECTED
Ice (caused by rime)	X		
Ice freezing water or snow water		X	
Freezing rain		X	X

Conclusion:

During the NIGHT slippery road conditions are expected because of freezing water on exposed areas. TOMORROW afternoon it could be icy because of freezing rain.

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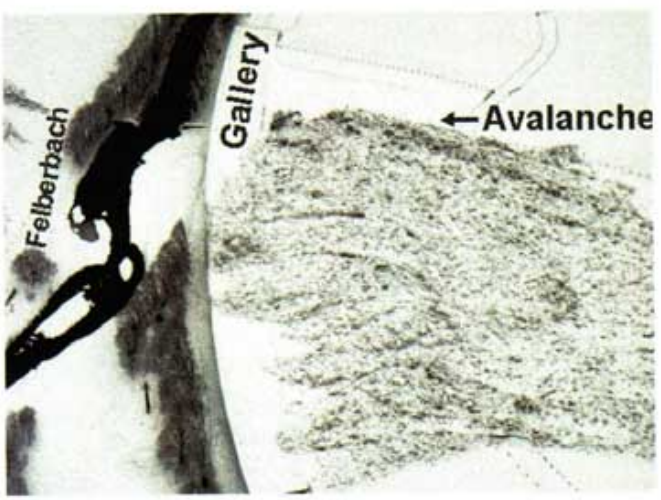
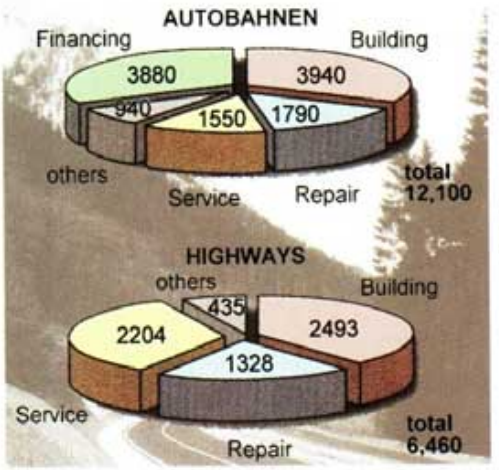
Torrent and Avalanche Control

The emphasis of Austrian Flood and Avalanche Control is to plan and build protective constructions such as avalanche control fences, avalanche galleries, and avalanche dams to minimise threats caused by heavy snowfalls. Special avalanche warnings are issued daily by the local weather information centres. In some cases roads have to be closed due to avalanche danger.

An experienced farmer has built his farmhouse near Unken, Salzburg on a protected site. Unfortunately the access to his house is not safe. Locally large quantities of fresh snow led to overload and to a big avalanche.



Avalanche gallery B108 Felbertauernstrasse



Expenses in Mio ATS

Expenses for maintenance of all federal roads, buildings, equipment and wages is $250 million / year. For winter service 22% to 24% of the whole budget, that is about $ 55 to $ 60 million has to be provided.

Road service vehicle in action on B107 Grossglockner
High Alpine Road, Salzburg Province

Winter Road Management Policies and Their Budget Scale

Standards of winter roads

Austria has four levels of winter road service:

a) Interstate highways

(Autobahnen) provide a 24 hour winter service, with maximum a period of three hours interruption for snow removal or application of salt. Defrost measures have to be used on Autobahnen without exception. Within winter maintenance interval, snow depth can reach from 5 to 10 cm .

b) Highways and provincial roads with over 3,000 vehicles / 24 hours

Service is provided 4 am to 10 pm, with a maximum of five hours between treatments. It is accepted that snow covered

Road Maintenance Base Mauterndorf, Salzburg Province

roads could impair driving between 10 pm to 4 am. Between service times snow depth can reach over 10 cm.

c) Highways and provincial roads with heavy bus / commercial / leisure use

Service is provided 5 am to 8 pm, with a maxiumum of five hours between treatments. It is accepted that snow covered roads could impair driving between 8 pm and 5 am. Between service times snow depth can reach over 10 cm.

d) Highways and provincial roads with less than 1,000 vehicles per 24 hours

Snow removal is provided only once to twice a day, between 8 am and 8 pm. Gravel application on the surface must be done after snow removal. No circulation time for winter maintenance is recommended. During heavy snowfall periods the use of chains could be necessary.

Salt consumption on Autobahnen and the provincial road network

The five years average of salt (NaCl) consumption, for one winter period (Nov. to March), on 1,600 km Autobahnen and 10,400 km Highways is about 150,000 tons. The expenses therefore amounts to $ 10 million. The average of CaCl consumption (same period) is about 5,000 tons/year.

In general the provincial maintenance centres are responsible for winter service. Specifically, in Salzburg Province no contracts are given to private companies concerning winter road service. This is different to other Austrian Provinces. The regional government of Salzburg believes that winter road maintenance is a public task. At present Salzburg Province has 70 lorries and 35 Mercedes Unimog, equipped with lateral snowploughs, and automatic spreading machines. For snow removal also lateral snowcutters and drum snowcutters are provided. Evaporated salt (NaCl) is used for chemical de-icing, often in combination with wet-salt technology. The supply of nearly 8,000 tons of salt is stored in silos and halls, and distributed over the whole of the Salzburg area. The average consumption of salt per year is about 12,000 to 15,000 tons.

In winter time each maintenance base provides an 24-hour phone service in order to react to police requests. If snow removal is necessary during the night, employees, on standby, can start ploughing the roads within one hour. On normal days road surface control starts at 4 o'clock in the morning. At noon the crew is changed and the next staff will work till 8 p.m. or longer. To keep staff costs down the vehicles usually are occupied by one person, the driver. Assistant are not provided anymore.

Obertauern, Salzburg Province

Lateral snowblower Obertauern, Salzburg Province

BELGIUM

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Area	30,500 km²	
Population	10.2 million	
Length of road	Motorway	1,700 km
	Regional main roads	13,000 km
	Local roads	131,000 km
Latitude (capital)		50°50'N

Facts and Figures Belgium

Belgium is a country small in size (30,500 km²) but densely populated (10.2 million), situated at the heart of Europe. The country occupies a privileged position in 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 directed to export (2/3 of production is exported). The prospects and prosperity of Belgium depend to a large extent on its transport infrastructure. So, the motorway and railway network is one of the densest in the world.

The country is a federal state with three regions: Flanders in the north (5.9 million), Brussels at the centre (0.95 million), and Wallonia in the south (3.35 million). These three regions have autonomy in several branches, including the construction, management and maintenance of the motorways and expressways on their territories.

Flanders is a flat region (0 to 100 m), whereas Wallonia contains the Ardennes, a group of plateaus 400 to 500 m in altitude.

The road network comprises 1,700 km of motorways, 13,000 km of regional main roads and 131,000 km of local roads, amounting to a total of 145,000 km of paved roads. The national fleet of 5.5 million vehicles includes 4.5 million passenger cars each travelling an average distance of 15,000 km a year. Traffic is also important during the night, particularly commercial traffic.

Road transport accounts for 71 % of total freight transport. 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 full organization for winter maintenance. The winter season extends from November to March.

The country has a temperate maritime climate characterized by a relatively high number of rainy days (one in three) giving an annual rainfall of 700 (in Flanders) to 1,500 mm (at certain points in the Ardennes). The number of days of snow varies considerably from one point of the territory to another: from 14 days/year on the coast to 63 days/year on the Ardennes plateaus. The number of days of frost in Brussels remains acceptable: 59 per year. What characterizes the winters, at least in Flanders and Brussels, is the existence of numerous daily cycles of frost and thaw. The further we move towards the Ardennes plateaus, the more temperature falls and the number of freezing days increases - to a mean value of 115 per year.

Winter Road Maintenance Products and Techniques

In former days, the means available to ensure the winter serviceability of roads were very rudimentary and limited to gritting, that is, spreading sand, gravel, metal slags, etc. These abrasives had a series of disadvantages. As a result, the use of abrasives was three times as expensive as the spreading of de-icing salts. That is why Belgium changed over to the systematic use of salts (NaCl and $CaCl_2$) in the sixties.

The choice between these two salts in Belgium is generally made in consideration of temperature. NaCl only works down to -7 °C, whereas $CaCl_2$ remains effective at temperatures ranging between -7 and -15 °C.

In comparison with NaCl, the main disadvantages of $CaCl_2$ are its higher price (in Belgium it is 4 times as expensive as NaCl) and the extra precautions to be taken to prevent lumping during storage.

NaCl and $CaCl_2$ used to be spread dry in the early days, but practice has gradually changed over to spreading brine (solution containing 25 % NaCl or 33 % $CaCl_2$) and - since the nineties - to the wet salt method.

Many other de-icing chemicals have been tested in Belgium: $MgCl_2$, urea, phosphates, calcium magnesium

acetate (CMA), etc. They are markedly inferior to NaCl and $CaCl_2$ and have, therefore, never gained acceptance. Only alcohols and glycols are used for preventive treatments ("anti-icing") on airfield runways. Road heating has been abandoned since the seventies, on account of high investment and operating costs.

Road Weather Information

To minimize the adverse effects of wintry weather, a coordinating road weather protection service has been operational in Belgium since 1953. This service belongs to the Meteorological Wing of the Belgian Air Force, which draws up weather reports for road users and those involved in winter maintenance. Forecasts are made in terms of standard winter types (marked by a letter - see below), while indicating the climatic zone of the country where the standard type reported is most likely to occur.

These standard winter weather types and other information about winter conditions are disseminated to road users through various channels (radio, television, Internet sites, etc.).

Coded winter condition types (Table 1) are also useful to staff in charge of winter road maintenance. A type of action is linked to each of these winter types (Table 2). Of course, district managers take additional information into consideration before making the decisions they think fit. Examples of such additional information are developments in local weather conditions, any information they receive from road patrols, data from local weather stations, etc.

Under weather conditions up to and including type D, decisions as to turnouts for winter maintenance are taken as much as possible at the district level.

Table 1

	Condition
A	No winter situation. Mild weather. Air and ground temperature above 0 °C.
B	Winter situation - dry weather, air and/or ground temperature below 0 °C - without risks to traffic, except a slight chance of a few isolated patches of rime or black ice or some limited insignificant snowfall.
C1	Cold mornings. No significant precipitation. Chance of patches of rime or black ice, of limited snowfall, of freezing fog or frost on wet roads.
C2	Cold evenings and/or nights. No significant precipitation. Chance of patches of rime and/or black ice, of limited snowfall, of freezing fog or frost on wet roads.
D	Several adverse weather conditions with a time-limited effect on traffic: snow, showers, general freezing fog or frost, frost on wet roads, etc.
E	Persistent winter conditions that severely disturb traffic. Frost and general snowfall.
F	Severe and persistent winter conditions, the consequences of which could severely dislocate the country's economy.
G	Exceptional conditions of a sudden and short-term nature that require immediate action.

Table 2

	Action
A	Do nothing.
B	Do nothing, but keep watch on changing situations.
C1	Spreading in the morning or curative spreading.
C2	Preventive spreading in the evening, or curative spreading.
D	Preventive or curative spreading at all hours of day or night. Possible introduction of standby rotas in the districts.
E	Spreading and/or snow clearing. Standby rotas in the provincial directorates.
F	As in E above, but with: - the calling in of backup equipment subject to deferred contracts, - the introduction of a standby rota at the central administration.
G	Direct warnings to persons responsible for winter maintenance and to road users: news flashes on radio, television, etc.

The introduction in recent years of a network of local weather stations has made it possible to refine forecasts by also recording, collecting and interpreting a number of road-related parameters. As a result, the system described above is gradually being abandoned.

Slipperiness Measurement Systems

To keep the road network free from snow and ice, reliable information must be available in due time. Where and when will road surfaces be slippery? Where should de-icing salts be spread preventively and where not? In this context, the installation of a system to measure road slipperiness was initiated in Belgium a few years ago, to support winter maintenance. This system allows future decisions - as to spread salt or not and as to the most opportune moment to start spreading operations - to be based on more solid grounds. Its purpose is, on the one hand, to automatically record road surface condition and a few meteorological data and, on the other, to help predict the probability of roads becoming slippery. The aim in view is to better anticipate the weather situations that normally result in rime ice, black ice or snow, so that preventive salting can be timed just before the occur-

Figure 1 A forecasting station

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Figure 2 A measuring station

Figure 3 PEREX centre in Wallonia

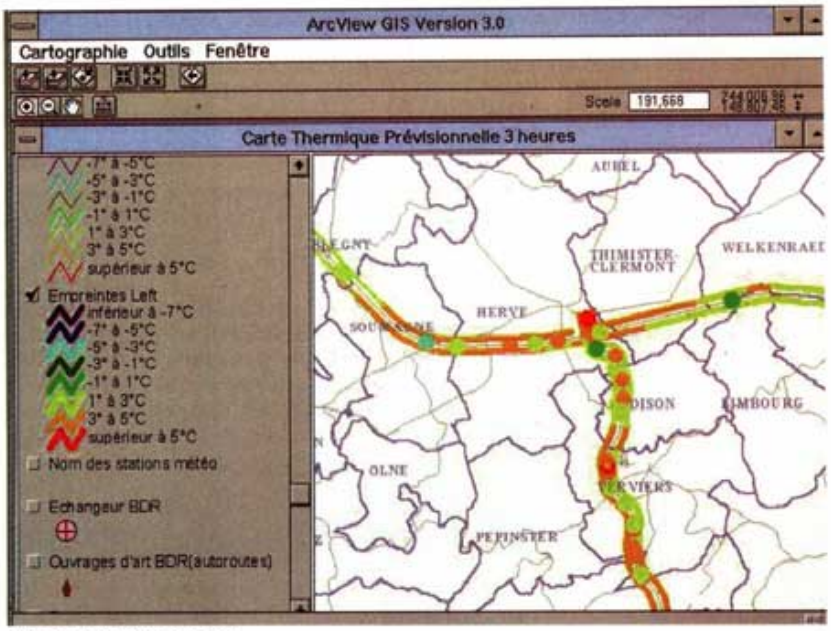

Figure 4 A thermal map

rence of the expected adverse weather conditions. This would make it possible to reduce or even abandon systematic preventive spreading, and replace it with precurative or curative interventions that are made as promptly as possible.

As a preliminary to the installation of such a system, an infrared scanning operation is performed on the whole network. This scanning (thermal mapping) reveals which areas of road surfacing within a given climatic zone are colder and hotter at a given time under equal conditions. The resulting data on heat sensitivity are thoroughly analysed and processed to thermal maps.

On the basis of these analyses and personal field knowledge, more than hundred weather stations have been installed in strategic places throughout the country. There are two types of weather station: forecasting and measuring stations (Figures 1 and 2). A measuring station is equipped with sensors for air temperature and humidity, one or more road surface sensors, a precipitation sensor, a visibility meter and one or two radiometers. A forecasting station has additional sensors for wind direction and speed, and one or several sensors for subsurface temperature. Data are transmitted frequently (e.g. every six minutes) by computer lines to the regional control centre (e.g. the PEREX centre in Wallonia, Figure 3) and to the national Meteorological Wing of the Air Force.

Each district has a local terminal to view data from the relevant weather stations. Special computer software makes it possible to predict road surface temperature and condition in the vicinity of each main station up to 24 h in advance, using the information gathered at the operational stations and the general weather forecasts of the Wing. The output of this software can be used to generate forecasting thermal maps (Figure 4).

The Organization of Winter Maintenance

The organization of routine and winter maintenance is the responsibility of:

- local authorities (towns and municipalities) as far as municipal roads are concerned (131,000 km in total);
- sixty regional districts for the 14,700 km of regional roads (= motorways and main roads).

District tasks

Winter maintenance by the districts comprises the following four tasks:

- a coordinating and executive task for the district manager, who is charged with the day-to-day running of operations. He monitors the weather forecasts and observations and makes the necessary decisions for turnouts. He calls up the necessary personnel of the unit and the contractors, and determines the type of de-icing agent to be used and its rate of application;
- a force account task for management authority personnel, who are responsible for carrying out winter maintenance on one or more salting routes account as far the number of workers permits;

- a supporting task for private contractors. The logistic support of the contractors takes the form of providing a lorry and a driver. The demountable spreader (to be placed on the loading floor of the lorry) and the de-icing salt are provided by the district;
- an inspection task, which consists of making inspection tours and monitoring the weather observations and forecasts.

Involvement of the private sector

The implementation of winter maintenance on most salting routes (80 to 90 % of them) is let to private contractors. The 3 years contracts made with them are based on a standard winter maintenance contract. Each contract stipulates the winter maintenance operations to be performed on a given route within the boundaries of one district. Routes may vary per type of action. Additional contracts for "exceptional operations" are concluded with the private sector as well.

Each year, a central unit of the competent road administration awards contracts to several salt suppliers after an open tendering action, so that the winter stocks can be replenished. Contracts for salt supplies are concluded at the central level, in order to derive maximum price benefit from large demands. The central unit also monitors the implementation of the contracts. Furthermore, it draws up directives for salting under various conditions (at extremely low temperatures, on existing layers of ice, on porous asphalt, etc.) if necessary and thinks along with the industry in further developing and improving salt spreaders, slipperiness measurement systems, etc.

Salt consumption

Annual salt usage is bound to vary with the severity of winters. For example, in the period 1982 - 1999 the aggregate total annual consumption of the de-icing salts (NaCl and $CaCl_2$) on the regional road networks is as follows (in tons) :

	Minimum	Maximum	Average	Proportion of CaCl2
Flemish Region	9,000	85,000	38,500 (470 g/m²)	1 to 3.5 %
Walloon Region	46,000	143,000	91,500 (1,220 g/m²)	3.5 to 38 %

The breakdown of winter maintenance costs averaged over the past 17 winters is as follows :

	Purchase of de-icing salts	Equipment and personnel	Involvement of the private sector
Flemish Region	37 %	36 %	27 %
Walloon Region	37 %	23 %	40 %

The average annual cost of winter maintenance in Belgium is about 0.25 Euro/m² (ranging from 0.12 to 0.40 Euro/m²).

Wet salt technique

In the early eighties, an economical spreading technique was introduced in Belgium: wetted salt. In this procedure, dry salt is wetted with a solution of calcium or sodium chloride at the time of spreading. The wet salt is spread with a normal spreader equipped with a tank and a pump for liquids. During spreading, the salt is wetted in a proportion of 1 part of liquid to 2.5 parts of salt. Wetted salt can be spread much more economically, since wind has little effect on it and the salt is actually spread on the road surface and not dispersed on the shoulders. Even high crosswinds appear to have less effect on the spreading pattern.

Wetted salt not only has the advantage that it can be spread more economically and at higher vehicle speeds (up to the double), but also works faster. Dry salt grains on a dry layer of ice need some time to absorb moisture from the environment and develop a saline solution capable of melting the ice. This time is saved when spreading wetted salt, since there is enough saline solution right from the start to initiate the melting process.

On the other hand, the technique requires an adaptation of the spreading equipment, which is a major item of expenditure. The Flemish Region has, therefore, adopted a policy for the full renovation of its fleet of salt spreaders over a period of twenty years - starting in 1990 -, by buying only wet salt spreaders.

Introduction of a data navigation and analysis system

In 1998, a software programme was purchased for all districts in the Flemish Region. With this programme it is possible to record and computer-process all the data on salting operations read from the control boxes of salt spreaders. Conversely, it is possible to preprogramme the control boxes of salt spreaders, so that only preset values (rates and widths of spread, etc.) can be implemented. After salting, the readings can be used to check whether the treatment was performed everywhere (and no roads or road sections were forgotten), whether the rate of spread was nowhere higher than strictly necessary, how much salt was spread, how much time the turnout took, what the travel speed of the spreader was, etc. The introduction of this system is a major step forward towards an environment-friendly approach to de-icing.

De-icing salts and the environment

The environmental impact of treatments performed to keep roads serviceable can be controlled by improvements resulting from technological progress.

Several such improvements have made it possible to considerably curtail salt usage in Belgium :

a) the wet salt technique,
b) the use of microprocessors in the automation of salt spreaders,
c) better weather forecasts, by such measures as the introduction of slipperiness measurement systems,
d) the recording of data on salting operations;
e) higher qualification of personnel through training activities,
f) the choice of the type of de-icing salt. Fast-acting salts can be spread in smaller amounts.

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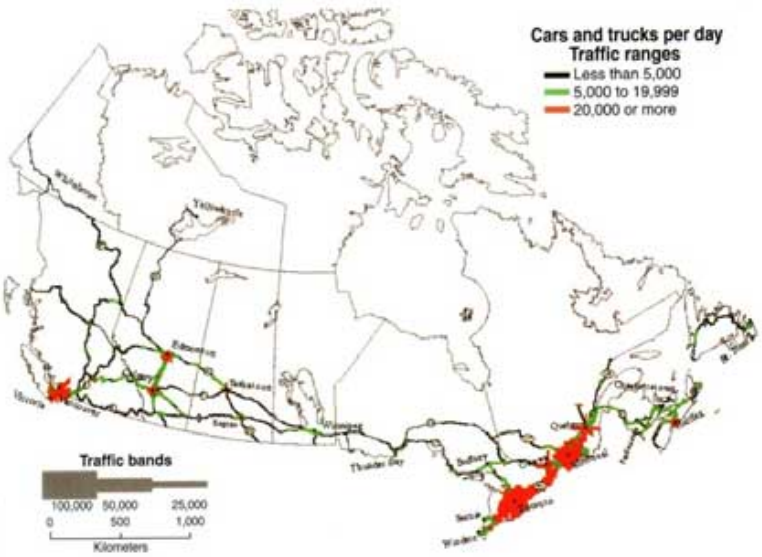
Demographics and Roads

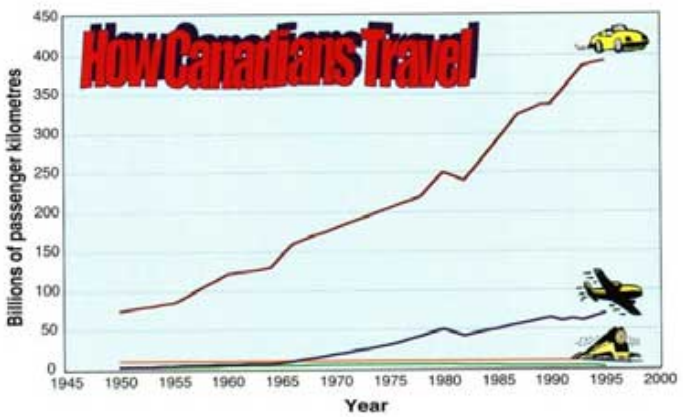
Area	9,093,507 km²	
Population	31,081,900 (as of July 2001)	
Pop. density	3.42	
Length of road	1,427,000 km	Primary highways/urban arterial 102,600 km
		Secondary highways/urban collector 102,900 km
		Local roads and streets 1,221,500 km
On-road vehicles (2000)	Total on-road vehicles 17,291,000	Passenger cars/light trucks 16,515,000
		Trucks over 4,500 kg 776,000
Latitude (capital)		45°27'N

Population & vehicle densities

	Land	Population ('000s)	Population Density	Cars/Trucks ('000)	Cars/1000 persons
Canada	9,093,507	31,082	3.42	16,515	531
Newfoundland	373,872	534	1.43	240	450
Prince Edward Island	5,660	139	24.47	71	516
Nova Scotia	53,338	943	17.67	502	532
New Brunswick	71,450	757	10.6	421	556
Quebec	1,365,128	7,411	5.43	3,736	504
Ontario	917,741	11,874	12.94	6,245	526
Manitoba	553,556	1,150	2.08	580	504
Saskatchewan	591,670	1,016	1.72	613	604
Alberta	642,317	3,064	4.77	1,874	612
British Columbia	925,186	4,096	4.43	2,190	535
Yukon	474,391	30	0.06	21	712
Northwest Territories	1,183,085	41	0.03	18	438
Nunavut	1,936,113	28	0.01	2	88

Traffic volumes along national highway system



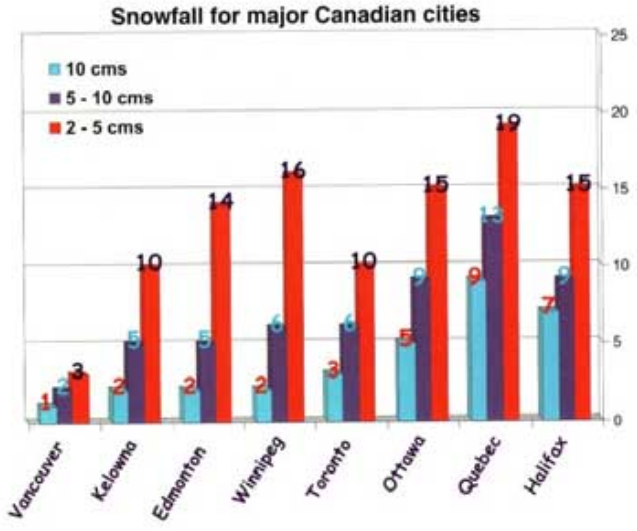


Climate

Canada is a northern country whose climate is marked by long cold winters. The southern few hundred kilometers north of the border with the United States, where the vast majority of Canada's population is concentrated, are generally snow bound from mid December through to the end of March or for about one third of each year. Annual snowfall amounts range from lows of 1 meter per annum on the central prairies to well over 3 meters in south central Québec and over 4 meters per year in parts of Atlantic Canada. The only exception is the west coast; the city of Vancouver and Vancouver Island, where the winters are very mild and wet. The following graphics and tables tell the story for whole land mass of Canada and for major cities along the National Highway System.

The following table depicts the characteristic of the snowfall for major Canadian cities. The number of events for a number of snowfall categories of importance to winter main-

Snowfall for major Canadian cities



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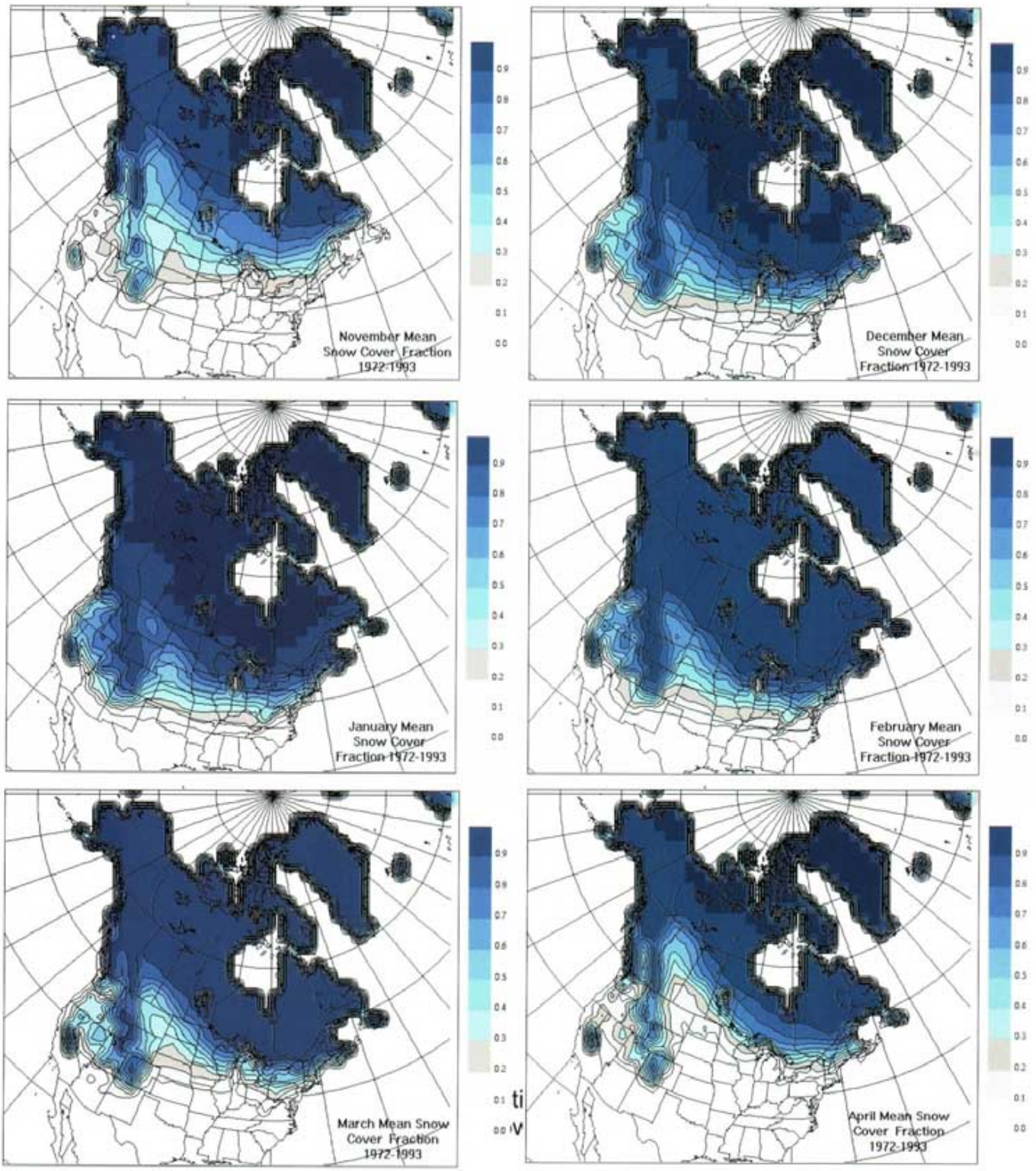

tainers are represented.

The next table provides detailed information about total snowfall in centimeters along with the mean annual number of days per year with freezing rain (see page 24), a good indicator of the mildness of the winter climates across Canada since freezing rain only occurs with temperatures hovering just below the freezing point. The final column provides a crude winter index. Existing winter indices were found to not correlate very well with the winter maintenance costs and salt used in Canada. This much simpler index (annual snowfall in centimeters divided by 5 added to the total annual number of days with freezing precipitation) was found to correlate as well as any more complex winter severity index with winter maintenance operations.

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Climate of the national highway system

Province or territory	Observation site	Mean annual snowfall centimeters	Mean annual number of days with freezing rain	Weather index by city	Mean weather index by jurisdiction
Newfoundland	St. John's	322.1	38	102.4	
	Gander	443.8	37	125.8	
	Stephenville	411.8	11	93.4	107.2
Prince Edward Island	Charlottetown	338.7	17	84.7	84.7
Nova Scotia	Sydney	329.5	19	84.9	
	Halifax	261.4	16	68.3	
	Yarmouth	205.3	8	49.1	
	Greenwood	283.3	11	67.7	67.5
New Brunswick	Moncton	365.5	17	90.1	
	St. John	283.2	12	68.6	
	Fredericton	294.5	13	71.9	
	Edmunston	372	10	84.4	78.8
Québec	Mont Joli	373	8	82.6	
	Québec	337	15	82.4	
	Bagotteville	344.7	13	81.9	
	Trois Rivières	242	14	62.4	
	Montréal	214.2	13	55.8	
	Sherbrooke	288.2	10	67.6	
	Val-d'Or	317.6	16	79.5	73.2
Ontario	Ottawa	221.5	17	61.3	
	Trenton	167.7	11	44.5	
	Toronto	124.2	10	34.8	
	London	212.3	13	55.5	
	Windsor	123.3	10	34.7	
	Barrie	214	10	52.4	
	North Bay	268.4	20	73.7	
	Kapuskasing	325.7	13	78.1	
	Sault Ste. Marie	316.4	10	73.3	
	Thunder Bay	195.5	7	46.1	
	Kenora	178.3	15	50.7	55
Manitoba	Winnipeg	114.8	13	36	
	Portage-la-Prairie	156.1	12	43.2	
	Brandon	195.8	11	50.2	43.1
Saskatchewan	Regina	107.4	14	35.5	
	Swift Current	127.8	8	33.6	
	Saskatoon	105.4	10	31.1	
	Yorkton	128.7	11	36.7	
	Estevan	110.2	9	31	33.6
Alberta	Medicine Hat	108.2	3	24.6	
	Lethbridge	160.1	3	35	
	Calgary	135.4	6	33.1	
	Edmonton	127.1	8	33.4	
	Peace River	140.7	6	34.1	
	Grande Prairie	174.6	7	41.9	33.7
British Columbia	Hope	169.2	3	36.8	
	Kamloops	86.2	2	19.2	
	Revelstoke	445.3	3	92.1	
	Castlegar	224.6	3	47.9	
	Cranbrook	147.9	2	31.6	
	Penticton	73	1	15.6	
	Prince George	233.8	6	52.8	
	Terrace	389	2	79.8	
	Victoria	46.9	0	9.4	42.8
Yukon Territory	Whitehorse	145.2	2	31	31
Northwest Territories	Yellowknife	143.9	11	39.8	39.8

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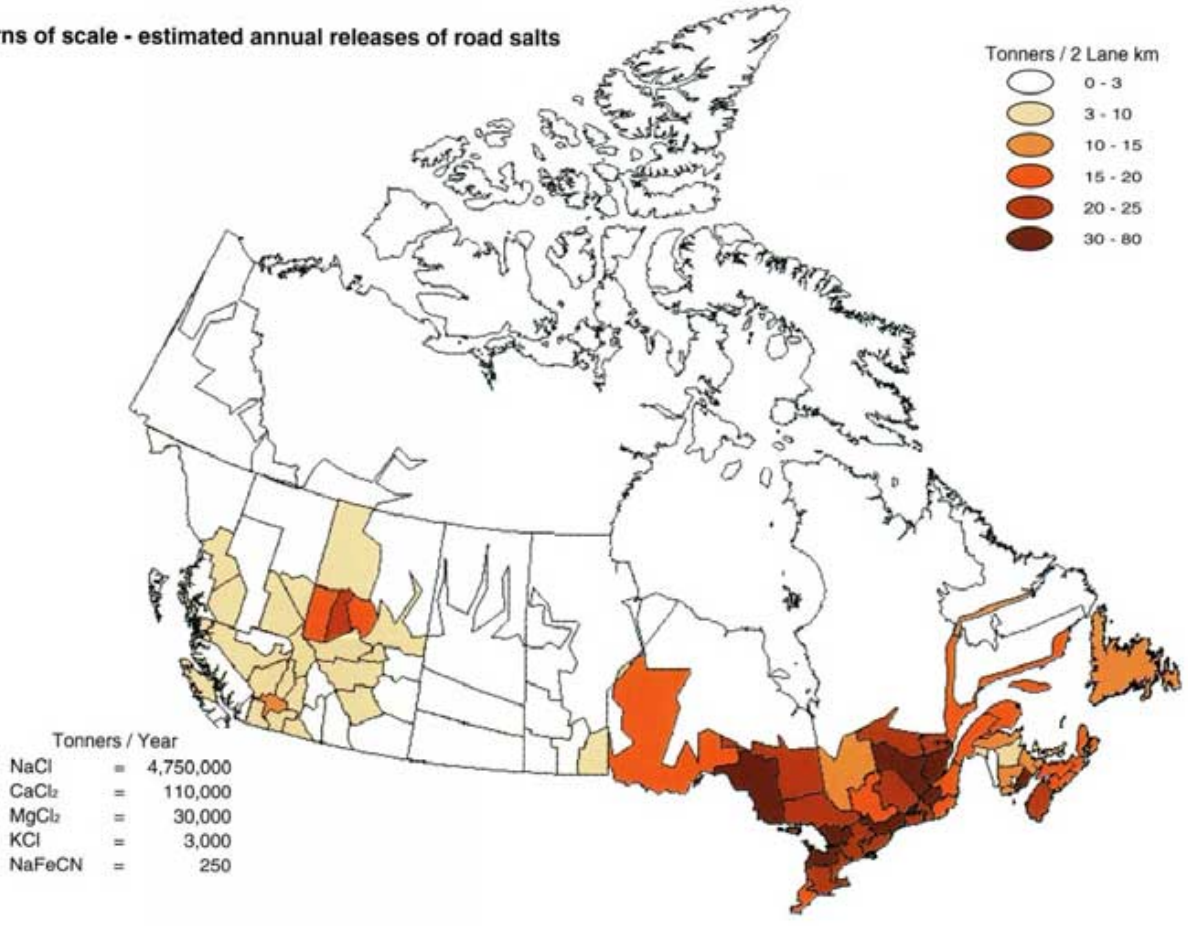
National Policy for Snow and Ice Management

Under the Constitution of Canada, the operation of the highway and road systems is a mandate of the provinces and municipalities. This extends to winter road maintenance. Provinces and municipalities have full autonomy to establish their own winter maintenance programmes. This includes determining the level of service and such fundamental policy issues as whether to use salt or sand and whether to perform the maintenance in-house or to contract it out. In some provinces (Alberta, Ontario), winter road maintenance is wholly (or nearly so) contracted out while in others (Saskatchewan, New Brunswick) it is largely or wholly done by government employees. Most cities use a mix of public and private maintainers.

Understandably, this decentralized approach coupled with the wide range of winter climates across Canada, has also led to some variation in winter road maintenance standards across the land. While the level of service does vary from jurisdiction to jurisdiction, it is generally higher for high-volume high-speed highways and for major thoroughfares within cities.

Transport Canada estimates that 90% of people kilometers and 70% by revenue of the transportation of goods rely on the road transportation network. Natural Resources Canada estimates that the total annual cost for winter road maintenance for all of Canada approaches $ 1 billion per year. Surveys conducted by the Environmental Protection Service of Environment Canada indicate that nearly 5 million metric tones of road salts (almost all NaCl but with some $CaCl_2$) are spread on Canada's roads annually. The application rates vary dramatically across Canada as indicated on the chart below. Salt usage is much greater in those parts of Canada with many freeze-thaw cycles, abundant winter precipitation, and high traffic volumes. Generally salt application rates for most jurisdictions have slowly increased over the last few decades. This is in response to growing traffic volumes and a public demand for safe transportation throughout the year.

Concerns of scale - estimated annual releases of road salts



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Snow and Ice Control for Ontario Provincial Highways

Introduction

The following details the specific practices for snow and ice control in the province of Ontario as applied to provincial highways. Ontario is a good choice since it is the largest and most populated province. In addition, it has a wide range of winter climates; from the very cold and dry continental-type in the northwest to the very moist and mild more maritime-type in the southern Great Lakes basin and so represents very well the range of climates across all of Canada. This section will then serve as a very good example of the winter maintenance practices across all of Canada.

Contracting of snow and ice control services

The Ministry of Transportation of Ontario contracts its snow and ice control services, but sets standards used by contractors and monitors operations before, during, and after winter storms. Contractors are closely scrutinized for compliance to standards and penalties for failure are severe and can include loss of a contract.

Quality standard

Winter maintenance operations are provided to maintain a consistent level of service across the province for varying classes of highways. Winter traffic volume is the primary indicator used to determine the winter level of service for each class of highway. The winter level of service is primarily the time taken to achieve a bare pavement. All highways in Ontario have been divided into five classes with Class 1 being the highest and Class 5 being the lowest. The following highway classes and corresponding Winter Average Daily Traffic Volume (WADTV) for southern and northern Ontario are used by all maintenance service providers (public or private) for the Province of Ontario:

Class	WADTV	
	Southern Ontario	*Northern Ontario*
1	> 10,000	> 10,000
2	2,000 to 10,000	1,500 to 10,000
3	1,000 to 2,000	800 to 1,500
4	500 to 1,000	400 to 800
5	< 500	< 400

The following winter maintenance summary table is a compilation of maintenance quality standards, best practices, and policies in effect. Actual conditions will dictate the appropriate work required.

	Class 1	Class 2	Class 3	Class 4	Class 5
Maintenance quality standard					
Primary objective	**Essentially bare pavement**	**Essentially bare pavement**	**Essentially bare pavement**	**Essentially bare pavement**	**Snow pack**
Time to Meet Primary Objective as soon as possible after the storm, but not exceeding:	8 Hrs.	16 Hrs.	24 Hrs.	Centre-bare within 24 Hrs. And essentially bare pavement when conditions permit	24 Hrs.
Operation					
Salting - Begin salting when snow accumulation: - Or before freezing rain produces icy conditions - Follow-up salting:[1]	<0.5 cm when required	<0.5 cm when required	<0.5 cm when required	<0.5 cm when required	N/A N/A
Plowing - Begin plowing snow accumulation when: [2]	≤ 2.0 cm	≤ 2.0 cm	≤ 2.0 cm	≤ 2.0 cm	≤ 2.0 cm
Sanding - Begin sanding when:	Slippery conditions	Slippery conditions	Slippery conditions	Slippery conditions	Slippery conditions
Equipment complement calculation					
Salting - Theoretical circuit time[3]	1.3 Hrs.	1.8 Hrs.	2.9 Hrs.	4.9 Hrs.	N/A
Plowing - Maximum single lane km/plow:	55 km	75 km	120 km	206 km	336 km
Sanding - Follow-up sanding:[4] - Theoretical circuit time:	When Required	When Required	When Required	When Required	When Required 8 Hrs

Caveat:

- While this Maintenance Quality Standard establishes levels of service, it is acknowledged that conditions may occur which temporarily prevent achieving levels as assigned. In such cases, attempts shall be made to keep highways open by utilizing all winter maintenance equipment at maximum efficiency.
- Winter operations will continue until the prescribed level of service is achieved where conditions permit. Should conditions not permit accomplishment of the prescribed level of service, operations shall continue as required to maintain a good driving surface.

Notes:

1. Follow-up salting and sanding will be determined by the precipitation, road conditions and weather. The goal is to maintain as good a driving surface as possible in the conditions.
2. Generally, salt on the road takes time to become fully effective and therefore plowing should not normally occur until at least 1/2 hour after the salt has been placed, but may be less if warranted because of snow accumulation, ambient temperature and traffic volume.
3. Circuit time is the theoretical time required to complete an initial coverage of a route.
4. Sanding should begin as soon as slippery conditions are detected and should continue, using available resources as necessary.

Best practices

Snowdrifting should not be permitted to accumulate on the driving surface and should be removed from the shoulder before the snowdrift extends to the driving surface.

From the time unfavourable road conditions are detected and winter equipment is required, maintenance staff has a maximum of 1/2 hour to have the required operator(s) in the vehicle(s) and equipment ready to begin work. For spreaders, this means in the process of having the spreader(s) filled with sand or salt. For plowing, this means en route to the area of concern.

Before, during, and after the storm, deicers and/or abrasives should be applied at the specified spreading rates to improve the friction of the road surface when required for safety reasons and to attain the specified level of service.

Echelon plowing

This is the practice of staggered snow plows operating across all lanes of a roadway together. This is particularly important for some sections of highway 401 near Toronto which can be as many as 6 lanes wide in each direction with 3 or 4 more feeder lanes on each side. For multi-lane highways, it is often the safest and most efficient snow removal method. Plowing in echelon clears all lanes at once by passing a ridge of snow from one plow to the next.

Technological improvements

The Ministry of Transportation is continually working on improvements in snow and ice control operations and on safe ways to reduce salt usage. Some technologies currently under investigation are:

- De-icing liquids are added to road salt to make it work more quickly than dry salt to melt ice and snow. "Pre-wetted" salt also tends to stay on the road better and works at lower temperature than dry salt alone.
- Integrated road weather information systems help staff and contractors make the best and most timely decisions on how to deal with winter conditions. MTO is at the forefront in the use of RWIS in Canada.
- Advances in salt and sand spreading equipment.

Road Weather Services

The lead agencies in road weather services in Canada are the road maintenance agencies although in at least one case, in British Columbia, the provincial auto insurance corporation was also involved in promoting advanced technologies. Road maintainers in Canada are beginning to invest in the information technologies necessary to improve road maintenance decision processes. Numerous road agencies in Canada at all levels, provincial, municipal, and private have invested in particular, in road weather information systems (RWIS).

Typically in Canada, the full purchase and installation costs as well as the on-going costs for the sensor systems themselves is borne by the maintenance organization that wishes to have the data. Telecommunications are generally by telephone (generally land line but some radio and cellular) and are also borne by the maintenance organization. The following map depicts the number of full RWIS systems in use by province as of late 2001.

The Meteorological Service of Canada has been working closely with a broad cross section of representatives from the winter maintenance community as well as with all of the provinces and territories on national standards for RWIS systems. This has led to the general adoption and application of World Meteorological Organization standards for the placement and siting of all of the atmospheric sensors. Uniquely Canadian common approaches were determined for the placement of the sensors located in the roadway. Finally, National Transportation Communications for ITS Prototocols for the Environmental Sensor Stations (NTCIP-ESS) were adopted. ITS stands for Intelligent Transportation Systems. The United States NTCIP committees have developed a broad range of standards for ITS. The ESS standard facilitates integration of networks across provincial boundaries and allows jurisdictions to select from among a range of compliant instrument vendors as opposed to being locked in with just a single supplier.

On page 29 is a picture of a typical RWIS installation in Canada. The photo is from the outskirts of the nation's capital city, Ottawa. Below is a picture of the type of passive road sensor most commonly encountered in Canada. With the adoption of the NTCIP-ESS protocol in 2001, the mix of vendors' equipment in use in Canada has become considerably more varied.

Road agencies control access to the road weather data acquired by their RWIS systems. Almost universally, the

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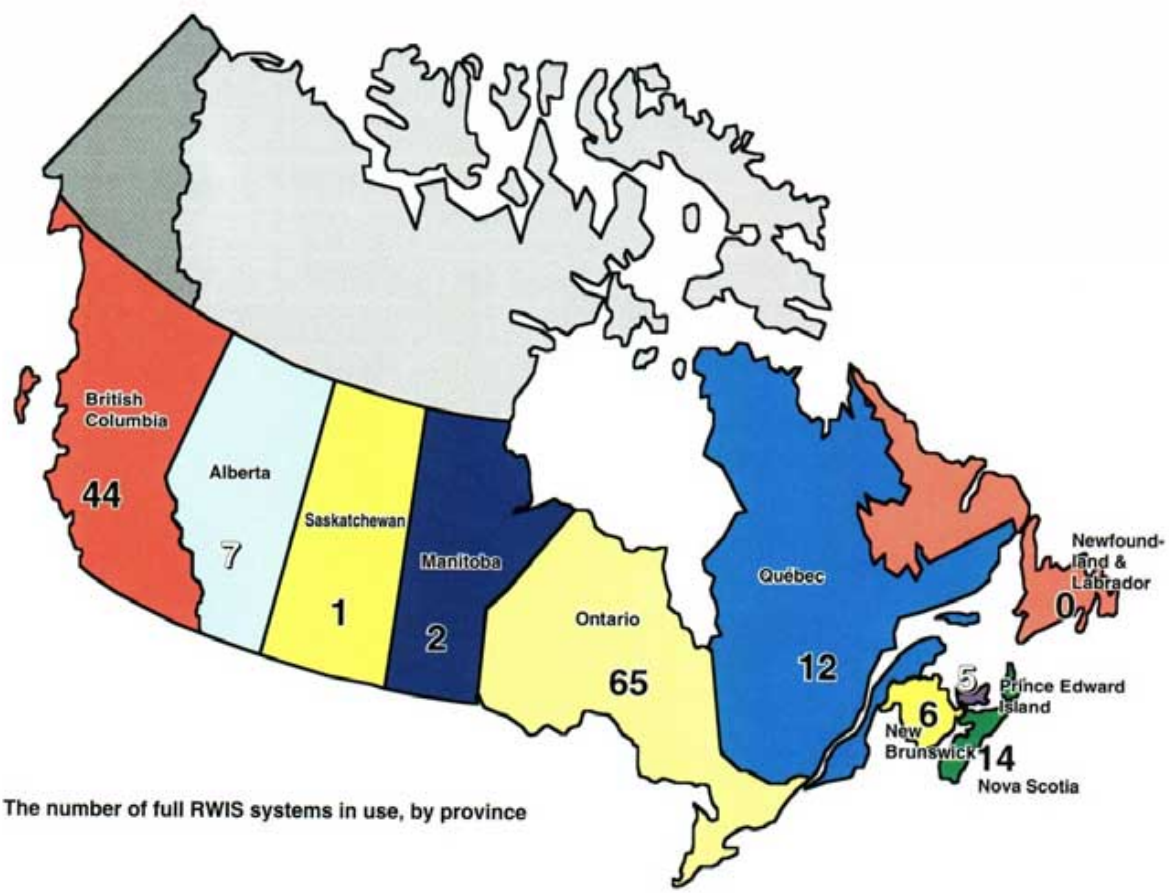
data are shared with the Meteorological Service of Canada (MSC). The MSC has developed physical heat-balance models for the preparation of road surface temperature and condition forecasts a sample of which is provided below right. This output is from the METRo model developed by Louis-Philippe Crevier and Dr Yves Delage. Volume 40, Issue 11, published in December 2001, of the Journal of Applied Meteorology of the American Meteorological Society provides a full description of the METRo model.

Proactive winter road maintenance or "anti-icing" is beginning to gain wide acceptance in Canada in recent years. Treating before conditions deteriorate requires less chemical, is more efficient, costs less, and reduces the periods of reduced road friction and thereby enhances safety. Treating before conditions deteriorate does however require a detailed knowledge of what the future road temperature and conditions will be with a high degree of confidence. The meteorological community is responding with equipment and services to meet this demand. The following developments are likely to have a major impact on the rapid progress in the road weather area over the next half dozen years.

a) In August of 2000, the Environmental Protection Service (EPS) of Environment Canada published its environmental risk assessment of road salts at the conclusion of a 5-year study. The public review period ended in the summer of 2001. A final ministerial decision declaring road salts "toxic" under the Canadian Environmental Protection Act (CEPA) was rendered public in November 2001. CEPA requires the EPS to lead a process to devise control strategies (over 24 months) and implement them (over the succeeding 18 months). All road agencies appreciate that road salts are causing some environmental damage and that measures must be taken to reduce the application rates without impacting road safety.

b) The provinces and territories are completing a proposal for a Road Weather Information System for Canada. Under development since late 1999, the RWISC proposes basically two fundamental components: a shared cost (on a 50-50 basis with Transport Canada) national integrated RWIS network along the



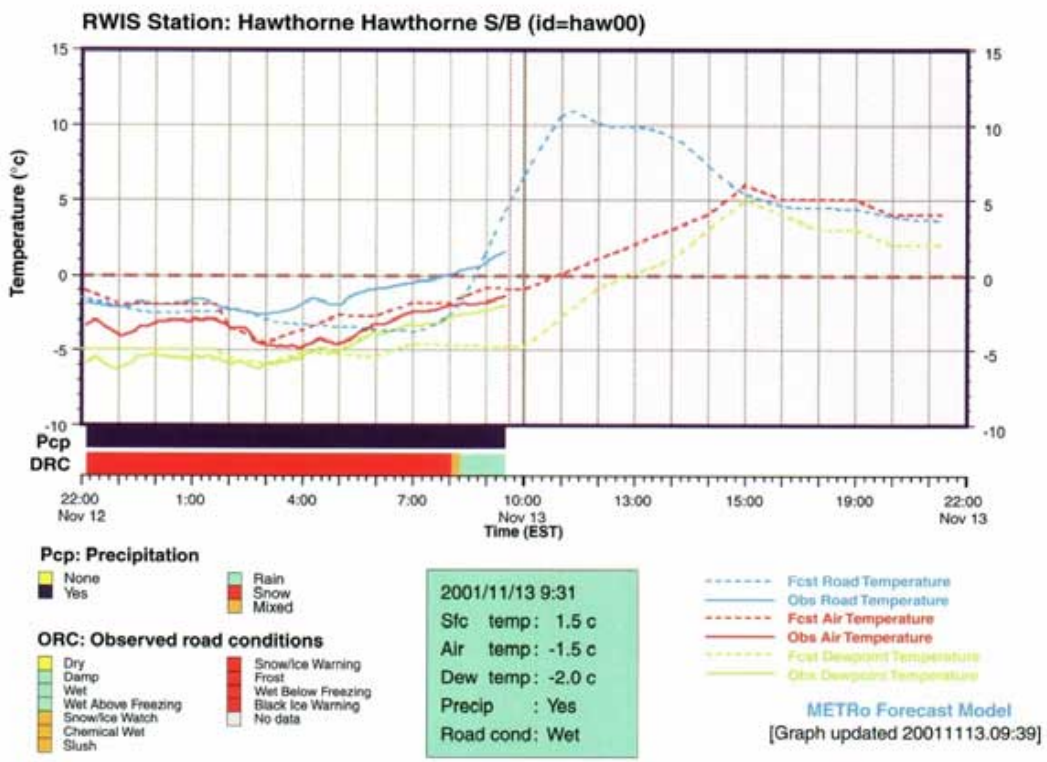
The number of full RWIS systems in use, by province

National Highway System and a core automated road weather forecast service from the Meteorological Service of Canada. The RWSC proposes the installation of some 500 new RWIS sites across Canada as a core network. All would have common standards. Municipalities would also be encouraged to apply the same standards as they invest in RWIS sites. In that way, the network would expand and become denser over time. In exchange for quality controlling the data to national standards and returning it to the transportation community in real time, the MSC would be entitled to ingest the data into its numerical weather prediction models. Model outputs would thus be refined and then supplied freely in return to the transportation community and the private-sector road weather service providers retained by them. The RWSC has received the endorsement of a majority of provinces and territories.

c) The MSC will endeavor to work closely with the private sector to facilitate the development of services in support of proactive winter road maintenance. The MSC hopes to license its models and software to private companies as well as make core numerical weather prediction outputs readily available. The MSC can also participate in training sessions and work with the private sector and academia to develop approaches for the production of road weather forecast services for entire road networks using numerical outputs.

Typical RWIS installation

Passive road sensor



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Area	1,667,926 km²	
Population	7,285,000 inhabitants Montréal: 3,430,000 inhabitants (80% of Quebecois live in cities)	
Length of road	Highways	4,854 km
	National, regional and collector roads	22,924 km
	Natural resource access roads	1,362 km
	Streets and municipal roads	94,000 km
Latitude (capital)	45°N to 60°N (46°48'N) (80% of the population lives below the 47th parallel)	

Table 1 - Population, territory and road network

Management of the Québec Road Network

The Ministère des Transports du Québec (MTQ) manages the primary road network comprising 29,140 km of highways and national, regional and collector roads, including 1,362 km of natural resource access roads. The department is also responsible for 4,700 bridges and viaducts.

In the early 1990s, the department transferred responsibility for over 32,000 km of local roads to the municipalities. However, it continues to offer them technical support and financial assistance programs covering the maintenance and enhancement of the local road network and repairs to bridges and other civil engineering structures.

The MTQ oversees the economic and technical regulatory framework governing the road transportation industry, with a view to maintaining safety, fairness, the protection of road

Road network - Map

structures and environmental conservation, which demands rigorous control.

The Ministère des Transports du Québec maintains close ties with other governmental agencies, municipalities, passenger and goods transportation associations, shippers, major roadwork contractors, research organizations and police departments.

The department is working increasingly with the private sector to build, repair and operate transportation infrastructure. This public-private partnership, in addition to keeping expenditures at a socially acceptable level, is enabling businesses to acquire worthwhile, exportable expertise.

The MTQ is very active on the international scene, welcomes foreign delegations, participates in missions and research projects, and distributes various products.

For 30 years or so, Québec has been a member of the Permanent International Association of Road Congresses (PIARC). It is also a member of the Northeast Association of State Highway and Transportation Officials (NASTO), which assembles road authorities in the north-eastern part of the North American continent, and of the American Association of State Highway and Transportation Officials (AASHTO).

Population, Territory and Road Network

Overall, the Québec road network encompasses more than 180,000 km of roads, of which the Ministère des Transports du Québec is directly responsible for 29,140 km.

The Québec government shares responsibility for transportation with the municipalities, which manage the local road network, public transportation services and para transit.

Climate

Québec has some of the heaviest snowfall in the world. However, the Québec winter is anything but dreary. Lengthy periods of sunshine make winter a marvellously luminous season.

- From the 45th parallel in the south to the extreme north, Québec covers 15 degrees of latitude and roughly 70% of its territory is located in the northern zone.
- Four climatic zones are found in Québec's immense territory covering 1,667,926 km², i.e. maritime, humid continental, sub-arctic and arctic. The most densely populated portion of Québec has a continental climate.
- The ground freezes for at least four months to a depth ranging from 1.2 m to 3 m. In some regions, the freezing season extends from September to May.
- Daily temperature variations can reach 25°C.
- Winter is the longest season. Depending on the region, it endures from 18 to 25 weeks. The number of days with snowfall varies from 50 to over 100. More snow falls in Québec City, the capital, than in Moscow or Oslo.
- On average, Québec receives 300 cm of snow a year, although snowfall can reach between 7 m and 8 m in some mountainous areas. However, the number of centimetres of accumulated snow is not directly proportional to latitude: Kuujjuak (58° 06') gets only 2.7 m of snow, while Québec City (46° 48') receives, on average, 3.37 m, and Montréal (45° 28'), 2.14 m.

Table 2 - Climate

City	Latitude	Average temperature in January (the coldest month) (°C)	Cumulative depth of nival precipitation (cm)
Kuujjuaq	58° 06'	-23.5	270
Gaspé	48° 47'	-17.1	391
Val-d'Or	48° 04'	-23.3	318
Québec City	46° 48'	-12.4	337
Montréal	45° 28'	-10.3	214

Preservation of the Road Network

Most of the primary road network was designed over 30 years ago. Since then, the total authorized loads, which have increased by 10% to 40%, are straining and hastening the deterioration of roads and structures. Québec winters, with lengthy periods of heavy frost (to a depth of 1.2 m to 3 m) and daily temperature changes of up to 25 °C, are gradually warping the roads, a situation that is exacerbated during thawing.

To ensure that the quality of the road network and its infrastructure meets current demand with respect to the transportation of passengers and goods, each year the Minière des Transports earmarks over $1 billion to preserve, maintain and enhance roads.

Winter Maintenance

The Ministère des Transports du Québec allocates over $180 million (Canadian dollars) a year to the winter maintenance of the road network for which it is responsible. Private contractors and the municipalities ensure winter maintenance of 80% of the department's network under nearly 800 contracts, worth $128 million. The MTQ provides the remaining 20%

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of maintenance. Overall, winter maintenance operations require the use of 1,500 trucks and between 3,000 and 4,000 staff. Each winter, between 600,000 and 700,000 tonnes of salt are spread on Québec roads.

A network of experts in the realm of the winter serviceability of roads

Winter is part of everyday life and Québec culture. Of course, while Québecers have not mastered winter - who could? - they have nonetheless adapted to it, and quite brilliantly. Over time and through recent scientific and technological advances, they have developed various means and methods to deal with winter. Their title of winter experts is well earned.

Winter Road Maintenance Policy

The winter road maintenance policy adopted by the Ministère des Transports du Québec seeks to enhance road safety, ensure the optimum allocation of in-house and contract winter road maintenance operations, and the efficient use of tools according to level of service, climatic conditions, work methods, the road network's characteristics and costs. It is also intended to streamline resources, optimize the length of contracts and improve the process of disseminating information on winter driving conditions.

The safety of road users is a constant concern during the winter. For this reason, judgement and experience are also important factors in decision-making during unusual events that threaten motorists' safety.

Moreover, a departmental procedure concerning road closings during snowstorms or emergencies that affect the safety of users is in effect throughout Québec.

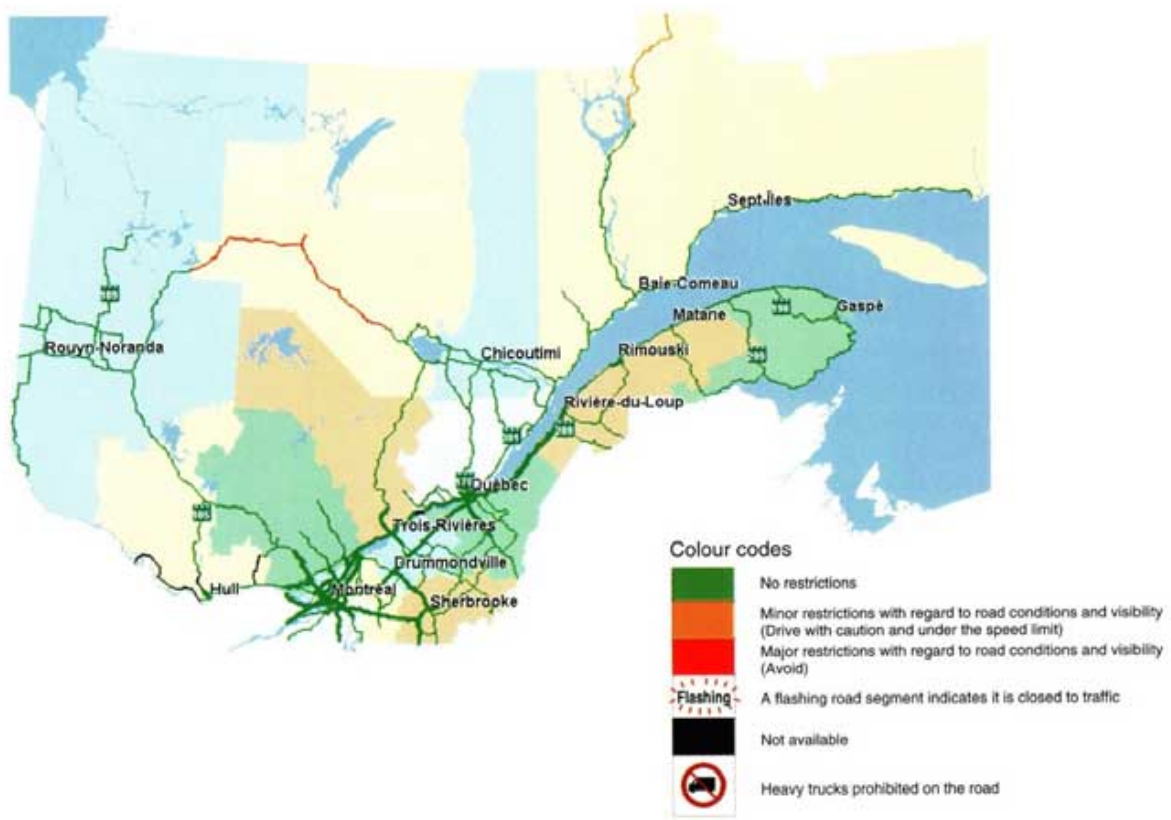
Since road safety does not depend solely on snow-removal and de-icing operations but also on the behaviour of drivers, who are largely responsible for their own safety, a public awareness campaign is conducted each year throughout Québec during the winter.

Standards

The standard governing winter road maintenance establishes the Ministère des Transports du Québec's requirements in this respect. It seeks to clarify and standardize the winter maintenance of roads with similar characteristics.

The Ministère des Transports du Québec determines the levels of service on the entire road network for which it is responsible according to two key criteria, i.e. the functional classification of the road network (highways, national, region-

Road condition - Map



al and collector roads and resource access roads) and the average daily winter traffic (ADWT).

Table 3 - Determination of the level of service

Functional classification	ADWT	Level of service*
Highway	-	Cleared road
National road	> 2500 ≤ 2500	Cleared road Partially cleared road
Regional road	> 2500 ≤ 2500	Cleared road Partially cleared road
Collector road and resource access road	> 2500 500 to 2500 < 500	Cleared road Partially cleared road Hardened snow on road

* With the approval of the manager in charge, the level of service may be modified when climatic, geographic, environment or traffic constraints warrant doing so.

ISO 9000

The Ministère des Transports du Québec recently sought to obtain ISO 9000 certification in respect of in-house and contract winter maintenance operations. One of its service centres has already received the accreditation and several others are about to do so.

Road condition service

The department provides a free, around-the-clock telephone road condition service. Moreover, radio and television stations regularly broadcast information on weather and road conditions and the information is also available on the department's Web site.

Road and Weather Information Systems

Several years ago, the MTQ noted the rapid expansion of road and weather information systems, which facilitate real-time monitoring of road networks, the detection of critical conditions and forecasting. The department has launched a number of initiatives in this field.

- Since 1997, it has developed expertise with respect to road and weather information systems.
- It launched a pilot project devoted to a decision support system in the realm of the winter serviceability of roads, an enhancement process in which the individual is the key to decision-making aimed at pinpointing and organizing the necessary road and weather information system technologies. In the wake of this initiative, several development projects have been implemented:
  - in 2000, a patrol vehicle was developed equipped with detectors to record air temperature, dew point, and temperature of the road surface;
  - in 2000, a departmental network of trainers in the realm of the winter serviceability of roads was set up;
  - in 2001, the department established a knowledge base for matters relating to the winter serviceability of roads.

Automatic vehicle location

The department is currently experimenting with automatic vehicle location (AVL) technology, through which it is possible to monitor in real time the movements of one or more vehicle fleets. For the time being, the AVL system is being used during snow-removal and de-icing operations.

In order to enhance road safety, the MTQ is examining the possibility of combining road and weather information systems with other systems already in use or under development, such as automatic vehicle location systems, driving condition systems, and smart transportation systems.

Use of ice melters

Since 1996, the MTQ has gradually implemented the use of wet salt and has produced a guide for its staff, municipal employees and the employees of private companies.

Technology watch

The department is providing technical support with respect to the single service outlet for applications for industrial qualification respecting materials. It is also participating:

- in the Aurora Consortium in the United States, a body that coordinates research on road and weather information system technologies;
- at the request of RWIS Canada, on a task force on the coordination of a Canada-wide road and weather information system development program;
- on the C17 technical committee of PIARC.

The association québécois du transport et des routes (AQTR)

The AQTR has elaborated a training program devoted to winter maintenance methods intended for the MTQ, the municipalities and contractors, and published the *Guide du professionnel en déneigement.*

Universities

Several research projects are now under way in the following fields:

- the behaviour of frost in roads (Université Laval, Québec City);
- the detection of surface condition (Université de Sherbrooke, Sherbrooke).

2001-12-06

ESTONIA

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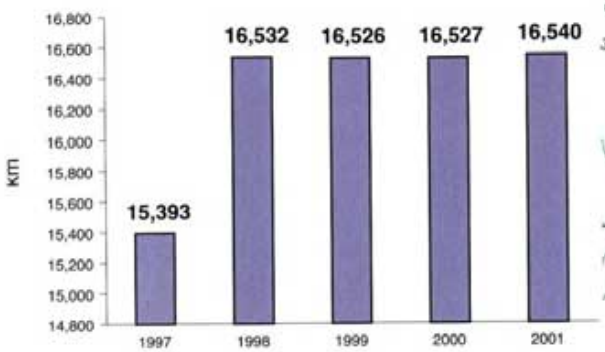
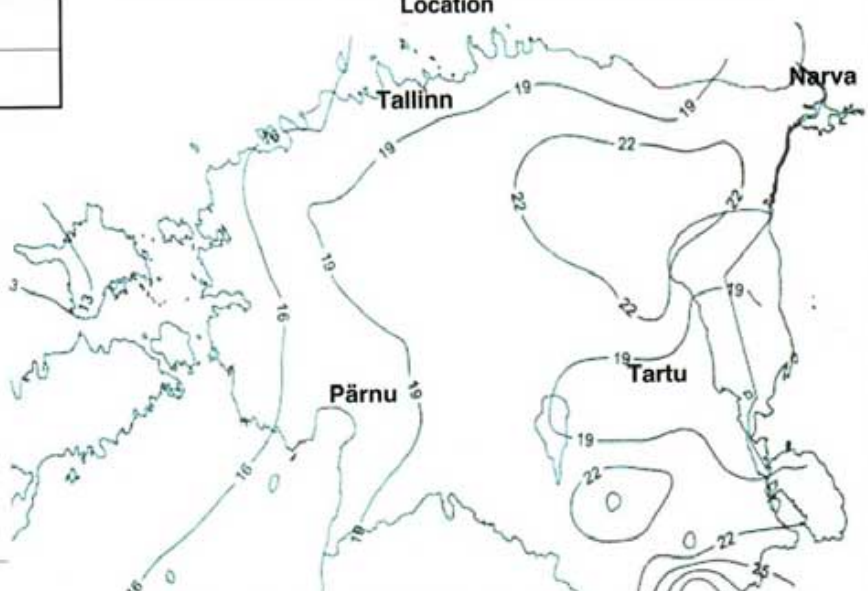
Demographics and Roads

Area		45,227 km²		
Population		1,439,197 (Capital: Tallinn, 408,329 inhabitants)		
Density of population		32 per km²		
Length of road			**Centerline-km**	**Lane-km**
	National roads (Centerline 16,430 km) (Lane 16,525 km)	incl. main roads	1,357	1,448
		basic roads	2,540	2,544
		secondary roads	12,492	12,492
		ramps	41	41
	Other roads		33,056	33,056
	Total road network		49,486	49,581
Latitude (capital)		59°37'N		
Cars per 1,000 inhabitants		320		
Density of national roads		380 km per 1,000 km²		

Location



Length of roads under snow and ice control
All national roads have been included in the winter maintenance network.

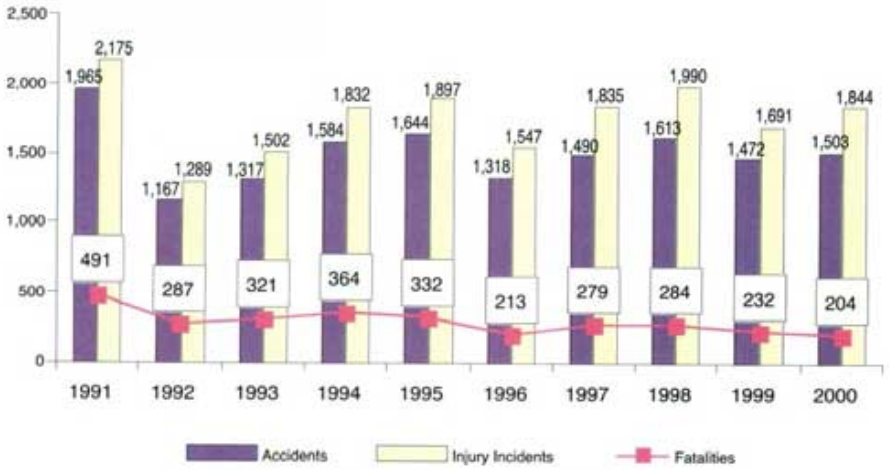


Average snow depth (cm), in the fields in February
There are 31 days per winter period affected by snow in Tallinn, the capital.

Climate

Town	Monthly average temperature (30-year average)					Snowfall (8-year average) [cm]			Precipitation (5-year average) [cm]				
	Nov	Dec	Jan	Feb	Mar	Daily maximum snowfall	Maximum snow depth	Cumulative depth of snowfall	Nov	Dec	Jan	Feb	Mar
Tallinn	1.0	-2.2	-4.1	-4.9	-1.4	22	58	2.8	6.7	6.0	5.8	4.3	3.7
Tartu	0.0	-3.6	-5.3	-5.8	-1.4	20	49	2.8					
Narva	-0.2	-3.9	-6.1	-6.5	-2.0	15	51	2.9					

The average number of days from September to May in 1992-1999 with daily min. temperature below 0 °C and max. temperature 0 °C or above, is 127.



Traffic accidents 1991 - 1999

Winter Road Management

Estonian National Road Administration is responsible for roadkeeping of national roads.

The Road Administration comprises 15 district road offices and the Technical Centre. Road maintenance in district offices is provided by 47 roadmaster areas and 17 submasters.

Road district offices administrate app. 800-1,400 km of roads.

Each road master area maintains up to 500 km of roads.

District road offices carry out winter maintenance with their own staff. In three road districts all maintenance works are done by private contractors.

Road Administration implements a policy of contracting-out maintenance of roads, including winter road maintenance, to private contractors through competitive bidding.

Winter Maintenance Technologies

Equipment

Three-axle SISU-type trucks are basic trucks for winter road maintenance. UNIMOG-, SCANIA- and VOLVO-type trucks are less used.

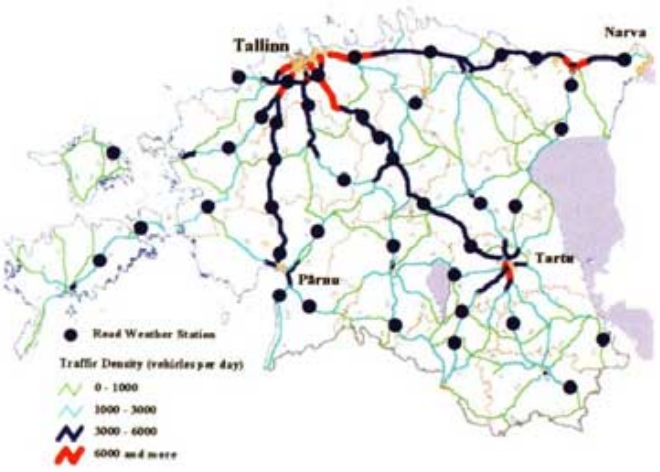
For de-icing treatment mostly NIDO and SALO-type salt-spreaders are used.

For snow removal different types of front-, side- and underbody ploughs are used.

Corbex-type graders are manufactured in Estonia.

Road weather information system

By the end of year 2001 there were 41 road weather stations installed on main and basic roads in Estonia. Road weather stations used in Estonia are manufactured in Sweden and Finland. By the end of year 2003 there should be 50 road weather stations in Estonia. Ordinary road weather station comprised of sensors for air, surface and body temperature, humidity, wind and precipitation sensors. Some stations also have visibility and surface conductivity sensors.



Observatory stations

The Traffic Information Centre informs road users 24 hours a day about the current road conditions and is gives forecasts about conditions using radio, television networks and internet.

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Winter Maintenance Regulations

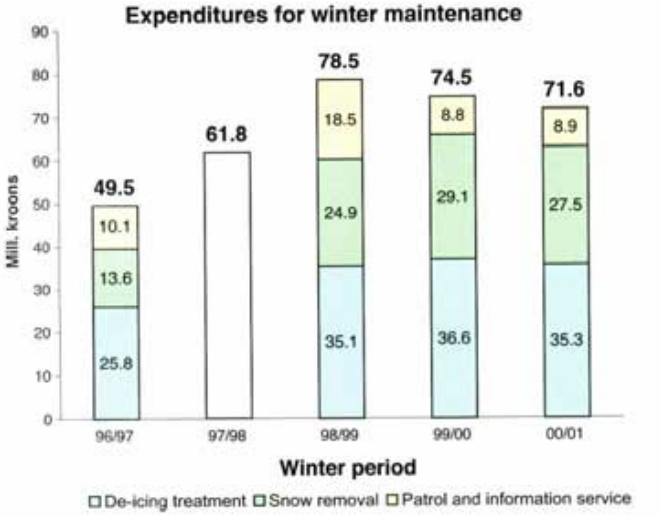
Winter maintenance on all roads is regulated by following acts enacted by Ministry of Transport and Communications:

a) Road Standard Requirements.

b) Requirements of winter maintenance technologies.

It is stated in the Traffic Law that winter tyres are required to be used by all road users during a period from December 1 until March 1. Driving with studded tyres is allowed from October 15 to April 15.

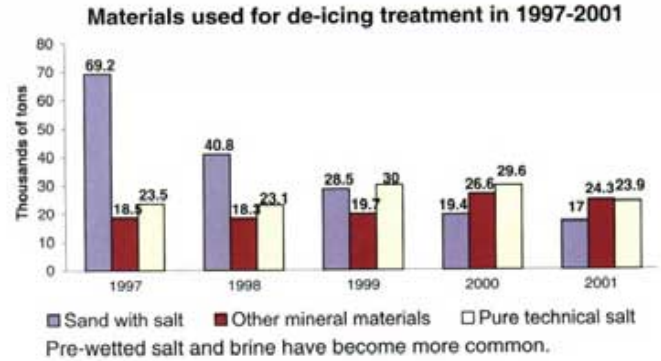
Ice roads have special requirements for construction, maintenance and use.



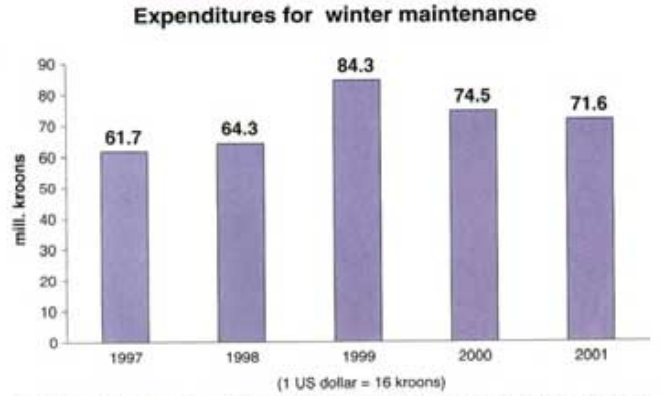
Level of service 1

Level of service 2

Level of service 3



Pre-wetted salt and brine have become more common.



Winter maintenance cost formed 60% of total road maintenance cost in 1999. Winter maintenance cost per 1 kilometre was on average 287 USD in 1998/99 winter period.

Main Development Directions of Winter Maintenance Management and Technologies

a) Contracting-out maintenance of roads to private entrepreneurs, including winter road maintenance.

b) Developing a maintenance standard.

c) Preventive winter maintenance - developing the road weather station network and RWIS.

d) Introducing advanced winter maintenance technologies and equipment.

Road Standard Requirements

Road class and ADT	Required level of service			
	Main road	Basic road	Secondary road	Local road
Motorway (8,000 -)	4	-	-	-
I (6,000 - 8,000)	3	3	3	-
II (3,000 - 6,000)	3	3	2	-
III (1,000 - 3,000)	3	2	2	2
IV (200 - 1,000)	3	1	1	1
V (- 200)	-	1	1	1

Cycle time (h)

Level of service	Snow and slush removal	De-icing	Salt-snow mix removal	Sidewalks cleaning and de-icing	Cleaning the road facilities
4	2	2	4	6	8
3	5	4	8	8	12
2	12	8	-	12	24
1	36	24	-	-	36

Road class	Hours when requirements apply
Motorway	Over a 24 h period
I	6:00 - 22:00 Other times one step lower Service Level is accepted
II	7:00 - 21:00 Other times one step lower Service Level is accepted
III	7:00 - 21:00 Other times Service Level 1 is accepted
IV, V	Determined by Road Administration or other road owners.

Indicators	States of road and their description			
	1	2	3	4
Slipperiness / State of road surface	Packed snow or icy road surface, anti-skid treatment of unsafe spots.	Packed snow or icy road surface, anti-skid treatment of entire road	Wheel tracks free of snow and ice	Pavement is free of snow and ice, bare pavement
Max. snow depth (Loose snow)	< 10 cm	< 5 cm	< 3 cm between wheel tracks	-
Thawy snow or slush, mix of salt and snow	< 6 cm	< 3 cm	< 2 cm between wheel tracks	-
Distance between snow mounds	> 6 m or at least road width	> 8 m or at least road width	> 9 m	>10 m
Evenness Ruts or unevenness in packed snow	< 4 cm	< 3 cm	Between wheel tracks packed snow layer is allowed under 2 cm	Bare pavement, temp. below - 12 °C between wheel tracks snow layer is allowed up to 1 cm

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Demographics and Roads

Area	Total snowy regions	338,145 km²
Population	Total snowy regions	5.2 million
Length of road	Public roads	78,000 km
	Streets and planning roads	24,000 km
	Private roads	300,000 km
Latitude (capital)		60°19'N

Climate

Finland is situated betveen the latitudes of 60th and 70th degrees north. Thanks to the Gulf Stream, the climate is pretty mild. In southern Finland the average January temperature is about - 5 °C (23 °F) and in the North approximately - 15 °C (5 °F) (Table 2). In Finland winter affects the functioning of the whole road network during 5 - 7 months of the year. Winter traffic (November - March) performance accounts for about 35 % of the yearly traffic volume.

Stations	Latitude	Longitude	Elevation of station
Helsinki-Vantaan Lentoasema	6019	2457	53
Turku Lentoasema/Rusko	6031	2216	51
Lappeenranta Lentoasema	6105	2809	105
Jyväskylä Lentoasema/Jyväskylän Mlk	6224	2541	141
Vaasa Lentoasema	6303	2146	4
Kuopio Lentoasema/Siilinjärvi	6301	2748	94
Joensuu Lentoasema/Liperi	6240	2938	116
Oulu Lentoasema/Oulunsalo	6456	2522	12
Sodankylä Observatorio	6722	2637	179
Utsjoki Kevo	6945	2700	107

Table 1 Wether data at road stations

	Mean (1961-1990) daily min. temperature (°C)							Snowfall (cm)		Mean precipitation (mm)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Max. snowfall during 24 h	Max. observed snow depth during 1961-1990	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Year.
Helsinki-Vantaa	2.3	-2.5	-7.3	-10.3	-10.3	-6.6	-1.1	37	89	73	72	58	41	31	34	37	651
Turku	2.7	-2.1	-6.7	-9.4	-9.6	-6.3	-1	44	77	69	71	59	45	33	34	38	661
Lappeenranta	1.6	-3.4	-9.3	-12.7	-12.2	-7.5	-1.6	30	117	64	58	50	37	29	33	31	602
Jyväskylä	0.4	-4.9	-10.8	-14	-13.8	-9.5	-3.3	25	105	56	59	47	43	30	35	37	639
Vaasa	1.6	-3.9	-9.4	-12	-12.2	-8.2	-2.2	38	93	52	49	39	30	22	24	26	501
Kuopio	1.5	-4.4	-11.2	-14.9	-14.3	-9.5	-2.9	27	105	51	50	38	35	25	30	31	562
Joensuu	0.4	-5.5	-12.1	-15.7	-15	-10.1	-3.4	25	118	59	54	45	37	29	32	35	612
Oulu	0.3	-5.9	-12.1	-15.4	-14.7	-10.1	-3.4	22	93	41	31	28	26	21	23	19	432
Sodankylä	-3.4	-11.4	-18.4	-20.6	-19.2	-14.7	-7.8	29	126	51	39	31	31	25	25	24	500
Utsjoki	-4.3	-12.8	-18.7	-21.2	-19.6	-15.2	-8.4	32	124	35	29	25	25	17	18	20	395

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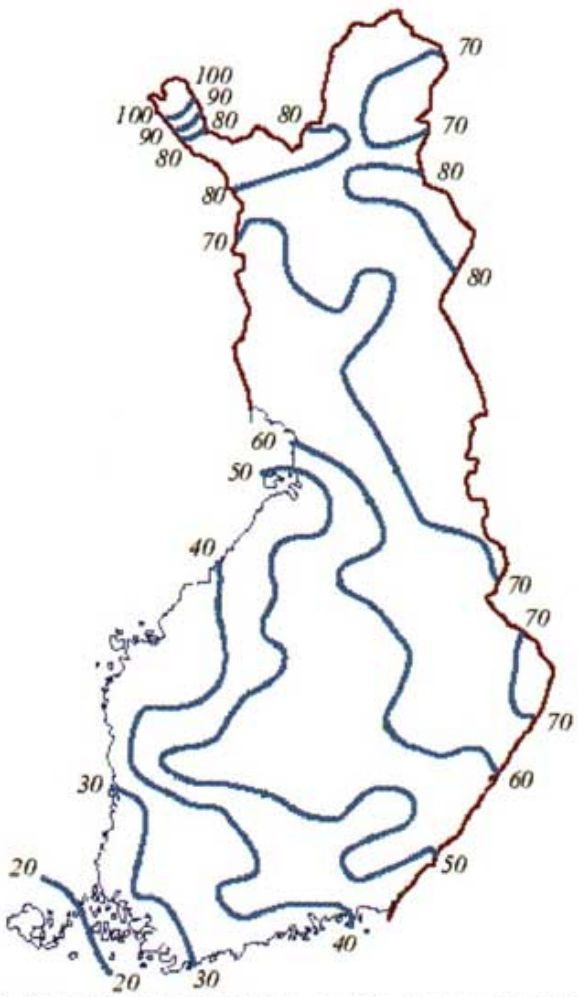

Figure 1 Mean annual maximum snow depth (cm) during 1961-1990

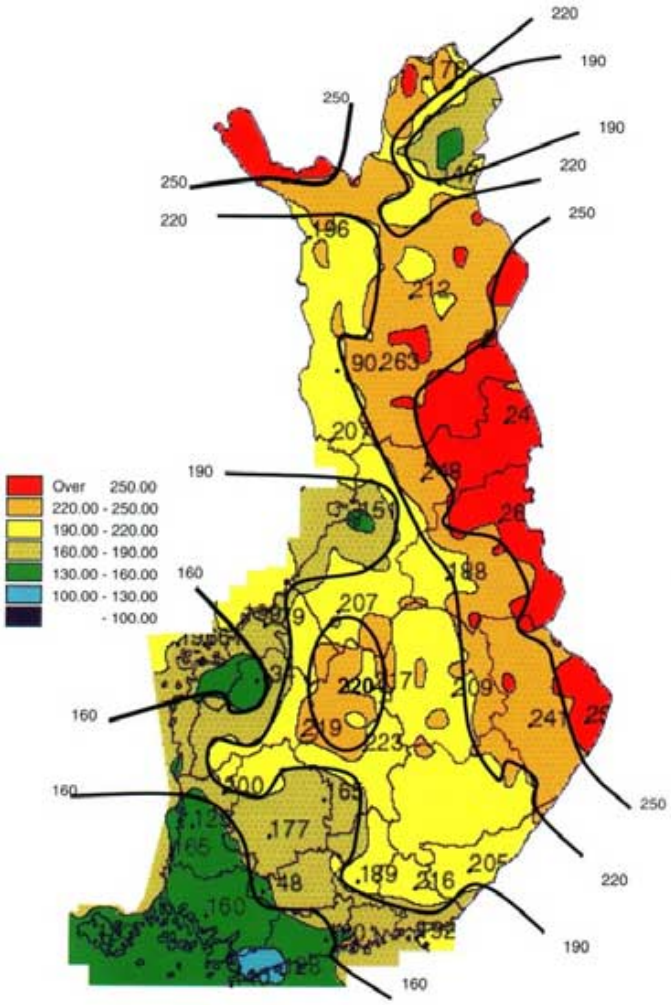

Figure 2 Mean annual snowfall (mm) in Finland, 1961-1990

Background

The Finnish Road Administration, which is a state agency, is responsible for the management of the country-wide public road network. In Finland, streets in cities and municipalities are the responsibility of the municipalities. The long private road network is the responsibility of the landowners living along the private roads. There are about 78,000 km of public roads, 24,000 km of streets and planning area roads and nearly 300,000 km of private roads.

In 2001 the Finnish National Road Administration was divided into the Finnish Road Administration, which orders services from producers, and the Finnish Road Enterprise, which takes care of construction and maintenance and also provides consultation services. As the functions were separated it became necessary to reconsider the manner in which the level of service is specified in contract documents, especially regarding quality standards, so that all involved parties would understand the issues in the same way.

The winter maintenance policy is a document that describes the principles and policies according to which the orderer wishes winter maintenance to be implemented. It specifies the desired level of service and includes the main quality standards used to describe that level of service. The policy also presents current views that act as guidelines for winter maintenance. The revised policy and quality standards were taken into use in Finland in public road contracts beginning October 1, 2001.

The policy presented in this presentation concerns the public roads, which carry around 65 % of all road traffic. The previous winter maintenance policy was taken into use in Finland in the autumn of 1995. The policy was based on the extensive Road Traffic in Finland Project. The results of research conducted in the project are for the most part still usable and also form a basis for new policies. Several studies were also made on the general development of road safety, pedestrian and bicyclist safety, and the environmental and economic effects of maintenance.

Winter maintenance is implemented in Finland as regional contracts based on the principle of quality responsibility. Winter conditions may change quite quickly, so to satisfy road users, contractors must be able to function at the right time and select the correct procedures for each situation. Therefore, the policy is an important way to inform contractors of the principles of winter maintenance.

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Basis of Winter Maintenance

Roads are important in all societies, but they are especially significant in Finland, which has a large area but is sparsely populated. What's more, from the viewpoint of central Europe, Finland is marginally located. Most exports to this most important market area are transported by sea. From the standpoint of the competitiveness of industry and commerce, functional logistics, and especially the functionality of the internal transportation system, are vital. Low traffic volume, a long road network and year-round trafficability naturally mean relatively low cost efficiency. For this reason the guidelines and the selection of areas of emphasis have a major impact.

Winter maintenance has a significant effect on the functionality of the entire transportation system. Traffic volume during the six winter months is around 44 % of the year-round volume. In many fields of industry and commerce, the share of transport taking place in the winter months is greater than that in summer. Communities, industry and commerce that depend on transport and road traffic expect transportation to function reliably all year round. Regardless of our northern location, Finland's winter is not especially difficult from the standpoint of road management. The long-term average snowfall converted to millimeters of water varies from 120 to 220 mm in different parts of Finland (Figure 2). This amount of snow accumulates throughout the winter season, mainly as snowfalls under 10 mm. Conditions in different parts of the country are different. 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.

The winter maintenance policy is based on current traffic laws concerning winter tires and especially studded tires. Studded tires are allowed in Finland from November 1 to March 31, and about 90 % of cars are equipped with studded tires, although studless winter tires have become more popular in recent years. The policy is also based on the possibility to use salt to combat slipperiness. Figure 4 shows the trend in salt use in 1959-2000. The exceptionally little use of salt in 2000 was due to a mild autumn and early winter, resulting in practically no salting in southern Finland. Sodium chloride (NaCl) is the main substance used for chemical de-icing. Sanding is used only on roads with little traffic.

Expectations of Winter Maintenance

Responsibility for road safety is one of the main factors in winter maintenance. Nevertheless, the risk of being in a serious accident in Finland is at the same level in winter as it is during the rest of the year. Only the number of minor accidents (fender-benders) is higher in winter than in summer. Head-on collisions are the only type of accident that occurs clearly more often in winter than in summer. Snowfalls and driving conditions together with other factors increase the risk of drifting into the lane of oncoming traffic. According to the latest study, 47 % of fatal winter accidents occurred when it

Figure 3 Road management financing[1] in 1985-2006, Mill. €

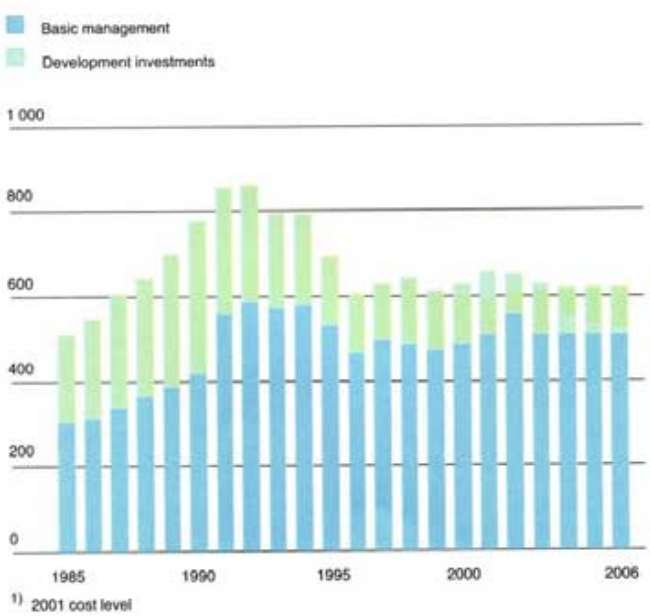

Figure 4 Use of salt in Finland 1959-2000.

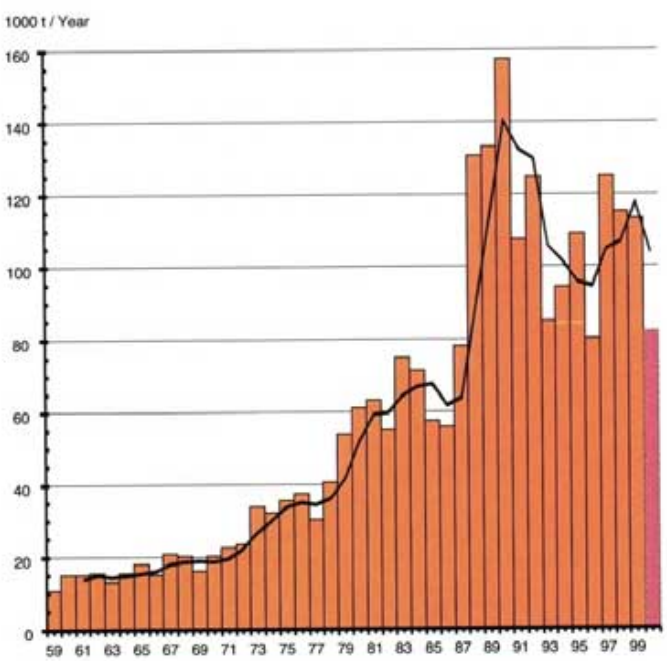

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Figure 5 Fatalities on public roads

Figure 6 Personal injury accidents on public roads

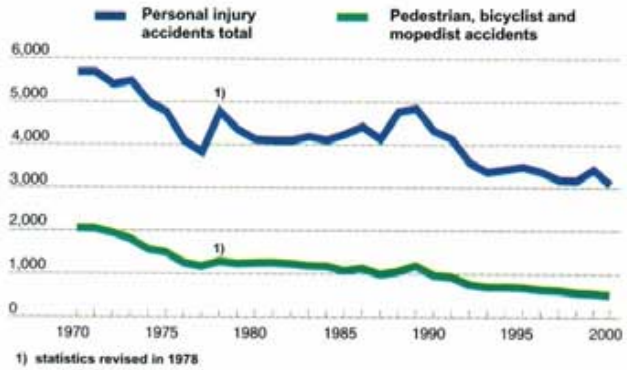

Figure 7 Accidents on public roads in 2000

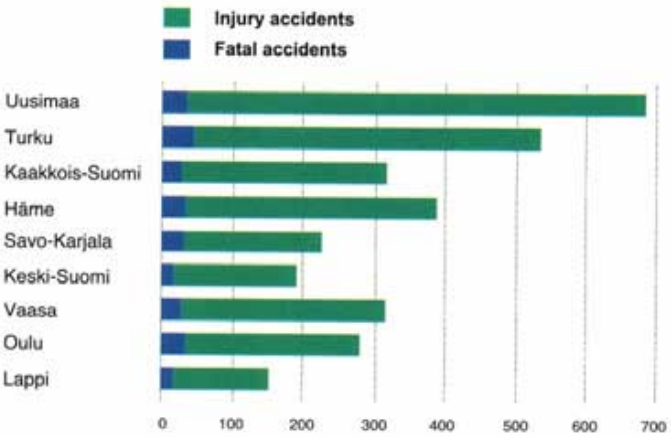

Figure 8 Injury accidents on public roads in 2000

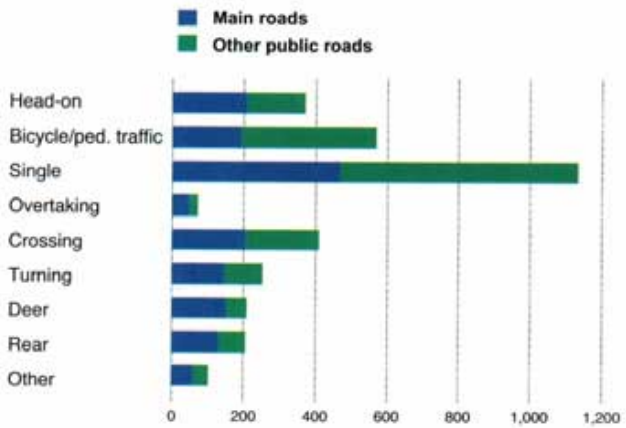

Table 2 Ratio of wintertime (6 mo.) and summertime (6 mo.) accident risk in Finland.

	Coast	Inland
All accidents		
ADT < 1500	1.33	1.31
ADT 1500 - 6000	1.45	1.43
ADT > 6000	1.36	1.41
total	1.39	1.38
Personal injury accidents		
ADT< 1500	0.83	0.88
ADT 1500 - 6000	1.00	0.98
ADT > 6000	1.23	1.12
total	1.02	0.97
Fatalities		
ADT < 1500	0.78	0.89
ADT 1500 - 6000	1.21	0.93
ADT > 6000	1.02	0.90
total	1.03	0.91

was snowing, even though snowfalls occur only 10 % of the time. Table 2 shows the relative risk of being in an accident in winter and in summer. If the risk ratio is higher than 1, the wintertime risk is greater than the summertime risk.

The main environmental problem of winter maintenance is still the effect of salt on groundwater. Although this issue has been studied much in Finland and it is still being developed, no simple solution exists. The objective is to decrease the total amount of salt used, and especially to decrease the amount of salt ending up in groundwater. Groundwater shielding is built along approximately 15 km of road per year in Finland. The new policy states that roads in groundwater areas will be maintained using no salt or less salt than is currently used. This means, however, that a lower speed limit must be set for these roads. The behavior of biologically decomposable salts (acetates and formiates) in the ground is being studied, and whether they would provide even a partial solution to the rising chloride contents.

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Policy

The main principles of the new winter maintenance policy are presented here:

Uniform, regionally equal prerequisites for travel throughout the country.
Uniform principles of categorizing road maintenance and uniform quality standards are observed throughout the country. Nevertheless, common principles are adapted according to regional and local needs and conditions. Especially differences in climate are taken into consideration.

A uniform level of service on connecting traffic routes.
Regardless of administrative borders, contract areas or different traffic volumes, the level of service of the road network should be kept sufficiently uniform along connecting traffic routes from the standpoint of the road user. Maintenance area borders should be located logically from the viewpoint of traffic.

Maintenance of main roads according to climate areas.
Winter climate differs in coastal areas and further inland, for which reason operating procedures are different. Salt is used to keep the main roads mainly bare in the coastal area. Less salt is used inland and more wintry driving conditions more often prevail on the road network.

That the level of service be focused according to location and time. That the demands of traffic and the condition of the road network be taken into consideration.
Even on similar roads, the demands of traffic vary with time and location. The amount and role of heavy traffic and public transport routes should be taken into consideration when deciding the maintenance class and specifying possible road-specific quality standards.

Winter maintenance that guarantees the best possible wintertime road safety and expected driving conditions.
The basic principle is that the wintertime road safety risk be no higher than during the rest of the year. It is important from the standpoint of road safety that the level of maintenance be as uniform and predictable as possible. Unexpected borders and other variations that lower the quality level should be avoided. Wintertime road safety requires matching the level of maintenance with speed limits.

That level of service be specified cost-effectively. That roads with little traffic have a basic level of service.
From the viewpoint of efficiency and good effectiveness, the quality level and amount of maintenance are graded according to road use. A basic level of service that allows 24-hour travel is guaranteed on quiet roads. However, travel may become significantly more difficult during exceptional weather conditions, which may occur a few times per winter.

That maintenance of the road network and its parts adhere to the principle of social fairness.
Road user categories and the routes and parts of routes that serve them are given equal status when defining the level of quality. Sufficiently good maintenance of pedestrian and bicycle paths and bus stops promotes the role of pedestrian and bicycle traffic. The special demands of pedestrian and bicycle traffic are taken into consideration in maintaining the shoulders of roads where there are no separate routes for such traffic.

That environmental hazards be reduced. That the use of salt be limited in groundwater areas.
The total amount of salt used is reduced by revising the maintenance classes of the road network and groundwater risk is reduced by locally reducing the use of salt.
Contractors are required to have knowledge and be precise in the use of salt, so that as little salt as possible is used, but keeping road safety in mind.

That the Finnish Road Administration as the orderer specify the level of service and ensure that contractors keep the roads at the agreed quality level.
It is important to ensure that the intent and content of the winter maintenance policy and the quality standards based on the policy are known and taken into consideration throughout the entire chain of operation from the orderer to the employ-

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ees of the contractor. From the standpoint of guaranteeing the level of service it is important that contractors are continuously aware of developments in the weather and driving conditions and the condition of the road network.

That providing road users with information improves their chance of affecting their own safe, smooth wintertime traveling.

Traveling in winter conditions requires adaptation of driving and travel habits in all situations and preparation according to the weather and driving conditions. Providing information related to winter traffic boosts road users' own chances of acting safely and responsibly.

Level of Service in Different Maintenance Classes

A uniform level of service and a classification describing that level are used throughout the country. The level of service is mainly defined according to traffic volume, the road's functional class and the regional climate. The road network is divided into five main maintenance classes (Is, I, Ib, II, III) (Figure 9).

In addition, class Ib has a corresponding maintenance class T-Ib for built-up areas. Each class has a different level of service and quality standards. Road classes are defined by connecting route in such a way that they function logically from the road user's point of view, and differences in quality do not cause unexpected situations. In deciding the maintenance class of a road not only are the classification criteria taken into consideration, but also local conditions, the nature and composition of traffic, the speed limit and qualitative integration with the level of service of the municipality's road network.

If special traffic needs so require, maintenance methods, timing or quality on specific sections of road may be modified locally without changing the maintenance class. The spirit of serving and customer orientation of winter maintenance calls for ensuring a good level of maintenance at times when the road network has an abnormally large amount of traffic or the nature of the traffic differs from normal. Such cases are the traffic peaks at Christmas and on other holidays.

The division of the road network into maintenance classes according to traffic volume is illustrated in Figure 10.

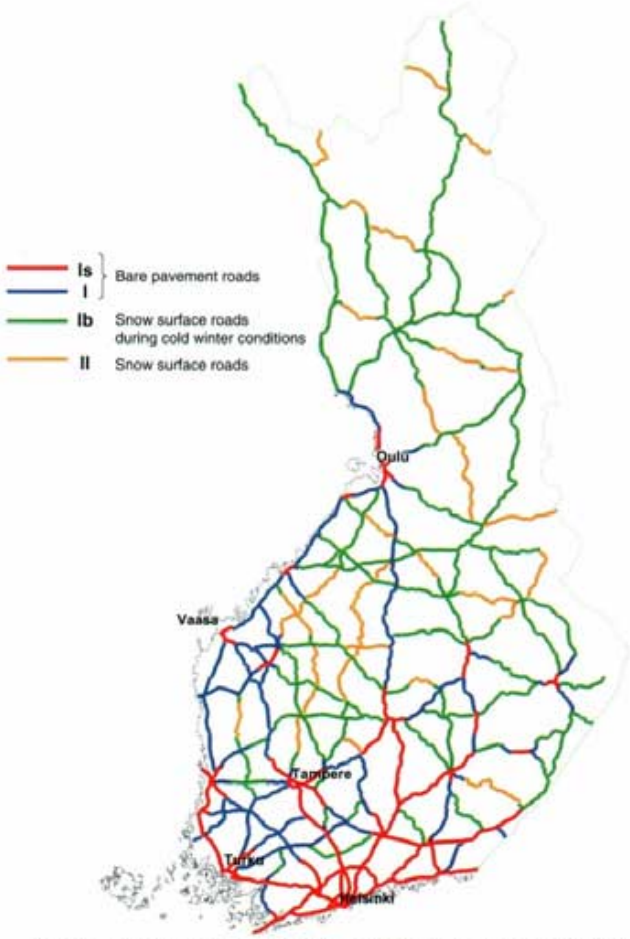

Figure 9 Winter maintenance classification of class I and class II main roads in Finland

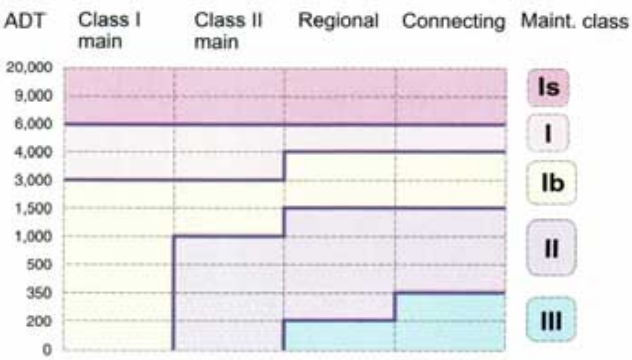

Figure 10
Division of the road network into maintenance classes according to traffic volume.

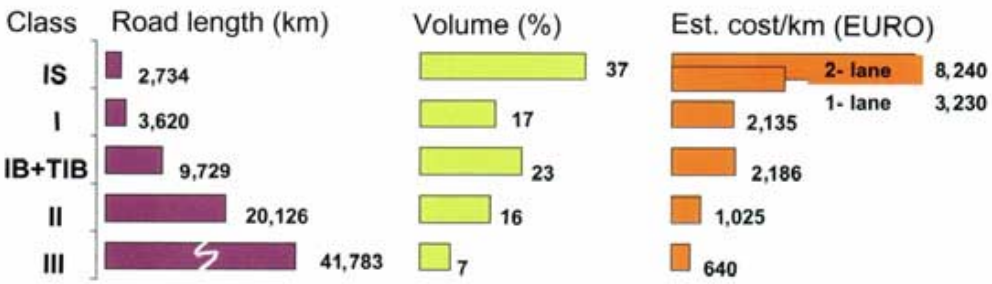

Figure 11
Distribution of the road network and traffic volume among maintenance classes in Finland and the approximate costs of different maintenance classes (EUR/km). 1 EUR = $ 0.9.

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Figure 12
Typical conditions on roads in different maintenance classes

Pedestrian and bicycle paths are divided into two maintenance classes (K1, K2). This way the procedures of different routes can be timed to serve traffic on the route as well as possible at the correct time, especially in the case of commuter traffic, routes to public transport, schools, day care centers and services.

Most of the main road network belongs to categories Is, I and Ib. Categories Is and I are completely free of ice and snow most of the winter. Salting is the main anti-slipping procedure. Class Ib is maintained using less salt and the conditions are clearly more wintry than in categories Is and I, but otherwise the level of maintenance is high. Roads have been intentionally moved into this class with the purpose of using less salt. The reasons have been environmental impact (salt penetrating groundwater) and drivers' negative attitude toward the use of salt.

Classes II and III are used on quiet roads. Very little salt is used. Instead, sand is used to combat slipperiness. The friction requirements of these roads are also lower, so the characteristics of car tires are very significant. Figure 10 shows road length, traffic volume and rough estimates of unit costs, and Figure 11 shows the typical conditions of the different maintenance classes.

Quality Standards

One of the quality standards of anti-slipping procedures in Finland is a friction value, which is measured with a device that measures deceleration. Evaluation of driving conditions also includes a verbal description (Table 3). The friction values are not exactly comparable with the values obtained with other devices like the BV-11 equipment commonly used at airports. The device (C-trip) that measures the friction value on the basis of deceleration is reasonably inexpensive and it can be installed on an ordinary passenger car, making its use routine for both the orderer's supervisor and the contractor. Although the measurement results are not fully reliable, the measurements make it easier for the orderer and contractor to agree on the prevailing level of quality than without any measurements.

Table 3 Correlation between friction values and driving conditions

Friction value	0.00 - 0.14	0.15 - 0.19	0.20 - 0.24	0.25 - 0.29	0.30 - 0.44	0.45 - 1.00
Road surface condition	bad driving conditions, wet ice, very slippery	icy, slippery	tightly packed snow, satisf. winter conditions	rough, packed ice and snow, good winter conditions	bare and wet, not slippery	bare and wet, not slippery

Friction measurements are held important 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

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them bare. Today environmental reasons strongly favor less use of salt. However, from the standpoint of road safety it is important to ensure that there is enough grip on the roads to allow safe driving under the circumstances.

Table 4 to 6 present the main quality standards of winter maintenance. These standards concern only the actual lane of traffic. Separate winter maintenance quality standards describe other parts of the road, like bus stops, rest areas, shoulders, ramps and road equipment.

Table 4 Quality standards of anti-slipping procedures

Winter maintenance class	Is	I	Ib	II	III	K1	K2
Normal	0.30	0.28	0.25	According to traffic needs	According to traffic needs	According to traffic needs	
Friction requirement	road surface below -6 °C 0.25	road surface below -4 °C 0.25	spot sanding 0.25 line treatment 0.20-0.22				
At night	22 - 05 0.28	22 - 05 0.25	22 - 05 as needed	22 - 06 as needed	22 - 06 as needed	after 22 K1 by 05 K2 by 06	
Cycle time	2 h	2 h	salt 3 h sand 4 h	6 h line sanding	10 h line sanding	2 h	

The **friction requirement** requires at least half of the width of the lane normally used by traffic to meet the requirement. Driving conditions in which the middle of the road and the area between the ruts meet the requirements but the ruts do not, do not meet the quality requirements.

The **temperature limit** refers to the lowest temperature of the road surface where the friction requirement of 0.30 is effective on winter maintenance class Is roads and 0.28 on winter maintenance class I roads. If the temperature is lower, the friction requirement of class Is and I roads is 0.25.

Table 5 Quality standards for snow removal

Winter main-tenance class	Is	I	Ib	II	III	K1	K2
Maximum snow depth	4 cm	4 cm	4 cm (8 cm, night)	8 cm (10cm, night)	10 cm (10cm, night)	3 cm (8cm, night)	
Cycle time	2.5 h (slush 2 h)	3 h (slush 2.5 h)	3 h	4 h	6 h	3 h	4 h
If snowing stops after 11 p.m.	Plowed clean within cycle time		05 or cycle time	06 or cycle time	06 or cycle time	05	06

The maximum snow depth must not be exceeded while it is snowing or during the cycle time thereafter. Only half as much slush is allowed as snow. Plowing must be started no later than when half the maximum amount of snow has accumulated on the lane. This starting threshold is not used at night in classes II, III and K. The starting threshold for class Ib at night is 4 cm.

Table 6 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)	3 cm	3 cm	2 cm hindering ruts	
Cycle time	1 day	1 day	1 day	2 days	3 days	12 h	

The evenness requirement refers to the maximum allowed depth of ruts and unevenness in packed snow. During very cold periods when salting is not possible, the evenness requirement of maintenance class Is is 1 cm. The evenness requirement does not allow sharp edges on ruts (classes I and Ib). In other classes, including Tib, the maximum edge is 10 mm. Even during the cycle time, evenness must not be worse than the requirement by more than 1 cm.

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Demographics and Roads

Area	Total	551,000 km²
	Snowy regions	64,000 km² 30 days of snow fall
Population	60 million	
Density	109 people / km²	
Length of road	Toll motorways	9,000 km
	National roads	28,000 km
	Departemental roads	361,000 km
	Municipal roads	580,000 km
Latitude (capital)		48°48'N

Climatic zones in France

These zones are defined in a 1996 French ministerial circular regarding winter service, and are used in particular in determining credits assigned to each departmental equipment division (DDE) for winter service on the national road network.

The average harshness of winters in a given area can be expressed as the sum of the following three terms:

D1, the average number of days per year on which enough snow falls to whiten road surfaces.

D2, the average number of days per year on which black ice forms under precipitation (rain on frozen ground, supercooled rain), excluding days counted in D1.

D3, the average number of days per year on which black ice forms other than under precipitation (frost, frozen existing humidity even if following precipitation, deposition of freezing fog), excluding days counted in D2.

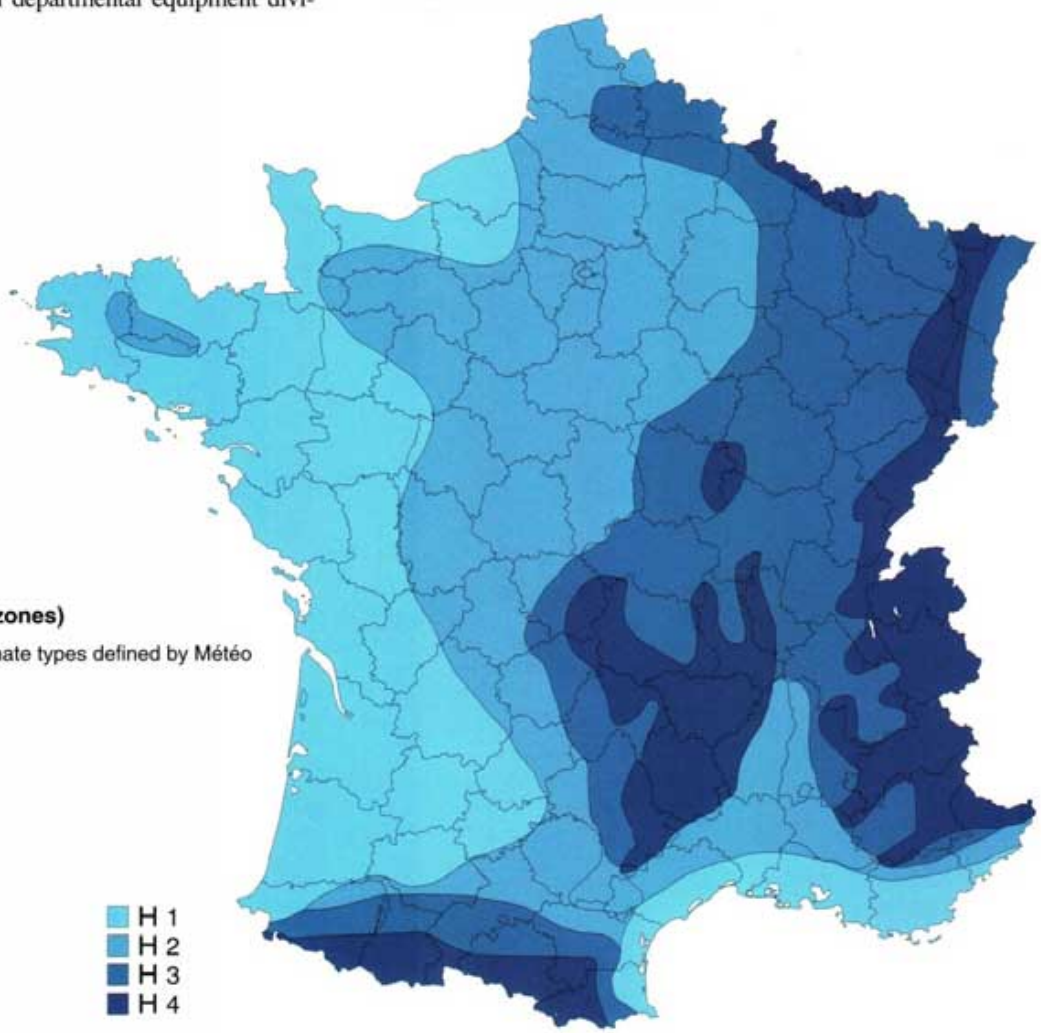
if D1+D2+D3<10 the winter is clement on average, symbolised by H1.

if 10 < D1+D2+D3 < 30 the winter is slightly harsh on average, symbolised by H2.

if 30 < D1+D2+D3 < 50 the winter is fairly harsh on average, symbolised by H3.

if 50 < D1+D2+D3 < 90 the winter is harsh on average, symbolised by H4.

The Hi areas conform with the climate types defined by Météo France and the altitude.



Winter harshness zones (Hi zones)

The Hi areas conform with the climate types defined by Météo France and the altitude.

Winter Road Conditions

The result of winter practicability action undertaken is the ease with which drivers can use the road network. The criterion chosen to define the quality of a situation, giving an objective reference understandable by all, depends on the road traffic conditions.

Four conditions have been distinguished, depending on the ease of using the road network

- **C1** normal conditions
- **C2** delicate conditions with potential danger but little risk of blocked traffic.

Here the problem is due more to individual perception of road weather conditions and its consequences on safety.

- **C3** difficult conditions with clear danger and high risk of blocked traffic.

For condition C3 the difficulty is much more in terms of running and a more widespread perception of conditions.

- **C4** impossible conditions

Three indicators are used to define the levels of service corresponding to these road traffic conditions and variations thereof:

Reference condition.
Minimal condition.
Expected time to restore service.

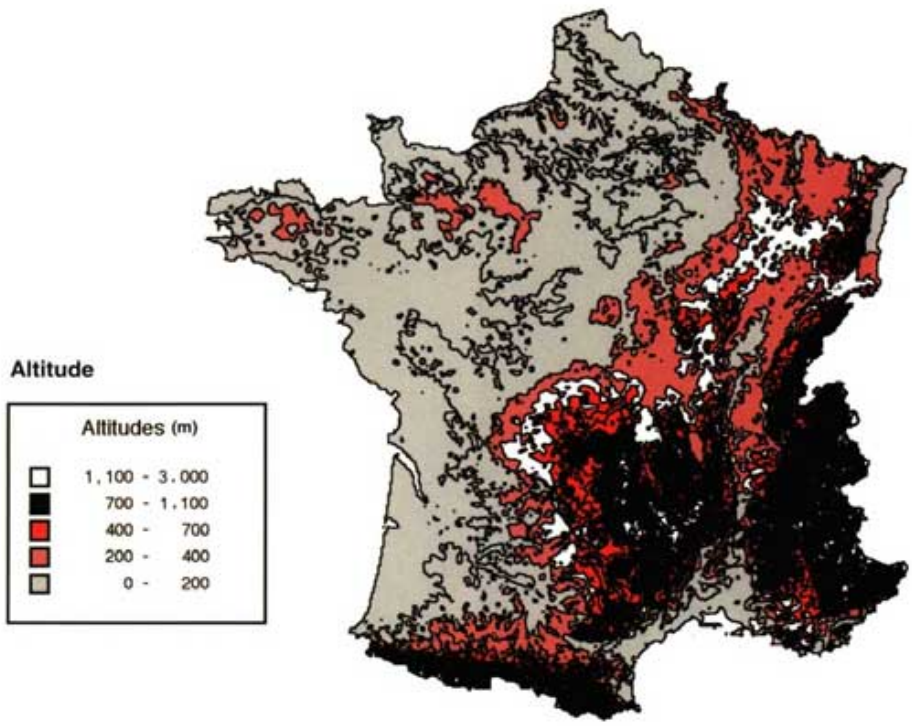
Application of the 1996 Circular to the National Road Network

The Roads Department, which is responsible for stating users' requirements and guaranteeing their application, defined the levels of service and the principles by which they are allocated in a circular dated 29 December 1994 and an addendum in September 1996.

The levels of service on national roads are assigned based on a combination of criteria: the climate zone, the importance on the master plan, the level of running and the traffic.

Level of service		N1	N2		N-
Valid between		24 hours/day	6 a.m. to 8 p.m.	8 p.m. to 6 a.m.	24 hours/day
Reference condition		C1	C1	C1	C1
Black ice	Minimal condition	C2	C2	C3	C3
	Expected time to return to reference condition	2 hours	3 hours	4 hours	---
Snow	Minimal condition	C2	C2	C3	C3
	Expected time to return to reference condition	3 hours	4 hours	---	---

---- not stated



GERMANY

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Demographics, Roads and Traffic

Area		357,000 km²	
Latitude		47°16' to 55°03'N	
Population		82 million	
Density		230 per km²	
Length of road 2001 - 01 - 01	Federal trunk roads	Federal motorways (Autobahnen); 4- and 6-lane divided highways)	11,700 km
		Federal highways	41,300 km
	Other federal-aid roads	State highways	86,800 km
		County roads	91,000 km
		Community/urban roads	415,000 km
	Total		645,800 km
Latitude (capital)		52°30'N	
Inhabitants		Berlin 3.4 million	

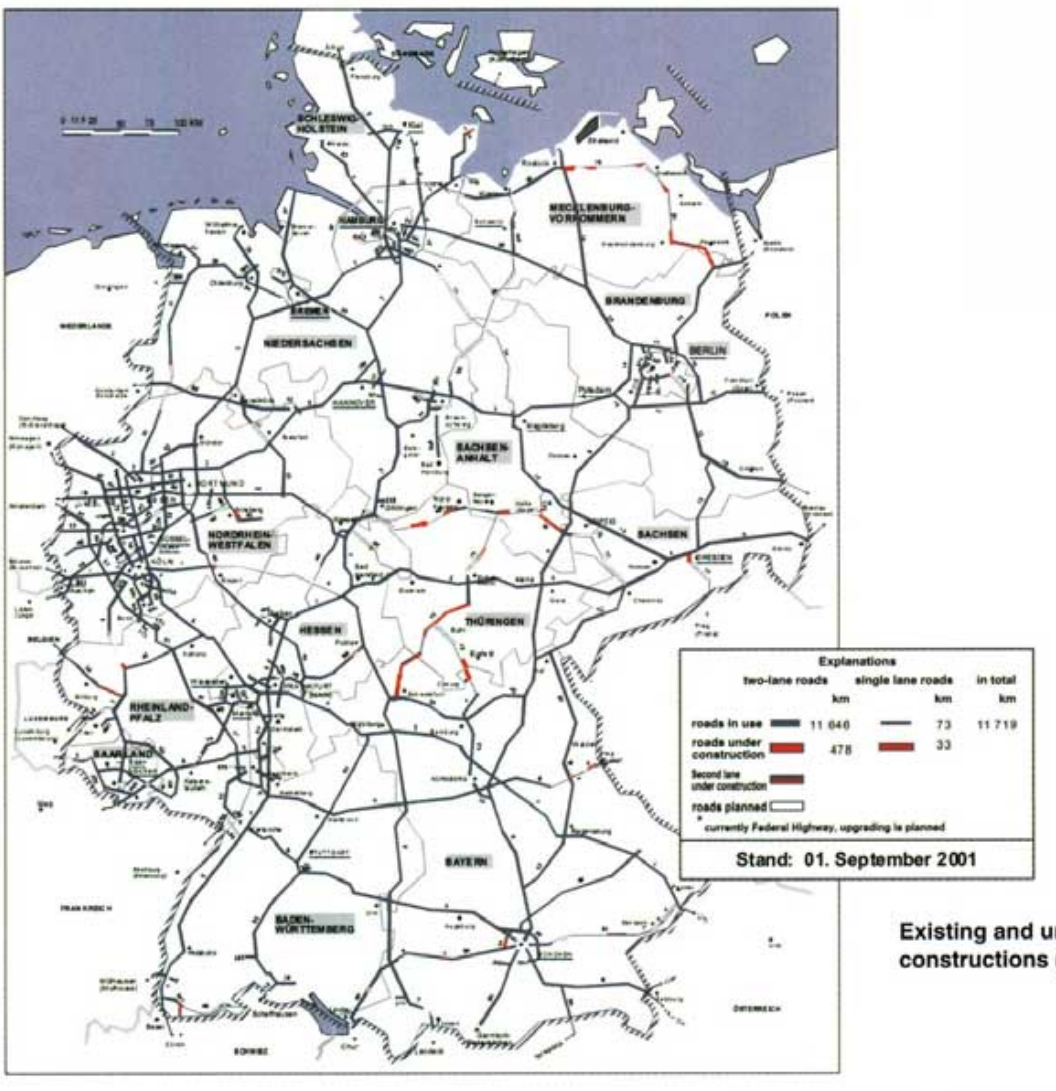
The Federal Republic of Germany, consists of 16 Federal States, including the 3 "City-States" (Berlin, Hamburg, Bremen), and they vary in size from Bayern (71,000 km²) to Saarland (2,700 km²). Each German State has its own constitution and public authorities.

Motorization

Number of vehicles	51 million
Number of passenger cars	44 million
Passenger cars / per 1,000 inhabitants	536
Forecast up to the year 2015:	about 600

Traffic volumes

Interurban, rural traffic	Average daily traffic ADT	Maximum ADT	Maximum daily traffic
Federal motorways	47,000	155,000	about 200,000
Federal highways	9,500	29,000	about 35,000
State highways	3,900	25,000	about 30,000
County roads	1,900	15,000	about 23,000



Existing and under constructions (red)

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During the past decades, particularly the past 10 years, Germany has faced an enormous increase of traffic. Today, passenger traffic (passenger-km) on the road amounts to more than 90 %, commercial traffic (tons of merchandise-km) is about 67 % of the total traffic, while the remaining traffic is distributed among other traveling and transportation modes, i.e. on rail, water or air. Motorways (Autobahnen); totaling 11,700 km, carry more than 40 % of the total traffic of the entire classified rural, inter-urban road net (consisting of Federal Motorways, Federal-, and State-Highways and County roads), although they represent only about 5 % of the total length of this road net.

The enormous increase of traffic volumes in recent years will continue even more rapidly in future as a consequence of political and economic developments, especially the European process of unification. Within the next 15 years the extension of the European Union to the east and increasing economic cooperation is expected to bring a 30 % increase of passenger traffic and 50 % increase of commercial traffic to the "transit-country" Germany.

Maintaining traffic safety, optimum driving conditions and availability of sufficient capacity of highways all year round, even during winter is of crucial importance. As a consequence, in future the quality of winter maintenance has to meet increasingly high standards.

Responsibility for Road Planning, Construction and Maintenance, including Winter Maintenance

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 financialobligation for planning, construction and maintenance	Administration of planning, construction and maintenance
Federal Trunk Roads	Federal motorways	Federal Government	Federal States on behalf of the Federal government
	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

Table: Level of requirement for winter maintenance

Level of requirement for winter maintenance				
		Level of service		
road/traffic function	period of traffic stand by	weather or road condition		
		snowfall, icy roads, hoarfrost	heavy continuous snowfall	severe drifting, avalanches, freezing rain
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, junctions, access roads to service areas; passability on parking facilities, shoulders, light obstructions must be accepted between 22.00 p.m. and 06.00 a.m.	trafficability on at least one through lane, access roads to service areas, if required with snow chains; passability on parking facilities is no longer guaranteed	trafficability cannot be any longer guaranteed
Important rural roads	from 06.00 a.m. to 10.00 p.m. (daily)	trafficability	trafficability, if required with snow chains; on mutilane highways at least one through lane, if required with snow chains"	
Roads with heavy rush hour traffic Roads with public transport	generally from 06.00 a.m. to 8.00 p.m. (workings days), additional service in response to local conditions	trafficability, light obstructions must be accepted between 20.00 p.m. and 06.00 a.m. or on Sundays and holidays	trafficability, if required with snow chains; on mutilane highways at least one through lane, if required with snow chains	
Roads with school bus traffic	generally from 07.00 a.m. (school days), additional service in response to local conditions	trafficability	trafficability, if required with snow chains	
Other rural roads	from 08.00 a.m. to 8.00 p.m. (daily)	trafficability, light obstructions must be accepted on Saturdays, Sundays and holidays	trafficability, if required with snow chains	
roads with weekend traffic, access roads at big events	in response to local conditions	trafficability, light obstructions must be accepted	trafficability, if required with snow chains	
sidewalks, bicycle route, multipurpose lane	in response to local conditions	trafficability, light obstructions must be accepted	trafficability, if required with snow chains	
important parking facilities	in response to local conditions	passability, obstructions must be accepted	passability is not 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.

"passability" on parking facilities and shoulders means, that lanes on parking facilities and shoulders can be used with an adjusted driving behaviour appropriate to existing obstructions and that proper parking is possible.

"light obstructions must be accepted" means that on account of only light obstructions a winter maintenance operation is not required.

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Climate

Germany has a moderate climate, and frequent weather changes are characteristic. From the low lands in the north-west to south eastern 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 snow storms, 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 annual 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 fall below - 6 °C , depending on the altitude (see Table below).

There is only heavy snowfall in mountainous regions and the surrounding areas. Bavaria, the most southern State includes the north edge of the Alps, and 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 in the amount of snowfall in different parts of the State as follows:

Snowfall in Bavaria (Southern Germany)

State of Bavaria	Annual cumulative snowfall (measured at motorway maintenance stations)	
	3-year average: 1998/99, 1999/2000, 2000/2001	Maximum: Winter 1998/99
Front of alpine region	440 cm	615 cm
Lower mountain regions	210 cm	295 cm
Lower areas, river valleys	50 cm	70 cm

Large parts of central and northern Germany receive the same amount of snow as the south and the Bavarian river valleys, while other areas receive less particularly, particularly coastal regions. Other typical features of the climate are the great variation in the severity of consecutive winters, in relation to temperature and amount of snowfall.

Correlation between winter severity and road-salt use

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.

Table: Representative meteorological data

	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 (455 m)	- 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

Reference: German Weather Service (Deutscher Wetterdienst - DWD), Offenbach

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Winter Road Maintenance

Snow clearing and ice-control management

For snow clearing vehicles the following service cycle time-periods are stipulated:

- 4-/6-lane divided motorways (Autobahnen) 2 hours
- motorway interchanges 2 - 2 1/2 hours, e.g. same cycle as for through-lanes or immediately afterwards
- federal and state highways 2 1/2 - 3 hours

For pure salt spreading activities distinctly shorter time-periods are standard.

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 however has to work effectively and efficiently from the very beginning of winter.

Only careful planning guarantees the 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 these roads.

A priority list is necessary, especially in urban areas where 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 cities major, 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, access roads to factories,
- 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).

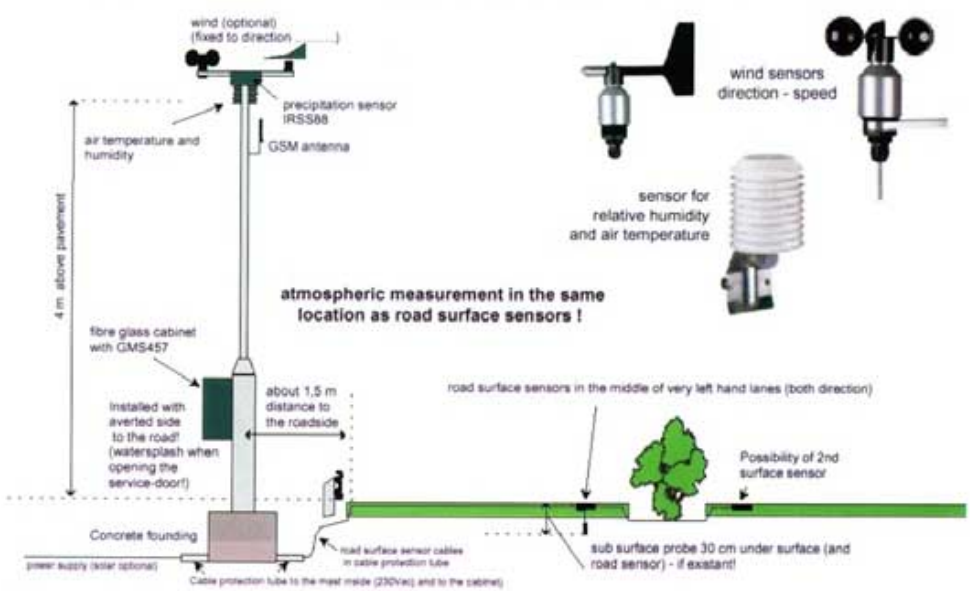
Snow-clearing strategies and control

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: the so-called **"bare pavement policy".**

In contrast with to other countries, the winter maintenance policy has to be considered in relation to Germany's **studded tires ban** in 1976, following enormous pavement damage. Detailed research in the 1970s revealed that the number of accidents in one year as a result of vehicles aqua planing on rain filled ruts, outnumbered those avoided by the use of studded tires.

On secondary and lower rank roads in urban areas, in municipalities and on minor rural roads, in general, where lower driving speeds are prevailing, **"differentiated winter maintenance"** is performed. According to the function and the traffic volumes of these roads and depending on weather conditions there is a gradation into three steps: application of deicing agents on major roads, gritting with abrasives on the lower categories and even so called "zero-gritting" e.g. only snow clearing, on the lowest, the residential streets.

Roadside meteorological station with atmospheric and road surface sensors



Reference: Fa. MickS GmbH, D-87561 Oberstdorf, Germany

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Road Weather Information Systems

Following data are measured and provided

- air temperature [°C]
- road surface temperature [°C]
- road structure (sub surface) temperature at various depths [°C]
- relative humidity
- precipitation (rain, snow)
- road condition (dry, moist, wet)
- wind (direction, speed)
- residual salt
- dew point (calculated from air temperature and relative humidity)
- freezing temperature after spreading of de-icing agents [°C]

Winter Maintenance Operation

Training and education

Before winter, the regular training and education of road crews is very important. Existing knowledge is brushed up and new information can be introduced. The workers should be made sensitive to the necessity of a fast, economical and ecological winter maintenance and to their responsibility.

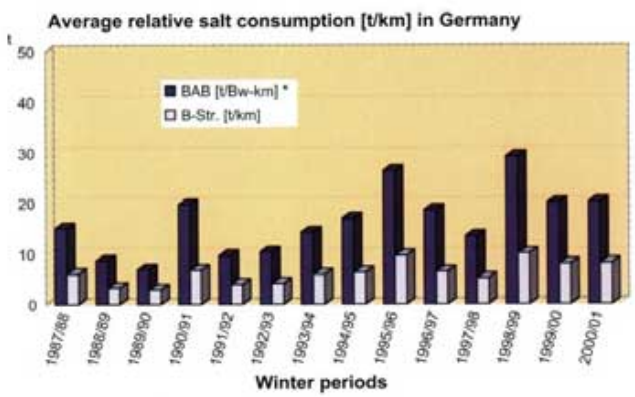
The education should be both theoretical and practical; important points are:

- Weather forecast and meteorological observation, connection between weather and winter maintenance (especially for road masters and heads of winter maintenance operation, how to use information effectively)
- Basis of the winter maintenance and use of gritting materials
- Measures for cutting down the use of salt
- Vehicles and equipment, operating instructions and practical training
- Experience gained in the previous winter (statistics, conclusions)
- Outlook for the next winter (new equipment, plans, rules)

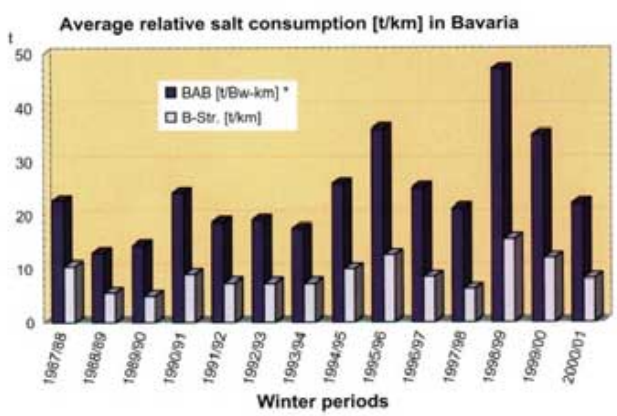
Salt Consumption and Expenditures for Winter Maintenance

According to variable climatic conditions in consecutive winter salt consumption and expenditures for winter maintenance show large differences as follows:

Salt consumption on federal trunk roads from 1987/88 to 2000/2001



BAB: = Federal Motorways
B-Str.: = Federal Highways
* Equivalent for 4-lane divided motorways



Reference: Federal Ministry of Transportation
BAB: = Federal Motorways
B-Str.: = Federal Highways
* Equivalent for 4-lane divided motorways
Reference: Federal Ministry of Transportation

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The situation on State highways is comparable; however salt consumption is slightly lower than Federal highways.

Expenditures for winter maintenance

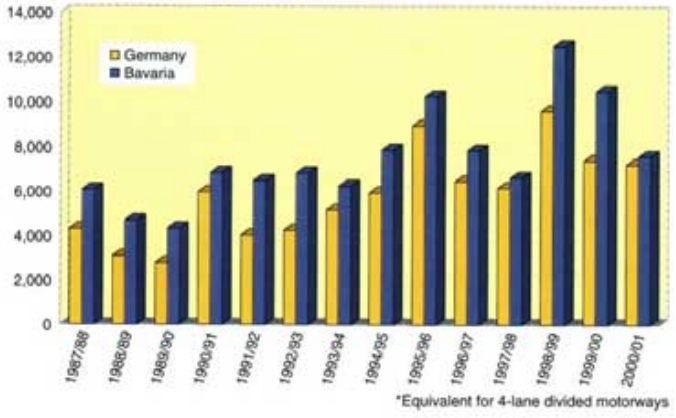
Different annual expenditures for winter maintenance reveal a strong correlation to salt consumption, as it is demonstrated with relative costs for winter maintenance on Federal motorways [t/km].

However there is no special budget for winter maintenance, only an annual budget for road maintenance. Annual variable expenditures for winter maintenance have to be covered by the budget for road maintenance. This means, that after extreme winters other road maintenance tasks have to be postponed to a certain extent; after extreme harsh winters additional funds from the construction budget are necessary.

These interactions can be demonstrated for Bavaria State Road Administration by comparison of salt consumption and winter maintenance costs (for Federal motorways and highways and State highways) and total expenditures for road maintenance. The situation is similar on the federal level.

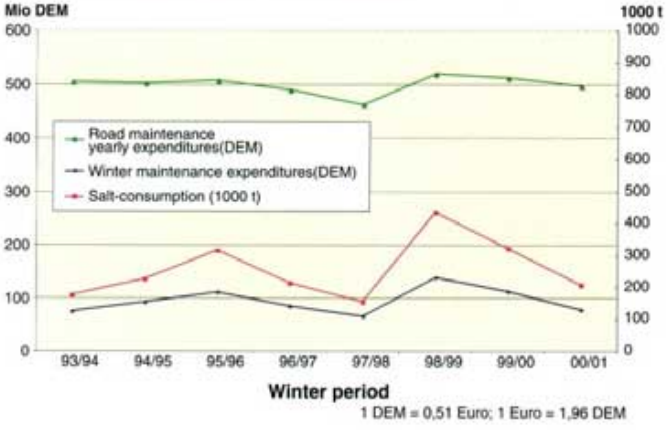
The State of Bavaria has about 19.5 % (2,280 km) of the Federal motorway, 16.5 % (6,800 km) of the Federal highways and 16 % (13,900 km) of the State highways.

Average expenditures [DEM/km *] for winter maintenence on federal motorways



*Equivalent for 4-lane divided motorways

Expenditures for road maintenance and winter maintenance of Bavaria State Road Administration

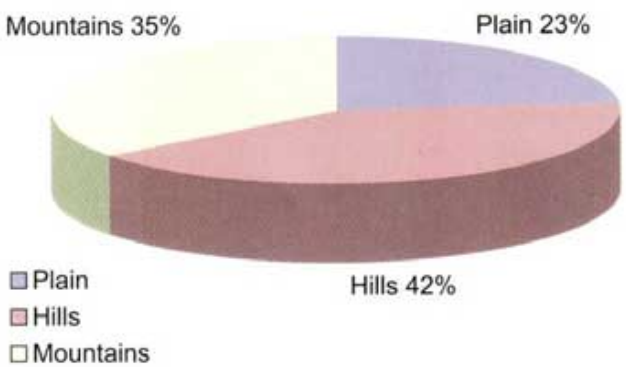


1 DEM = 0,51 Euro; 1 Euro = 1,96 DEM

Demographics and Roads

Area	Total	301,302 km²
Population	Total	57 million
Length of road	National roads and highways	26,128 km
	Prefectual roads	139,917 km
	Municipal roads	285,634 km
Latitude (capital)		41°53'33"N

Orography



	Plain	Hills	Mountains	Total
Area (sq.km.)	69,902	125,342	106,058	301,302
(%)	23.2	41.6	35.2	100.0

Climate

			Alt.	Monthly mean temperature (5-year average) (- C°)				Daily min. temperature 1992/96 (C°)				Snowfall (4-Year average)	Precipitation (5-Year average)
			(m)	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	days	mm.
NORTH	Lombardia	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
CENTRE	Lazio	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
SOUTH	Calabria	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
ISLANDS	Sardegna	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

Winter Roads Mobility

With regards to winter climatic conditions, Italy has very different features along the territory. The northern borders of the Italian 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 plane. 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 2,000 m with the Gran Sasso reaching 2,914 m. On the two bigger Italian islands too there are tall mountains such as Etna (3,340 m) in Sicily and Gennargentu (1,834 m) in Sardinia.

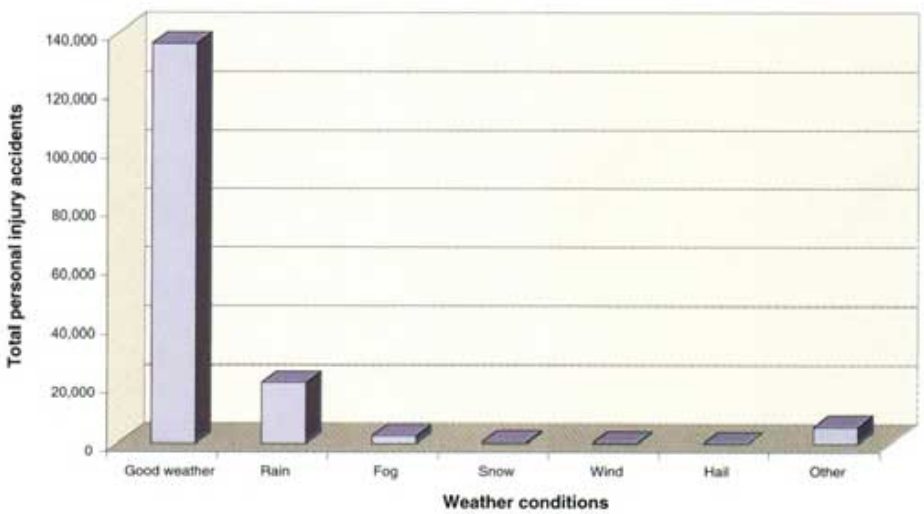
These features give a big variety in climate and in microclimate so special attention must be given to snowfall possibility as well as where it appears unlikely in regions located in the southern latitude and near the sea. The snow is different in the northern regions, where it is dry and light, compared with, wet and heavy snow in the southern regions.

No. of accident by weather (years 1991/92/93/94 average)

Weather conditions	Total
Good weather	136,417
Rain	20,729
Fog	2,655
Snow	554
Wind	235
Hail	77
Other	5,730
Total	166,397

ANAS (the Italian Agency for National Road Construction and Management), highway management organizations, prefectures 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.

Annual road accident / weather conditions: years 91-92-93-94 average



JAPAN

Road Bureau, Ministry of Land Infrastructure and Transport
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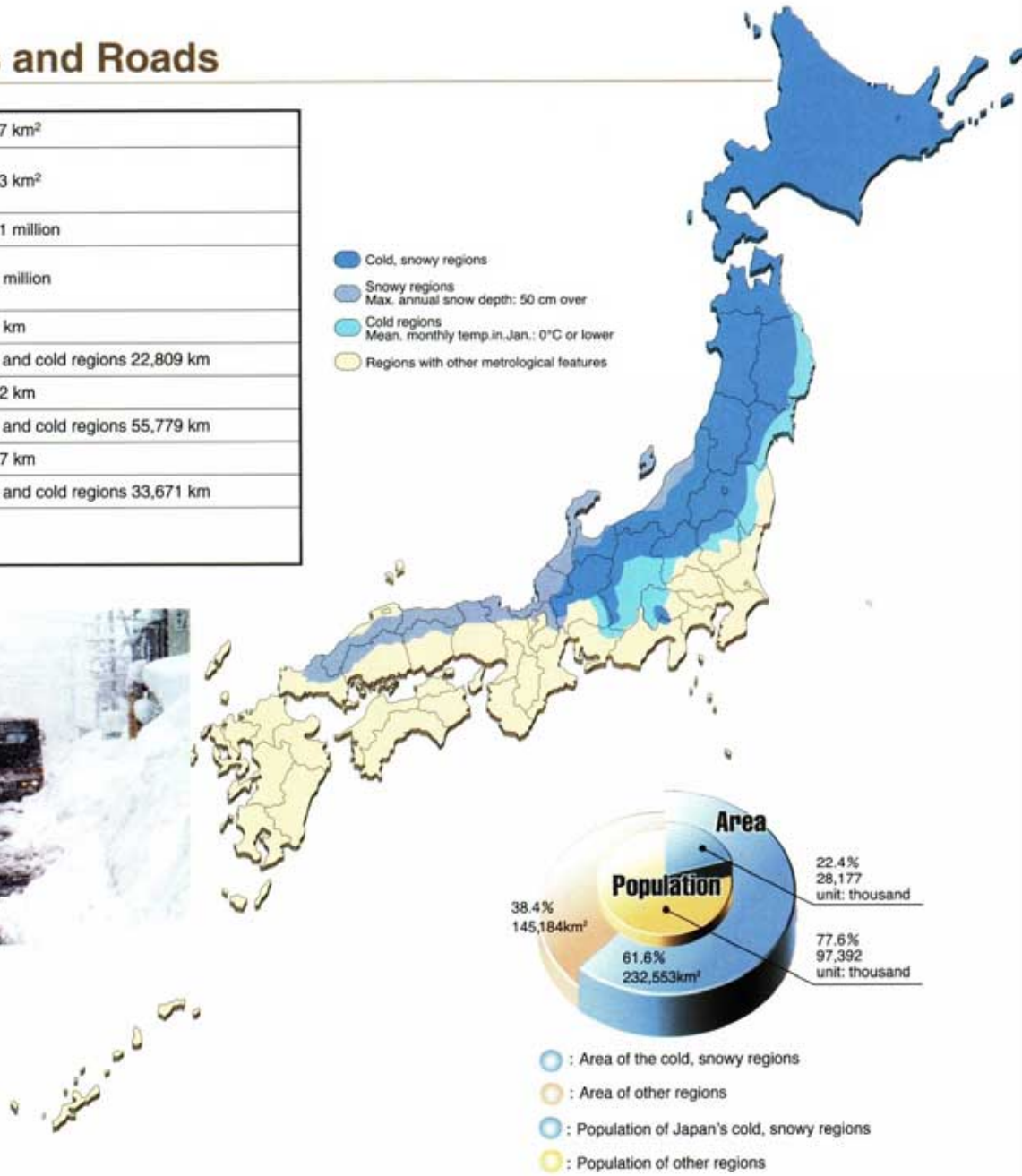
Demographics and Roads

Area	Total	377,737 km²
	Snowy and cold regions	232,553 km²
Population	Total	123.611 million
	Snowy and cold regions	27.511 million
Length of road	National highway	46,661 km
		Snowy and cold regions 22,809 km
	Prefectural road	128,202 km
		Snowy and cold regions 55,779 km
	Municipal road	925,137 km
		Snowy and cold regions 33,671 km
Latitude (capital)		35°N



Climate

	Daily min. temperature [°C]				Snowfall (5-year average) [cm]			Precipitation (5-year average) [mm]				
	Dec.	Jan.	Feb.	Mar.	Daily maximum snowfall	Maximum snow depth	Cumulative depth of snowfall	Dec.	Jan.	Feb.	Mar.	Total
Sapporo	- 4.9	- 8.4	- 8.0	- 3.9	41	169	480	100	108	94	82	1,130
Aomori	- 2.2	- 5.0	- 5.2	- 2.4	45	209	809	162	170	122	82	1,360
Sendai	0.1	- 2.6	- 2.4	0.0	18	41	76	36	41	49	68	1,205
Niigata	2.0	- 0.5	- 0.6	1.5	30	120	200	219	191	129	103	1,778
Tokyo	3.9	1.2	1.7	4.4	8	46	15	46	45	60	100	1,405
Fukui	2.2	- 0.2	- 0.5	1.8	35	213	296	293	307	193	148	2,368

History and Background of Snowy and Cold Area Works

Snowy and cold area works were established to ensure smooth winter traffic that supports winter living in cold, snowy regions.

In 1956, the Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas (Snowy and Cold Area Law) was enacted. In snowy regions, snowfall causes road closures and traffic accidents including slip accidents on icy roads, and the road structure is damaged by frost heave. The law was legislated to minimize local governments' mounting financial burdens and to provide measures against these hindrances amidst a rapid increase in the number of vehicles.

An emerging issue is the need for countermeasures to the extremely slippery roads that have emerged since studded tires were banned causing vehicle skidding and pedestrian fall. 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 condition year-round. The increasing mobility of people between snowy and non-snowy regions highlights the need for road service level improvement.

Outline of snowy and cold region works

As shown in the chart below, in accordance with the Snowy and Cold Area Law, a five-year program was established that focuses on snow removal, snow countermeasures, snow and ice disaster prevention, and snow-removal machinery development in the areas designated under the Law.

Main focuses of snowy and cold area works

- Ensuring winter mobility toward a new era in which regional exchanges and cooperation are expected to intensify. The main focuses of the Five-Year Program launched in 1998 follow:
- Ensuring safer walking spaces for pedestrians, and comfortable and attractive living surrounding.
- Development of winter road information systems to support safety and reliability of roads, and utilization of new ice - and snow-control technologies

Five - Year Program

A five-year program based on the Snowy and Cold Area Law is aiming at efficient, smooth, and well-organized implementation of snow countermeasures, to ensure winter mobility. The details and budgets of the program for five-year terms, a duration stipulated by the Law, are determined in Cabinet meetings. The current five-year program (1.43 trillion yen budget) was determined at the Cabinet meeting of May 29, 1998.

Outline of Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas

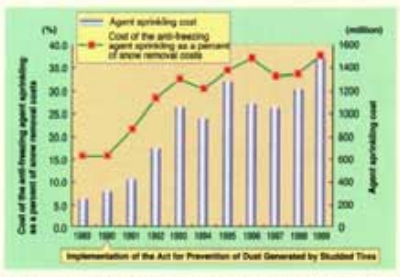
Designated routes: Roads within the region designated under the Law that meet the traffic volume criteria set by the Minister of Land, Transport and Infrastructure and where securing of traffic is especially important for the promotion of industrial and daily life activities.

Snow removal on carriage way

- Anti-freezing agents are applied to reduce the freezing point of water so as to prevent road-surface freezing or to melt snow by using the heat produced when the agents mix with water.
- Commonly used anti-freezing agents are sodium aloride and calcium chloride.

Recently, a new type of agent effectively prevents metal corrosion caused by chloride ions is being investigated.

- To meet the growing need for application of anti-freezing agents, the sprinkled quantity is significantly increasing (see graph).



Cost of anti-freezing agent sprinkling, and that cost as a percent of snow removal costs for roads managed by the Tohoku Construction Bureau

Road Bureau, Ministry of Land Infrastructure and Transport
Chuo- Godo- chousha 3, Kasumigaseki 2- 1- 3, Chiyodaku, Tokyo

Snow- and Ice-Control Measures

Snow removal

Snow removal on roadways

To maintain traffic functions of national highways and principal prefectural roads and to promote interregional exchanges and living activities, snow removal on roadways is conducted around the clock.

Snow removal on sidewalks

Snow removal on sidewalks is promoted around schools, railway stations, downtown, and social welfare facilities to ensure safe and reliable walking spaces in winter.

Sprinkling of anti-freezing agents

Since the ban on studded tires, extremely slippery road surfaces frequently have emerged in winter. Anti-freezing agents are efficiently sprinkled to reduce traffic congestion and slip accidents.

New technology

Slush remover used for the Hokuriku Expressway

On the Hokuriku Expressway, snowfall of two centimeters deep per hour is common. Snow removal of such shallow snow leaves a thin layer of slush on the road surface, which may be a factor in about fifty percent of winter traffic accidents. For this reason, a frozen slush remover was developed. It is able to remove slush efficiently even on a rutted road and to blow off not only slush and snow, but also water. It makes it effective in removing slush and useful in extending the effects of anti-freezing agents because the agents do not become diluted.

Conventional Removal

A single-lane rear-loading rotary machine

Three lane removal

Sidewalk removal

Sprinkling of anti-freezing agents

Snow-control measures

Countermeasures to avalanche and blowing snow

Various facilities are constructed as countermeasures to avalanche and blowing snow.

Snowbreak woods

Snowbreak woods catch falling snow and hold it as snowdrifts within the woods or on their windward side to prevent snow from blowing on roads on the downwind side.

Snowbreak woods

Snow fence

Avalanche control fence

Snow shed

Snow fence

A snow fence mitigates the development of snow piles created by removed snow and snowdrifts on the road shoulder and thereby improves visibility.

Avalanche control fence

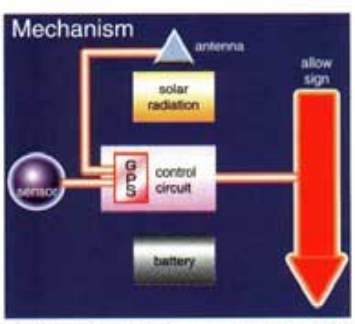
Avalanche control fences are constructed on avalanche-prone roadside slopes.

Snow shed

A snow shed is constructed over a road so that avalanches will pass over it without endangering the safety of the roads.

Illuminative delineator on the Asahikawa airport route (Hokkaido)

The delineator, which runs on eco-friendly solar energy, is more easily recognized and improves the efficiency of snow-removal.



Illuminative delineator, system and on-site

Snow-Melting Facilities

Road heating

Road heating, a system of melting snow or preventing road surface freezing not by sprinkling ofwater but by heating of pavement by radiator or electric wire.

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.

Without road heating

With road heating

Snow-flowing gutter

The city of Sapporo has been promoting the construction of snow-flowing gutters, to dispose of snow with the cooperation of the local residents. Snow-flowing gutters are constructed at the roadside. Snow on the street is moved into the waterways and is carried away using natural inclines. An underground box culvert method is used to mitigate the effect of freezing. In general, the water source is river water. However, Sapporo uses processed sewage effluent at 10 °C from sewage-treatment plants. Compared with general river water, the use of processed sewage water has the advantage of reducing the required discharge capacity of the gutter, because the higher water temperature reduces the snow volume by melting the snow.

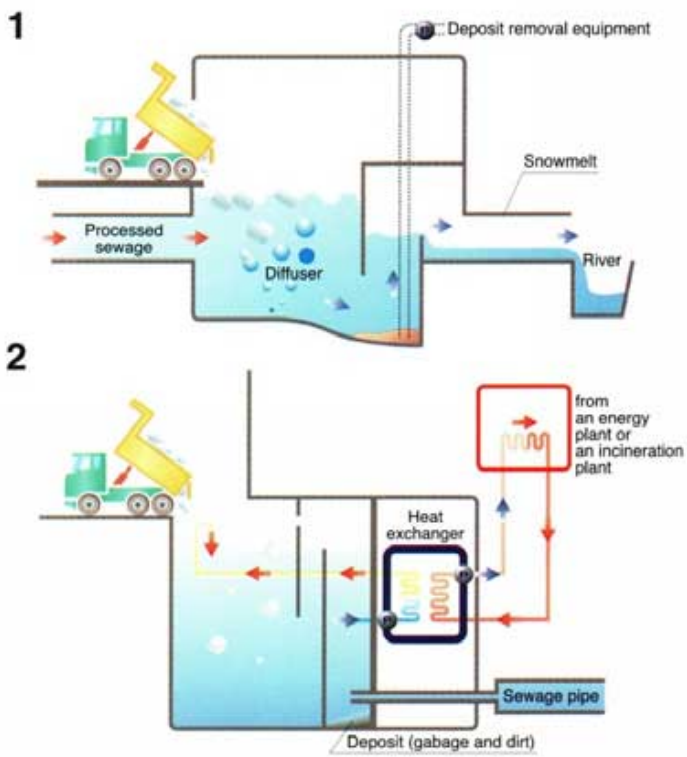
Residents using the snow flowing gutters

Equal number of traffic lanes in summer and winter

Snow-melting tanks

The construction of snow-melting tanks in the urban area has been actively promoted by the city because the facilities melt a large quantity of snow using relatively small land areas.

Snow-melting tanks dispose of snow removed from roads, carried by dump trucks and dumped directly into the tanks that contain heated water. The energy sources used to melt snow are those previously considered as waste including processed sewage and the heat generated in garbage incineration. The tanks are effectively used not only during winter, but also during other seasons, as fire-fighting water tanks and balancing reservoirs to retain rainfall and sewage.



Heat sources of snow-flowing tanks 1) processed sewage that already carries heat to melt snow, and **2**) residual heat from incineration plants, etc.

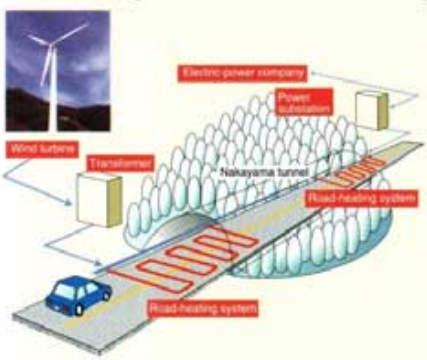
A snow-melting tank

Road Bureau, Ministry of Land Infrastructure and Transport
Chuo- Godo- chousha 3, Kasumigaseki 2- 1- 3, Chiyodaku, Tokyo

New Technology

Snow-melting facility that uses wind-generated electricity on National Highway 49 (Fukushima Prefecture)

National Highway 49 has suffered problems including blowing snow and road surface freezing at both ends of Nakayama Tunnel because of strong winds in winter. Such conditions have threatened traffic safety there. The Ministry of Land, Infrastructure and Transport installed a road-heating facility to melt snow by utilizing the problematic strong winds as a resource for generating electricity. This system is beneficial because it mitigates adverse effects on the environment and affords low operation costs. The wind-powers generated electricity is used in summer for the tunnels jet-fan ventilation and lighting.



A snow-melting facility on National Highway 47 that uses of hot spring waste heat (Miyagi Prefecture)

Snow-melting facility construction needs to consider two issues: reduction of energy consumption on the environment and reduction of running costs. As a solution, a clean and low-cost snow-melting facility, the Heat Pipe, a road heating system was developed. This measure cannot completely melt snow on a road, but it is able to melt snow to slush and to keep the road sufficiently safe.

Road Weather Information System

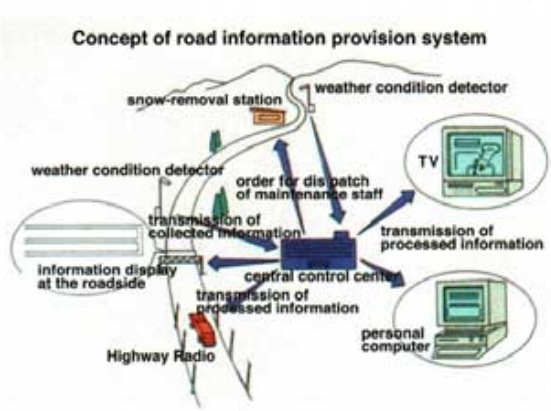
Pilot system in the Yuzawa district (National Highway 17, managed by Nagaoka National Road Works Office, Ministry of Land, Infrastructure and Transport)

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 geographic conditions. The 25 km of this highway between Mikuni and Kandatsu area on the border between Niigata Prefecture and Gunma Prefecture, one of the snowiest areas in Japan. The geography of part of the highway is complex: nine curves have a radius of 50 m or less, and 13.3 km of it have a gradient of 4% or more. The Ministry of Land, Infrastructure and Transport has implemented advanced ice - and snow-control measures on the part of the highway that has been designated a pilot area with various winter problems. The Ministry has introduced a traffic system to promote snow removal, road patrol management, and collaborative linking of various systems including that for automatic road information provision.

Meteorological telemeter

Snow-depth meter and thermometer

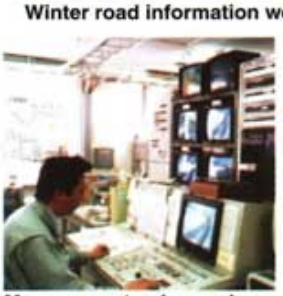
Road-surface hazard management



Winter road information web site

On-site monitors

Surface freezing detector



Management using real-time images

Road information board

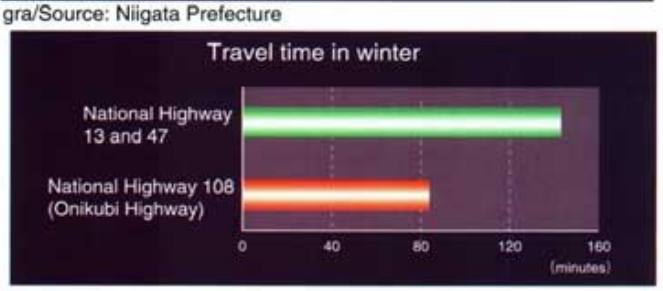
Achievements

Snowy and cold area works 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 minimized.

Vitalization of interregional traffic

The removal of snow on most national highways has contributed to improved winter mobility that stimulates 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.

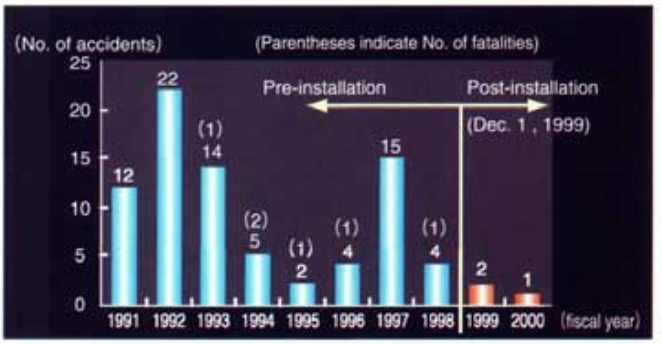
gra/Source: Niigata Prefecture



Comparison of well-developed National Highway 108 and other national highways between Ogachi in Akita Prefecture and Naruko in Miyagi Prefecture
Source: Ministry of Land, Infrastructure and Transport

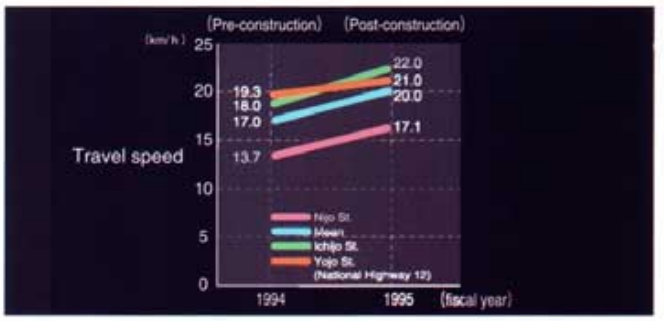
Reduction in traffic accidents

The graph shows a significant reduction in the number of traffic accidents at Harushinai Tunnel after installation of a snow-melting facility.



Mitigation of traffic congestion

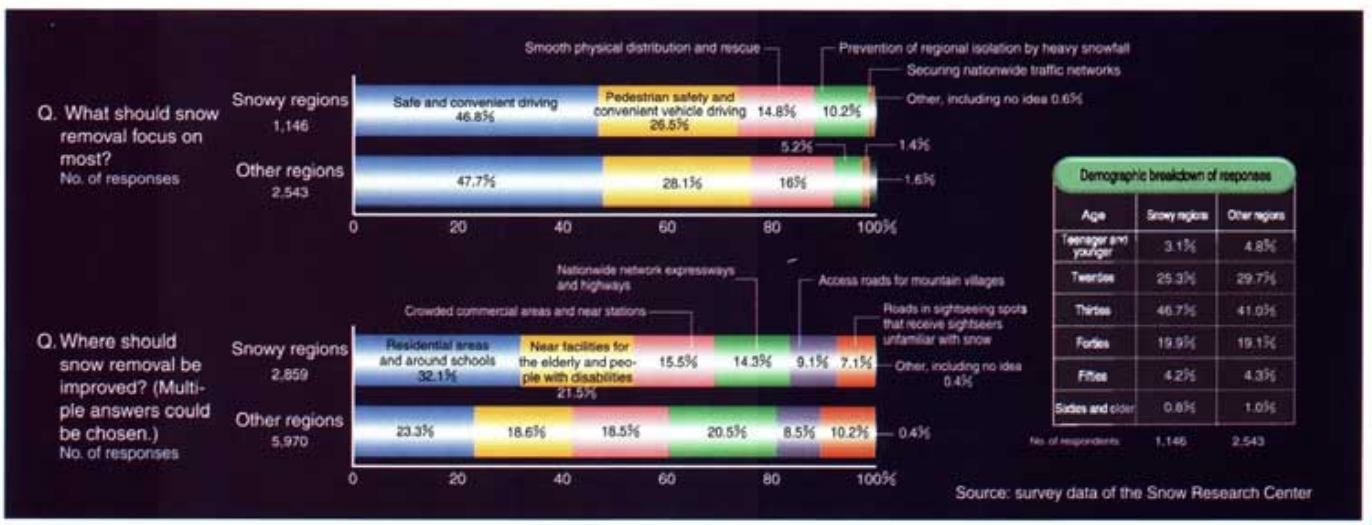
Construction of snow-flowing gutters has shortened travel times in Asahikawa City by as much as 25 %.



gra/Source: Hokkaido Development Bureau

Improvement of snow-removal for pedestrians including the elderly

A questionnaire survey to identify residents' opinions on snow removal was conducted at a Web site from February 1 to March 30, 2001. The survey indicates high need for snow-removal improvement for pedestrians including the elderly. Most respondents were in their thirties.



NORWAY

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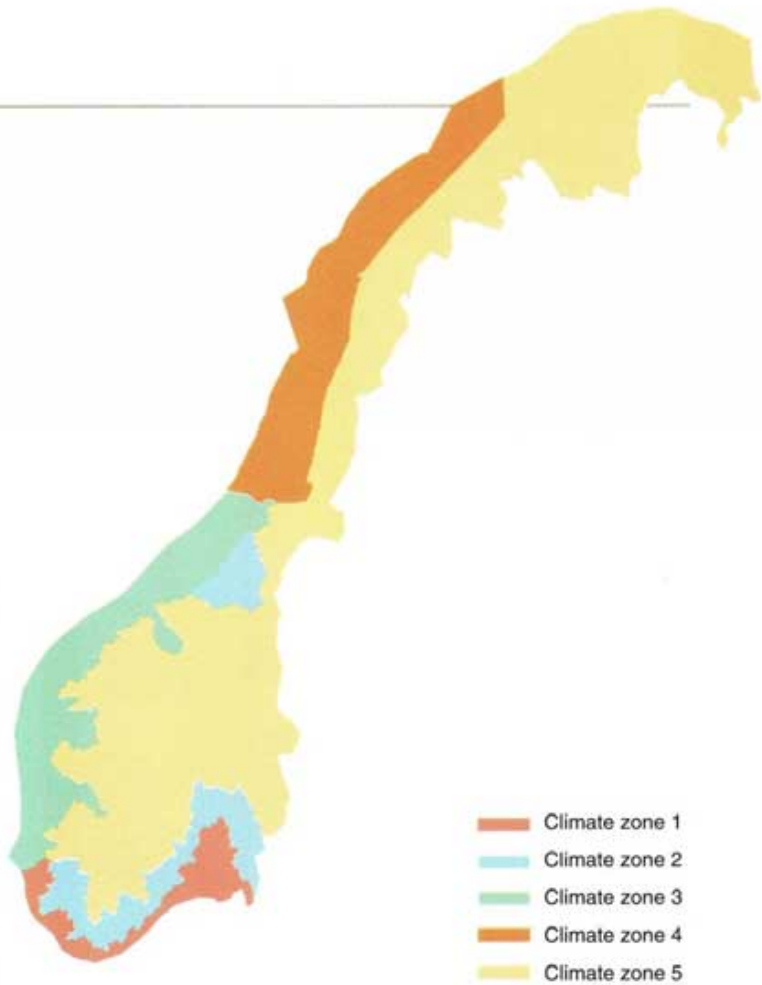
Demographics and Roads

Area	Total	385,000 km²
	Snowy regions	385,000 km²
Population	Total	4.5 million
	Snowy regions	4.5 million
Length of road	National Highway System	27,000 km
		Snowy regions 27,000 km
	Other federal-aid roads	27,500 km
		Snowy regions 27,500 km
	Non federal-aid roads	38,000 km
		Snowy regions 38,000 km
Latitude (capital)		60°N

Climate

In Norway there are large variations in climate within short distances. For winter maintenance purposes we can divide the country into five climate zones.



Climate parameters in different climate-zones

	Climate-zones				
	Zone1	Zone 2	Zone 3	Zone 4	Zone 5
Length of winter, (days)	152	173	157	206	201
Snow-depth (cm)	41	55	41	63	72
Precipitation, (snow) (mm)	158	225	258	332	248
Precipitation, (rain) (mm)	830	734	1,632	860	603
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

Zones are shown in the figure above

Climate zone	Population (mill)	National roads (km)	Transport volume (billion km)	AADT
1	1.7	2,900	7.7	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

Background

The population of Norway is 4.5 million and the total area is 385,000 square km.

Much of Norway is covered by mountains and the western coast is gouged by deep fjords and dotted with islands.

More than 75 per cent of the country is covered by mountainous terrain. It also has 56,000 km of coastline. Nine-tenths of the country's area is located north of the 60° latitude where there is heavy snowfall six months of the year.

Winter traffic (November through April) accounts for about 35 % of the annual yearly traffic volume.

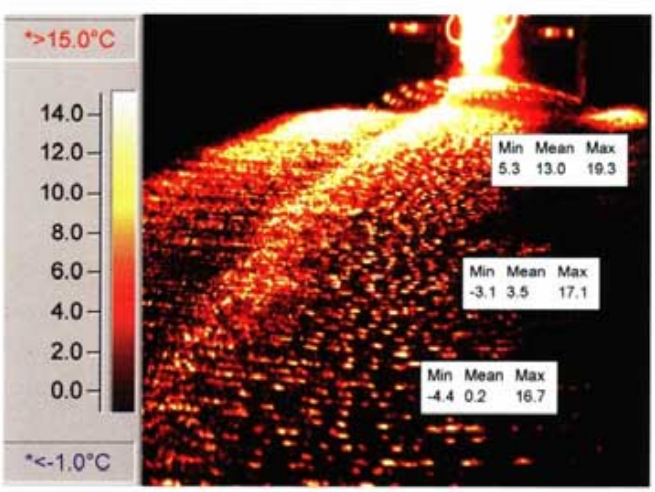
Policy, Research and Methods

Sodium chloride (NaCl) is used for chemical anti-icing and is used where the policy is "bare roads". Sanding is 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 tons pr. year. The "winter road" policy is used on about 46,000 km of roads, which is maintained by the Norwegian Public Roads Administration.

Studded tyres were until the late 1990's commonly used. However, that has changed due to improved friction measures, better effects of non-studded tyres and for environmental reasons. In the largest cities no more than 20 % of the vehicles are in the future supposed to use studded tyres. In Norway today 75 % are using studded tyres. The three larges cities have now nearly achieved their goal, and non-studded tyres were used on 70 % of the vehicles in the winter season 1999/2000.

During the summer there are legal penalties for using studded tires. There are no penalties for the use of summer tires in winter. However one will be penalised for not securing proper road-grip during the winter period.



In 1991 The Norwegian Directorate of Public Roads started a three-year programme to examine the effect of road salting on traffic safety. The study was nationwide and included all counties. The result of the study showed that road salting as it is carried out today, reduces the number of police reported accidents by 20%.

An investigation to study environmental effects of salt on the area surrounding the roads was carried out in the period 1992-1996. Today we have a small programme to follow the development and the consequences of salting for a longer period.

Winter speed limits are tried out to lower accident rates, and so far it has given satisfactory results.

A programme for reporting the achieved level of the winter standard has been started. This system will be further developed, and will be extended to include summer conditions.

There is a need for methods of comparing cost levels relating to variation in winter conditions. To implement this a programme for calculating a winter index has been started. This will be helpful in calculating the right actions for the winter maintenance in the future.

A number of 200 Road Weather Information Stations are placed along the side of trunk routes. NPRA also has a close co-operation with the meteorologists in order to be updated on changes in the weatherforcast several times a day. This information is distributed to computers around the country and sent out to the work force.

Norway has a well organised system for collection and dissemination of road information based on co-operation between maintenance bases, five regional traffic information centres and a national road information centre. The five regional road traffic centres and the local centres are connected to the same public telephone number 175.

Air pollution is measured throughout the day in five major cities. Those measurements are used to take action towards the road-user and make local restrictions if necessary.

A four-year winter research programme is in progress. The main subjects for this programme are to develop educa-

NORWAY

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tional material for winter tasks and scientific studies relating to methods and equipment for sanding, salting, ploughing and friction measurements.

Winter Maintenance Standards

Maintenance of roads is financed by three different parties being the state (trunk and national roads), the county and the municipalities.

The level of service for national roads in Norway is described in the maintenance manual, handbook No. 111 "Standard for Maintenance and Operations". The county and the municipal roads have levels of standard different from that of the trunk and national roads.

The level of service for national roads is described according to functional classes and traffic volume. Traffic safety, traffic volume and environmental effects are considered to make the most cost efficient standard.

The level of maintenance standards for trunk and national roads is described according to the importance of the roads and the annual average traffic flow.

Passability, traffic safety and regularity during the winter period

The road shall 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 after two different strategies:

a) "Winter roads" Roads with acceptable snow- and ice-cover during the winter period

b) "Bare roads" (roads without snow and ice):

Roads that normally should be free from snow and ice during the winter period

The regularity on all roads, throughout the day, is supposed to be attended to the elected strategy, types of roads and AADT (annual average daily traffic rate).

Winter Roads Strategy

Snow depth

Snowy weather conditions: Ploughing shall be carried out in such a way that maximum snow depth does not exceed the values that are given in the table below:

AADT	Ploughed through before (snow depth)	
	Dry snow (cm)	Wet snow (cm)
0-500	15	12
501-1500	12	8
1,501-3,000	10	7
>3,000	7	6

During continuous snowy weather, ploughing shall be a continuous operation. The frequency must be as high as is necessary to meet the requirement to the maximum snow depth.

When there weather condition is extreme, the requirement can be deviated from.

If snow falls during the night, the whole road net is supposed to be ploughed through before 6 a.m. Subsequently ploughing of the road breadth including bus stops shall be done immediately afterwards.

Drifting snow: Action shall be taken when the height of the drift in the middle of one of the traffic lanes reaches:

AADT < 1,500	15 cm
1,500 > AADT < 5,000	10 cm
AADT > 5,000	8 cm

Snow- and ice-thickness, visibility for vehicles and snow clearing

Triggering road standard, maximum period before action takes and when the action is supposed to be finished is shown in the table below:

Tasks	Triggering criteria and maximum time for action in regard to different AADT			
	< 1,500	1,501-3,000	5,001-10,000	> 10,000
Snow and ice - max. thickness: - removed within:	* 3 days	2 cm 2days	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, i.e.) 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

* On roads with AADT below 1,500 there are no requirement to maximum thickness of ice cover, but the maximum requirement to rutting is 3 cm.

Bus stops shall be cleared before 7 a.m. on weekdays. Ice "patches" shall be removed before danger arises for the road-user (this ice becomes a problem due to water coming from frozen dishes etc).

Road-grip and friction

Sand and salted mixed sand shall be used for improving friction on the roads.

Sanding shall be done when low friction prevents normally winter equipped vehicles having problems when driving up and down hills etc. Action takes place shown in the table below:

AADT	Action and action time due to different friction-coefficients.	
	Friction coeff. < 0.15	Friction coeff. < 0.25
0-500	Full sanding within 4 hrs	Point sanded within 4 hrs
501-1,500		Full sanding within 4 hrs
>1,500		Full sanding within 2 hrs

Spot sanding takes place in curves, hills, junctions etc. When friction action is required this shall be done before 6 a.m. This means before the heavy traffic starts in the morning. In the evening rush action shall have taken place before 3 p.m.

One can use salt or salt-solution (brine) during the transition periods in spring and autumn.

Bare Roads Strategy

Snow-depth

Snowy weather conditions: Ploughing shall be done in such a way that maximum snow-depth do not exceed values in the table below:

AADT	Ploughed through before (snow-dept)	
	Dry snow (cm)	Wet snow (cm)
1,501-3,000	10	7
>3,000	7	6

Remark: It is supposed that "bare roads" strategy only applies to roads with traffic above an AADT of 1,500.

During continuous snowy weather, ploughing shall be a continuous operation. The frequency must be as high as is necessary to meet the requirement to the maximum snow depth.

When there are extreme weather conditions, the requirement can be deviated from.

If snow falls during the night, the whole road-net is supposed to be ploughed before 6 a.m. Subsequently ploughing of the full road breadth including bus stops shall be done immediately afterwards.

Drifting snow: Action shall be taken when the height of the drift in the middle of one of the traffic lanes reaches:

AADT	15 cm
1,500<AADT<5,000	10 cm
AADT>5,000	8 cm

Snow and ice thickness, visibility for vehicles and snow-clearing

Triggering standard for snow clearing and time before action shall take place after the road is fully ploughed is shown in the table below:

Tasks	Trigging criteria and maximum time for action in regard to different AADT		
	1,501 - 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, i.e.) removing snow in front of traffic sign within:	1 day	1 day	1 day
Visibility clearing in intersections within:	3 days	2 days	1 day

Ice "paths" shall be removed before danger arises for the road user.

Road grip and friction

Salt and salt-solution (brine) is supposed to be used in this type of friction action. Other chemicals can also be used.

When air- and the pavement-temperature is above -5 °C the roads which are salted should normally be "bare" (without snow and ice). Action takes place as shown in the table below:

Tasks	Triggering criteria and maximum time for action in regard to different AADT		
	1,501 - 3,000	3,001 - 5,000	> 5,000
Salting before precipitation	This is carried out if friction coeff. is expected to below 0.4	This is carried out if friction coeff. is expected to below 0.4	This is carried out if friction coeff. is expected to below 0.4
Bare road after snowfall within:	6 hrs	4 hrs	2 hrs

One shall use one step better of AADT standard for the transition periods, spring and autumn than the table describes.

Special winter works

Clearing after avalanche

Clearing and repairing shall be done as soon as it is safe to work at the site.

Pedestrian foot-paths and bicycle-roads

Pedestrian roads and cycle paths should be passable in such a way that people prefer to use these instead of the road lanes meant for vehicles

Ploughing

Pedestrian foot - paths and bicycle-roads shall be ploughed through before 6 a.m. Snow-depth shall normally not exceed 5 cm.

Sanding

Pedestrian foot-paths and bicycle-roads shall be sanded before 7 a.m. or within 2 hrs after the paths became slippery.

SLOVENIA

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Demographics and Roads

Area	20,256 km²	
Population	1,984,923	
Length of road	Motorways	249 km
	Expressways	132 km
	Main road	1,022 km
	Regional road	4,654 km
	Interchanges to public roads	113 km
	Total public roads	6,170 km
Latitude (capital)		46°4'N

Profile

In central Europe, between the Alps, the Dinaric mountain range, the Pannonian plain and the Adriatic sea, across an area of slightly over 20,000 km², lies a mostly hilly country, more than half of which is covered by forests. The valleys of the rivers Sava and Drava connect it to the Danube basin and the Balkan Peninsula, while mountain passes link it with Central and Western Europe. The Port of Koper and the airports in Ljubljana, Maribor and Portoroz are its connection with the rest of the world.

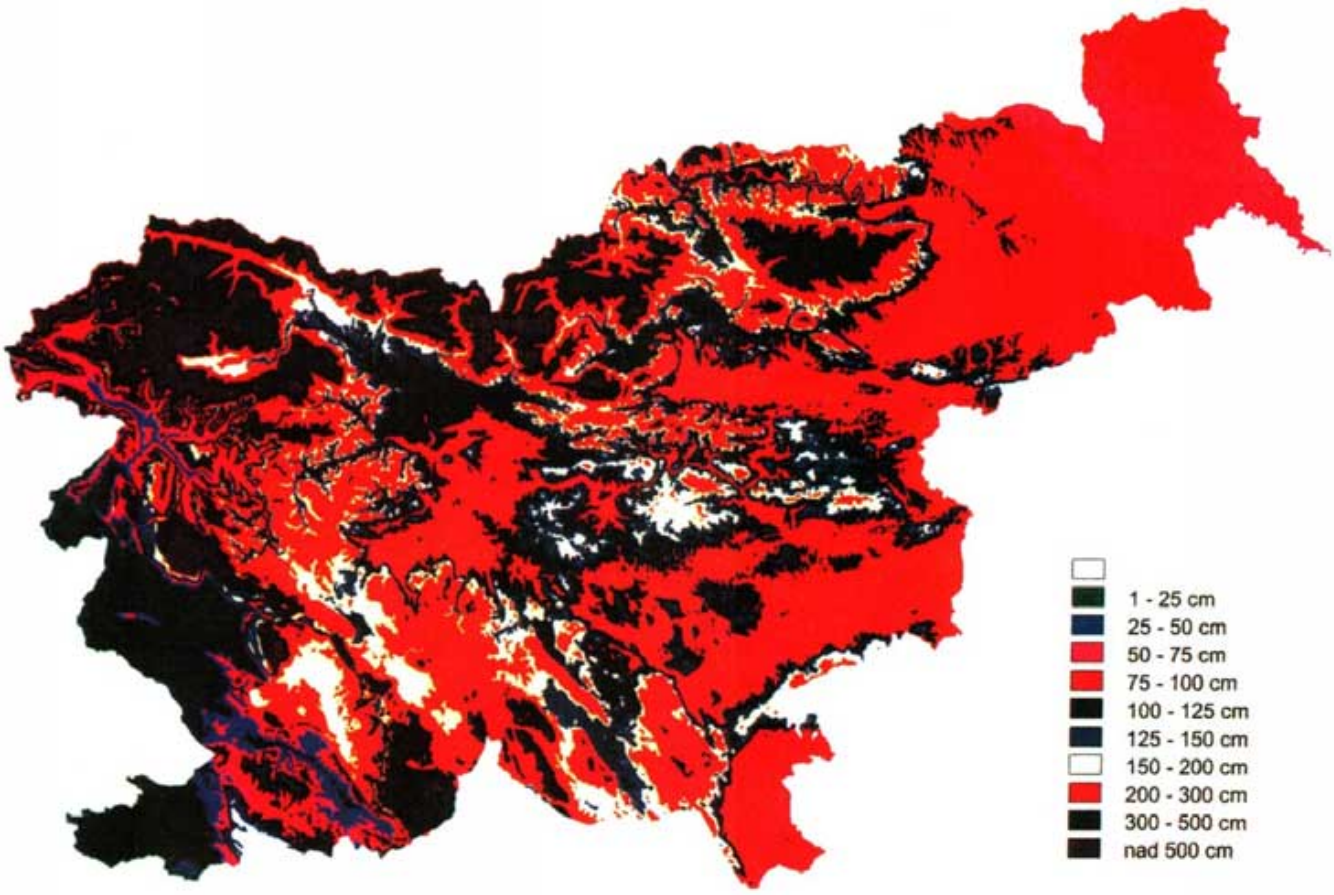
Archaeological finds show that through the centuries this area became a transport crossroads, and the shortest link between the Po plain and Pannonia. Three major European ethnic groups come together in this area: Slavic, Germanic and Roman. And Slovenia - one of the youngest European countries - was founded here in 1991.

Political system: Parliamentary republic (two chambers: National Assembly, National Council) with a president
Capital: Ljubljana
Official language: Slovene
Monetary unit: Slovene tolar (SIT)
Area: 20,256 km²
Protected natural reserves - nature parks
144,509 ha

Share in total area:

roads	0,4 %
railways	0.1%
forests	56.6 %
farmland	38.0 %

Average total amount of new snow during the winter



waters	0.6 %
rocks	1.8 %
urban areas	2.5%

Population (1991 census)

1,984,923 inhabitants
5,963 settlements in 147 municipalities,
49 % Rural population (1981-91)
Annual population growth rate: 0.4 % (1981-91)
Nationalities: 87.8 % Slovene
Minorities: Hungarian 0.43 %, Italian 0.16 %
Population/km^2: 98.7
GDP per capita: 14,916 USD (1997)

Waters:

Rivers; 2,385 km (longest: Sava 221 km, Drava 142 km, Soca 96 km, Mura 95 km) Waterfalls; 75 (highest: Cedca 130 m), **Larger lakes :** 2 glacier lakes (Bohinj, Bled), 1 intermittent (Cerknica)

Sites of natural interest:

Triglav National Park (84,805 ha), 9 nature reserves (1,515 ha), 4 regional parks (5,168 ha), 10 natural monuments, and 25 landscaped natural monuments.

Landscape:

The eastern part of the country is fertile plain; the central and southern parts are hilly, with karst plains, valleys and caves. Primorje, the Karst, Brkini, and the coast lie to the south-west, with the Alps lying to the north. Almost one half of Slovenia is covered with forests, which is an unusually high proportion by European standards.

Climate:

Alpine, Mediterranean and continental. Annual precipitation is 800 to 3,000 mm.
Average January temperatures: 0°C (Pannonia), 0 - 2°C (central region) and 2 - 4°C (littoral). Average July temperatures: 20 - 22°C (central region) and 22 - 24°C (littoral region).

Highest point on a national road:

Mangartsko sedlo: 2,055 m

Climate

There are great differences with regard to the average number of days with snow cover. In Primorje there are only two such days yearly, Postojna has 45 such days, places situated in lower parts of the interior of Slovenia 50 to 70 days and the places in higher parts over 100 such days. The average annual number of days with more of 1 cm of fresh snow is 10 to 15 in the area of both mountain barriers, except in Primorje, where snow falls are rare. The average annual amount of newly fallen snow is from 100 to 300 cm in higher parts of the country, and up to 100 cm in lower parts.

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Traffic Distribution by Road Category

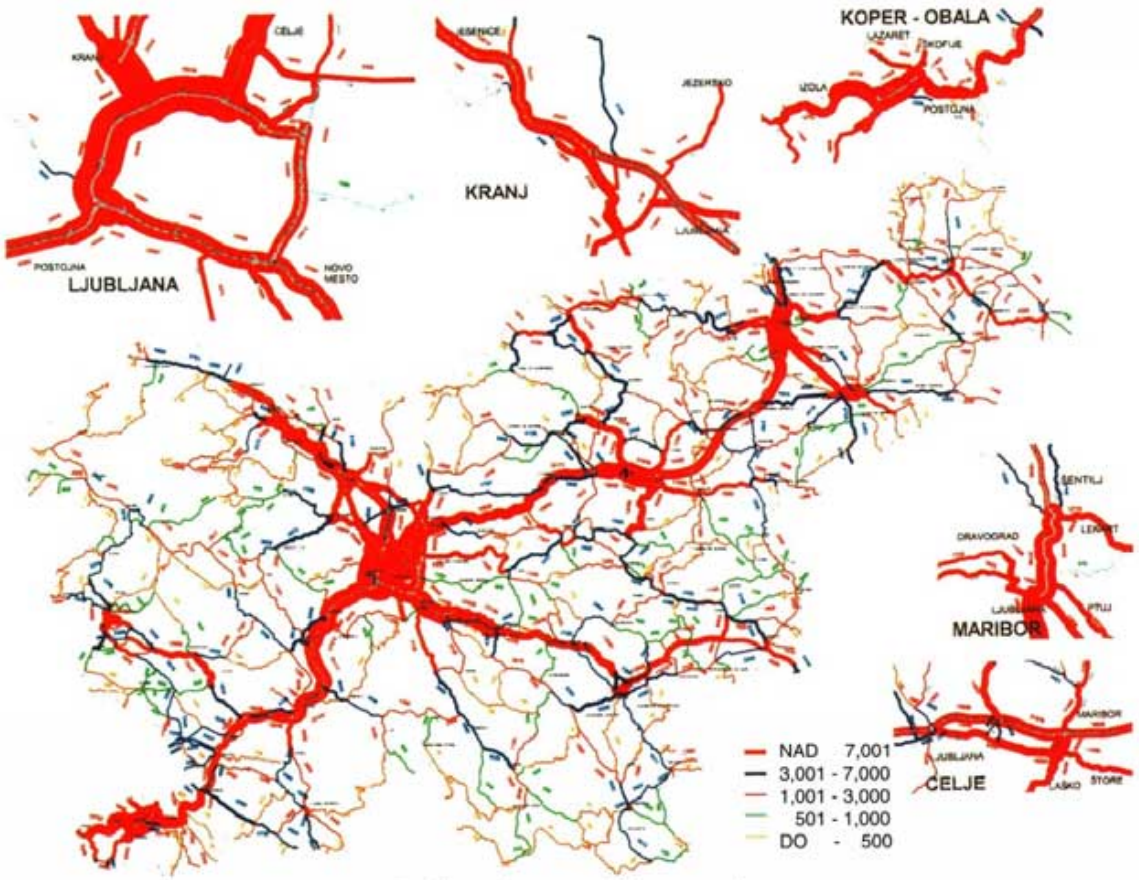
Traffic increase by road category

The highest increase in traffic in 1998 compared to 1990 was recorded on the following road directions:

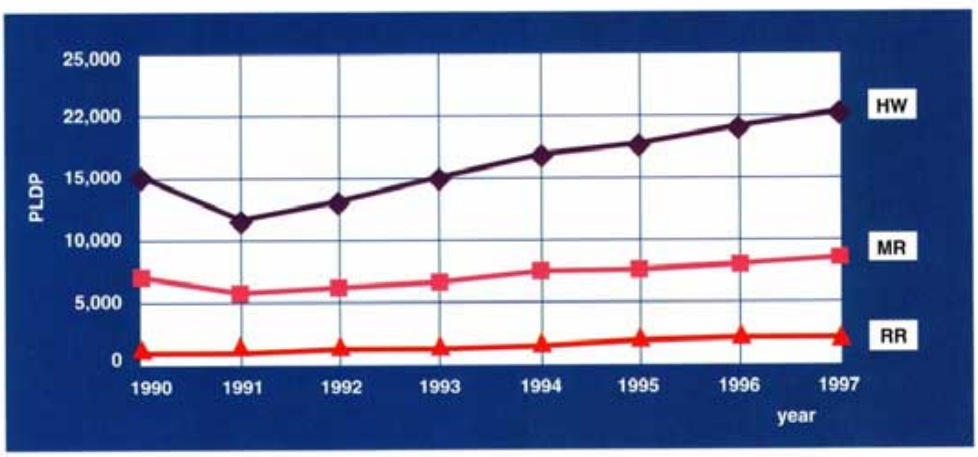
- Šentilj - Ljubljana by 52 %
- Ljubljana - Koper by 48 %
- Karavanke - Ljubljana by 50 %
- Razdrto - Ljubljana by 57 %

A comparison of the results of average annual daily traffic running through international border crossing between the years 1990 and 1998 shows that it was increased on the border with:

- Italy - by 50 %
- Austria - by 51 %
- Hungary - by 300 %



Traffic volumes on highway system



Traffic increase by road category

Categorization of public roads in Republic of Slovenia

Road Category	Length in km
Motorways	249
Expressways	132
Main road, Class I	578
Main road, Class II	444
Regional road, Class I	936
Regional road, Class II	1,128
Regional road, Class III	2,590
Interchanges to public roads	113
Total public roads	6,170

During winter the road companies observe the following six priority groups for road maintenance:

1	**Mortorways and fast roads**	24-hour passability of at least one lane and access to at least the larger parking areas must be ensured
2	**Roads with AIDT (average idle daily traffic) above 4,000 vehicles**	Passability of at least one lane must be ensured between 5 a.m.and 10p.m..Traffic interruption may be possible for up to 2 hours, mainly between 10 p.m. and 5 a.m..
3	**Regional roads, important local roads, main town and village roads**	Passability must be ensured between 5 a.m. and 8p.m.. Interruptions may be possible for up to 2 hours, mainly between 8 p.m. and 5 p.m.
4	**Other local road, town and village roads**	Depending on needs, passability must be ensured between 7 a.m. and 8 p.m. Interruptions may be possible for up to one day.
5	**Publis paths, parking areas, cycle paths**	Depending on local needs Interruptions lasting several days may be possible.
6	**Roads which are closed in winter conditions**	

Consumption of gritting materials

Season	Aodium chloride (tonnes)	Calcium chloride (tonnes)	Gavel (m^3)
1995/96	40,608.98	704.05	56,516.50
1996/97	31,483.83	667.17	48,677.78
1997/98	16,139	424.60	14,829
1998/99	50,000	1,000	55,000

An average of SIT 2 billion is annually allotted to winter services, for the purchase of gravelling materials and for the costs of activities. The consumption of gravelling materials depends on the season.

Winter Service Policy

Winter road maintenance service duration

The winter service is divided into several periods:

- the period of preliminary activities (preparatory works);
- the period of the winter service performance;
- the period of later activities (work after the conclusion of the winter service.)

The period of preliminary activities

This period lasts from 1 October to 15 November.

The preparatory works include:

- elaboration of the winter service implementation programs;
- erection of winter traffic signalling devices and snow fences
- erection of winter posts;
- preparation of depots for gritting materials;
- preparation of winter depots for personnel lodgment;
- preparation of machines and equipment.

The period of the winter service performance

The winter service lasts from 15 November to 15 March.

During this time all winter service activities are performed:

- stand-by (readiness for duty);
- duty service;
- winter road inspection;
- preventive gritting;
- machine gritting of black ice;
- removing of snow from the pavement - machine and manual methods.

The period of later activities

The later activities are performed after the conclusion of the winter service, i.e. from 15 March to 15 April, namely:

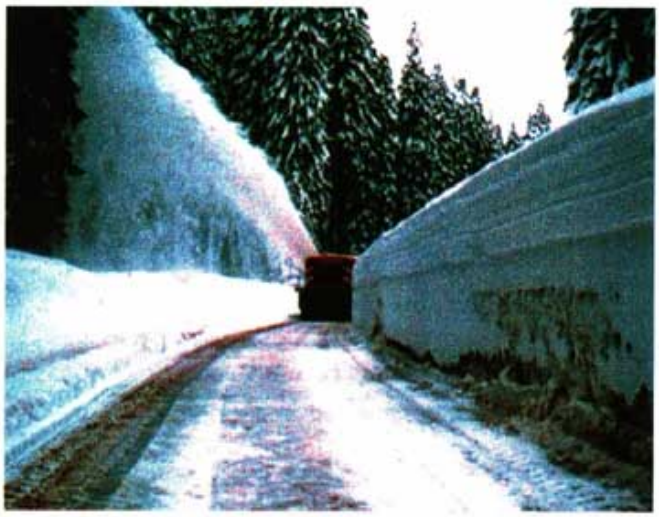
- removing of winter signaling devices and equipment;
- cleaning and putting in order of depots;
- cleaning, repair and storage of winter mechanical equipment.

In times during the winter service period, when no action are necessary, other regular maintenance works shall be performed, such as:

- cleaning of troughs and pits;
- lopping-off, chopping-up, pruning:
- cleaning of drainage systems;
- patching of pot-holes...

Duty service of maintenance units

In order to ensure the rationality of the winter service there are three degrees of stand-by (readiness for duty), which are determined by the duty service of the Directorate of the Republic of Slovenia for Roads on the basis of weather forecast monitoring. In a longer period of fine weather the readiness of a minimum size of the maintenance group is paid, which takes care also for daily gritting of roads. When the winter service works are not necessary due to fine weather, the workers carry out the works according to the annual maintenance plan in their regular working time.



SWEDEN

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Demographics and Roads

Area	Total	410,929 km² Mainly forest
	Snowy and cold regions	Fields 8 %, lakes and rivers 9 %, cities 3 %
Population	Total	8.9 million
Length of road	Total trafficable by car	420,000 km
	Open to the public	210,000 km
	State roads	98,049 km, 46 billion vehicle km
	State cycleways	2,200 km (estimated)
	Municipal roads	39,523 km, 23 billion vehicle km
	Municipal cycleways	11,000 km (estimated)
	Private road (Subsidies)	74,501 km
Latitude (capital)	59°20'N	Sweden covers almost 55-70°N

Climate

All statistical data is calculated from a 30 years period at the Swedish Meteorological and Hydrological Institute (SMHI). (See also Figures 1, 2 and 3)

Through its elongated form in north-southerly the temperature climate in the south differs considerably from that in the northern parts. The Golf 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.

Winter Road Management

Legal obligation

According to the Swedish constitution the Swedish National Road Administration (SNRA) is responsible for the road transports system and must work for attaining the objectives of the transport policy. The SNRA must especially work for securing that the road transport system is available, accessible and effective and that it contributes to the regional balance. The SNRA 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.

	Daily minimum temperature (Celcius). Average 1961-1990							Snowfall in cm during 1961-1990			Precipitation (mm). Average 1961-1990							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mars	April	Daily maximum snowfall	Maximum snow depth	Cumulative depth of snowfall	Oct.	Nov.	Dec.	Jan.	Feb.	Mars	April	Total
Kiruna	- 4.6	-12.2	-16.7	-18.8	-17.6	-13.9	- 8.0	26	132	243	41	37	30	26	22	23	26	488
Luleå	- 0.6	- 8.0	-14.3	-17.0	-16.0	-11.2	- 4.0	30	111	233	51	49	35	31	24	29	29	488
Östersund	1.2	- 4.9	- 9.6	-12.8	-11.6	- 7.7	- 2.7	31	100	251	46	43	45	36	28	30	32	563
Stockholm	5.3	0.7	- 3.2	- 5.0	- 5.3	- 2.7	1.1	27	60	153	49	52	42	33	24	25	30	514
Göteborg	6.5	2.1	- 1.4	- 3.2	- 3.5	- 1.0	2.4	28	52	131	87	87	85	68	41	54	42	791
Jönköping	3.1	-1.2	- 5.1	- 6.6	- 7.3	- 4.6	- 1.1	27	102	225	63	66	53	48	31	38	37	641
Malmö	6.7	2.8	- 0.8	- 2.5	- 2.5	- 0.5	2.4	26	38	113	57	61	60	50	31	40	38	603

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Figure 1
Average January temperature 1961 – 1990

Figure 2
Maximum snow depth during the winter. Average value 1961 - 1990

Figure 3
Winter climatic zones

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. OPERATION 96.

Snow-free and skid free roads are divided into four standard categories, A1 - A4, where A1 has the highest level of service. Snow-covered roads are divided into two standard categories, B1 - B2. Also pedestrian and cycle paths are divided into standard categories, C1 - C3.

The choice of standard categories for a certain road network is done according to the following recommendations given in the technical description:

	Road category	
Traffic flow, AADT	**National road network**	**Regional and local road network**
≥16,000	A1	A2
8,000 - 15,999	A2	A3
2,000 - 7,999	A3 or B1	A3 or B1
500 - 1,999	B1 or A4	B1 or A4
< 500	B1	B2

Snow-free and skid-free roads

For the lower standard classes more snow and longer treatment times are accepted. The temperature limit (-8, -8, -6 resp. -3°C) above which the road surface must be free from snow and ice is also higher. For all classes the traffic lanes shall be free from ice and snow in fair weather during other

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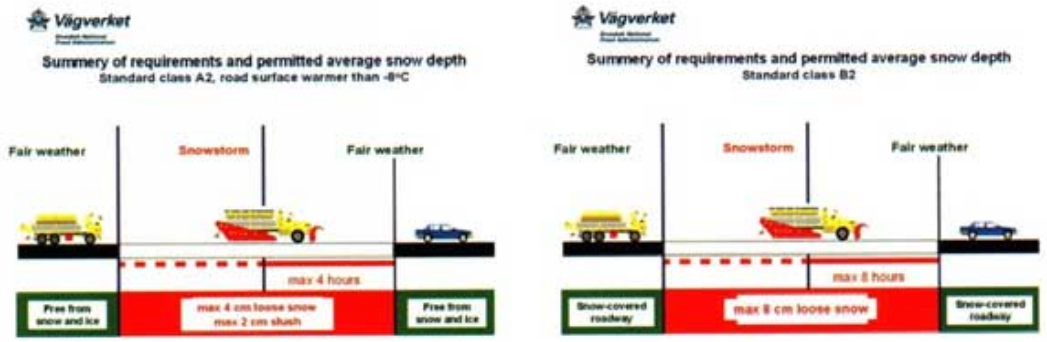

Figure 4

times than given in the table. When colder than temperature mentioned in the table to always have satisfactory friction, it should be even and free from loose snow. (See also Figure 4).

Type of requirement	Category			
Traffic lanes	A1	A2	A3	A4
Max. snow depth, cm loose snow	2	4	6	6
Max. snow depth, cm slush	1	2	3	3
Free from ice and snow within __ hours after snowfall.	2	4	6	6
Road surface temperature above which the road surface has to be snow and ice free, °C	-8	-8	-6	-3
Max. time with slippery conditions after rain when warmer than temperature limit given above.	1	2	3	3
Satisfactory friction after rain within __ hours if colder than temperature limit given above.	2	4	6	6
Max time (days) going from snow-covered to snow- and ice-free road surface when temperature changes from colder to warmer than limit temperature.	1	1	2	4

Snow-covered roads and cycleways

For snow-covered roads (B-classes) and cycleways (C-classes) the requirements are similar to those above except that snow and ice is accepted at all times as long as the friction is satisfactory. There is also a limit for maximum allowed snow depth during snow-fall (table below).

Type of requirement	Category				
Traffic lanes	B1	B2	C1	C2	C3
Max snow depth, cm loose snow	6	8	4	6	8
Max snow depth, cm slush	3	4	2	3	4
Max 2 cm loose snow within __ hours after snow-fall.	6	8	4	6	8
Satisfactory friction within __ hours after rain.	6	8 (not very slippery)	2	3	4

Both B and C-classes shall have less than 2 cm loose snow be even and have satisfactory friction in fair weather in other times than in the table above.

Definitions

In the table below are given the threshold values for defining satisfactory friction, slippery and very slippery conditions.

Friction class	Friction coefficient*
Satisfactory friction	$\mu \geq 0.25$
Slippery	$\mu < 0.25$
Very slippery	$\mu \leq 0.15$

*The friction coefficient is determined according to the SNRA method description 104:1990. For the friction measurements a SAAB Friction Tester, BV 11 or BV 14 should be used. Retardation measurements can also be used (SNRA method description 110:1996).

A surface is considered even if ruts or any other unevenness that has developed in thick ice or packed snow does not exceed 2 cm measured with a 60-cm long straightedge placed across the unevenness.

De-icing/Anti-icing

Materials

NaCl (rock salt) is the only salt used for de-icing/anti-icing. The NaCl should be 98 % pure and must not contain more than 100 g of Potassium or Sodium Ferrocyanide per tonne NaCl. A gradation curve is specified and the maximum allowed grain size is about 3 - 4 mm. The consumption on state roads during the last years is shown in Figure 5.

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.

Reduced use of salt

The SNRA is working for a reduced use of salt. Some examples of this are given below:

- Roads with less than 2000 AADT should not be treated with salt, except during autumn and spring.

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- Increased use of brine, especially for preventive actions.
- Improved weather forecasts.
- Improved equipment for snow removal and ice control.

Winter Indices

During recent years an experimental work has begun calculating a number of winter indices starting from these weather situations. Mean values are calculated for each month and for each county. Representative RWIS stations are chosen for each county and values for SNRA region are given in the figure.

- The Weather Indices describes the number of occasions with slipperiness, snow and snow drift, respectively (Figure 6).
- 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 SNRA Road Sector Training and Development Centre.

Organisation

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 SNRA. 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 SNRA was to be divided into a client / contractor organisation. In addition, it was stipulated that the contracting arm of the

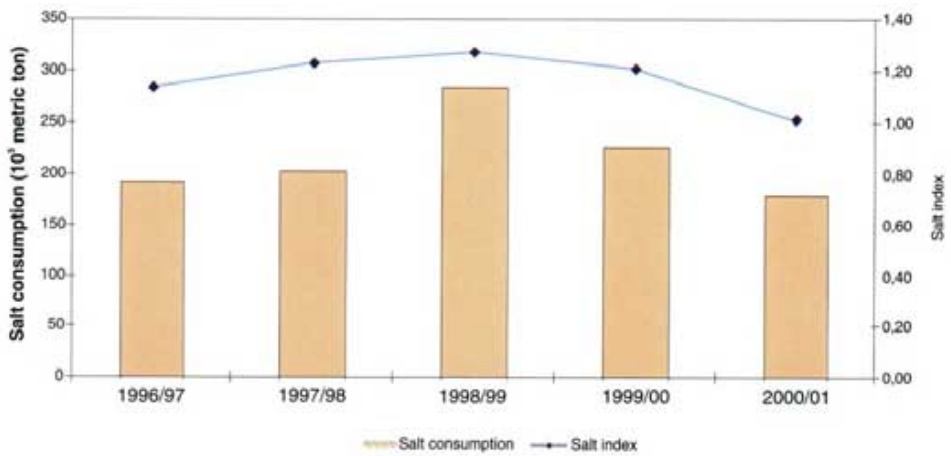

Figure 5 Salt consumption and index. (Source: SNRA).

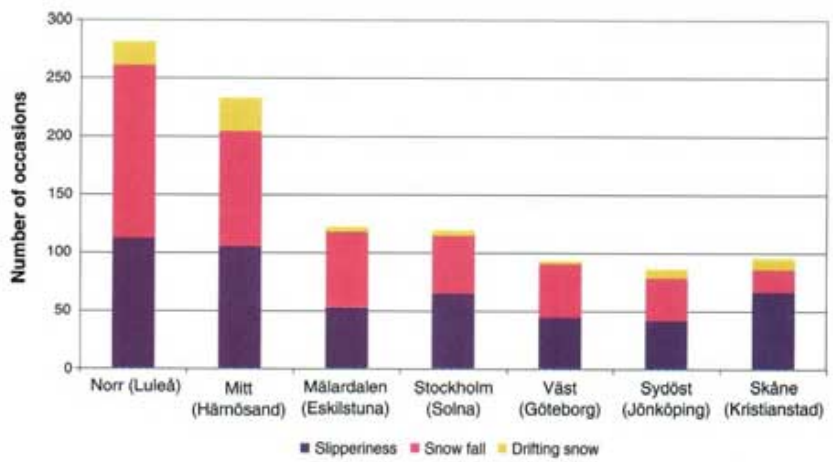

Figure 6 The weather index for the winter season 2000/01 calculated for the seven regional road management areas of the SNRA (see Figure 7 below). The weather indices describes the number of occasions with slipperiness, snow and snow drift, respectively.

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Figure 7
The seven regional road management directorates/areas of the SNRA.
The head office of the SNRA is in Borlänge. (Source: SNRA)

organisation 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.

The SNRA today has one head office, seven regional road management directorates and four profit centres (Figure 7). The regional directorates are responsible for the SNRA's regional road management and for purchasing the maintenance. The SNRA Construction and Maintenance today has about 70 % of all the maintenance contract areas. The other areas have gone to private contractors.

Forms of payment

Two forms of payment are used at present: current accounts and unit-price payment based on weather data statistics. There are advantages and disadvantages to both. In order to reduce salt consumption there is a bonus and fine system.

Finance

Twenty-five percent of the SNRA appropriation for road maintenance and operations, a total of almost SEK 1.5 billion (US$ 150 millions), is spent on snow ploughing, 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. All in all, there are about 2,500 contracted pieces of equipment, mostly trucks, but also road graders, snow blowers and tractors that are part of the winter maintenance organisation. In addition to this, there are several less extensive work units for the maintenance of pedestrian and cycle paths.

There are 146 maintenance contract areas, covering the state roads, in Sweden. The maintenance contract areas comprise between 600 and 1,000 kilometres of road, centreline.

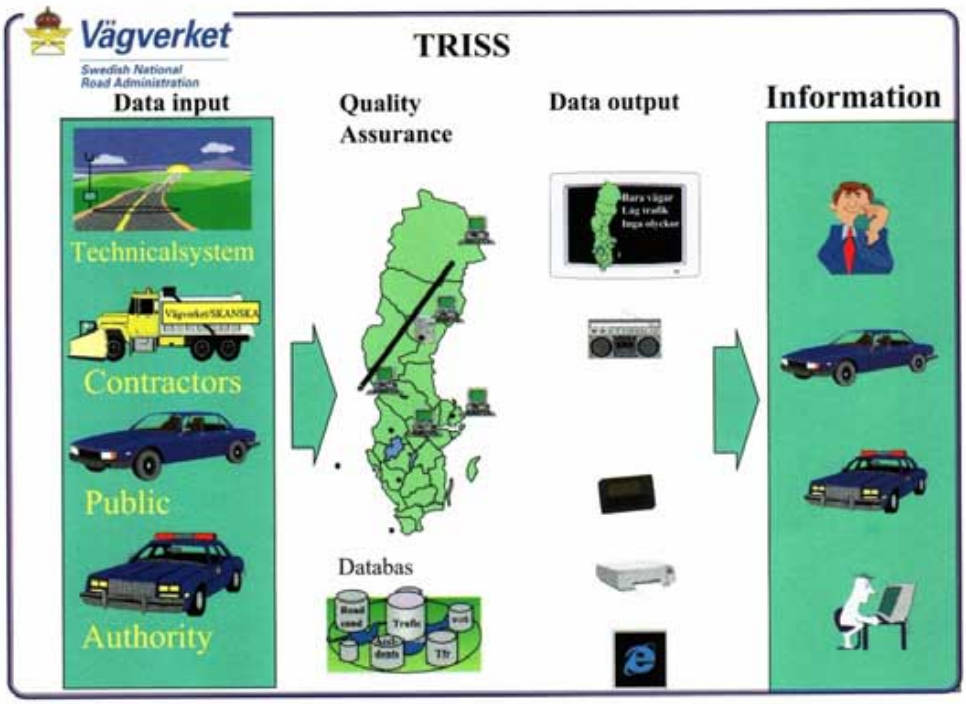

Figure 8 Wether infomation provision

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This size has proven sufficient to be financially viable for contractors.

Weather information provision

RWIS Field Stations

Sweden has in year 2001 about 680 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. Due 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 centre at the head quarters of SNRA and can then be obtained via Internet. See also Figure 8.

Measurements of efficiency

Internal

- Both the SNRA and the municipalities follow up the consumption of salt and abrasives.
- The SNRA calculates a salt index for each of its regions and for the whole country (the state roads)

External

* The road user's satisfaction with winter maintenance is surveyed by the SNRA every year. The road users are divided into two categories: private and professional drivers.

Information to Road Users

All operation centres have to report at least 3 times a day to the TIC (Traffic Information Centre) 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 SNRA
* Road users can also call the TIC to get information.

In some places there are traffic signs showing road surface temperature and air temperature.

Tyres

Since 1999 passenger cars, lorries and buses with a total weight up to 3,5 tonnes shall have winter tyres or equal equipment during the period December 1 - March 31 if winter road condition (slippery). It is allowed to use studded tyres October 1 - April 30. The fine for not using winter tyres when you should is SEK 800 (US$ 80) and for using studded tyres when it is not allowed is SEK 400 (US$ 40).

The use of different tyres in northern Sweden is almost the same after the regulation 1999 as it was before because almost all passenger cars had studded tyres already. In southern Sweden almost 50 % of the passenger cars previous had summer tyres during the whole winter. After the regulation this number has decreased to 8 % and 37 % now has studded tyres and 55 % other winter tyres.

Effects of Winter Road Maintenance

Road condition

A normal winter (93/94) the state roads, in different winter maintenance classes and in different climatic zones (Figure 3), have the percent of bare road condition shown in the table to below.

Climatic zone	Maintenance class					
	A1	A2	A3	A4	B1	B2
South	96%	94%	89%	82%	59%	58%
Central	97%	95%	89%	80%	69%	58%
Lower North	No road	86%	79%	64%	58%	49%
Upper North	No road	77%	54%	No road	28%	22%

Traffic speed and volume

The traffic volume during the six winter months is about 42% of the year round traffic volume.

Winter speeds vary widely, but can be estimated for passenger cars as 75 - 90 % of those on bare roads. For constant stopping distance, speed should be halved. Speed reduction is determined more by the appearance of the road than by the actual friction/road traction. Friction is the primary road variable with regard to safety.

Compared to the speed on dry bare roads the car speed reduction on moist and wet bare surface is about 1 km/h. Average speed reduction on different road conditions vary between 5 and 10 km/h with the highest speed reduction on slush. Precipitation entails greater reduction than slippery road surface alone.

Traffic safety

The temporal variation of the traffic safety situation can be exemplified by the variation during the year of the weekly

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accident rate, the number of accidents per one million vehicle km (Figure 10), and the number of injured per accidents (Figure 11). Normally, the accident rate is highest during the winter period while the number of injured per accident is highest during the summer. The injury rate, the number of injured per one million vehicle km is highest during the winter and summer period (Figure 12). The latter relationship is however a relatively weak one and is affected by the road condition situation in the winter period during the first and last months of the year. The effect of different road conditions can easily be seen in the example from Central Sweden (Figure 13). The accident rate on bare road conditions (dry and moist/wet) is higher on the roads with lower standard than on those with higher standard, while the opposite counts for slippery conditions. On roads with winter maintenance standard A1 black ice occurs very seldom, but as can be seen in the figure (Figure 13), the accident rate is more than hundred times higher than on bare road conditions. On B-standard roads black ice "only" has about 5 times higher accident rate but the condition can last for a quite long time.

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 metres 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 tyres. The fear about wear-particles has increased the last decade.

Corrosion

Statistics show that notations of rust damage that caused cars to fail inspection were 2-4 more often in areas where salt is used than not used. Experts estimate that the lifetime of cars would increase by 25 % if roads were not salted. Even if the car body corrosion will decrease even in salted areas because of countermeasures costs will continue to be high as a result of corrosion to electronic equipment.

Figure 9 The most common road condition in the winter is bare road

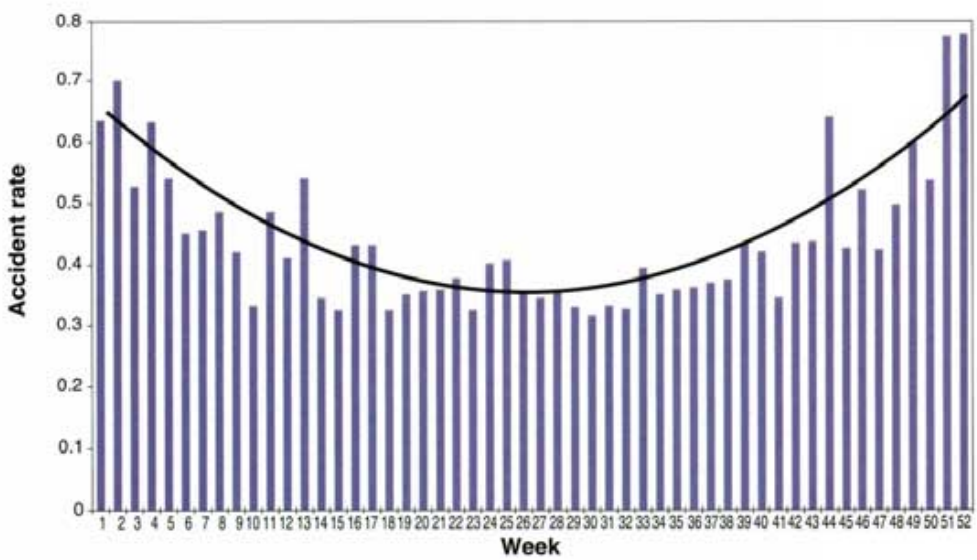

Figure 10 Accident rate per week during 1995 on the national road network. (VTI-report 435A)

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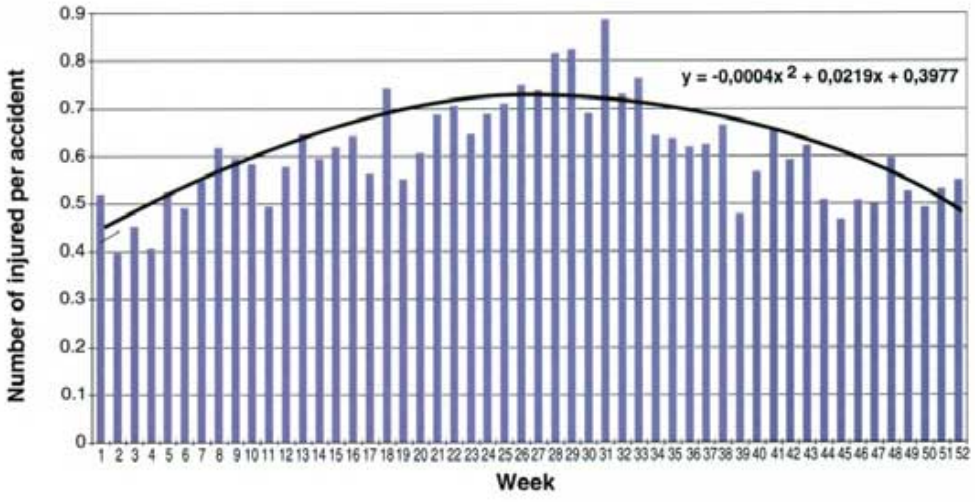

Figure 11 Number of injured per accident, per week, in 1995 on the national road network (VTI-report 435A)

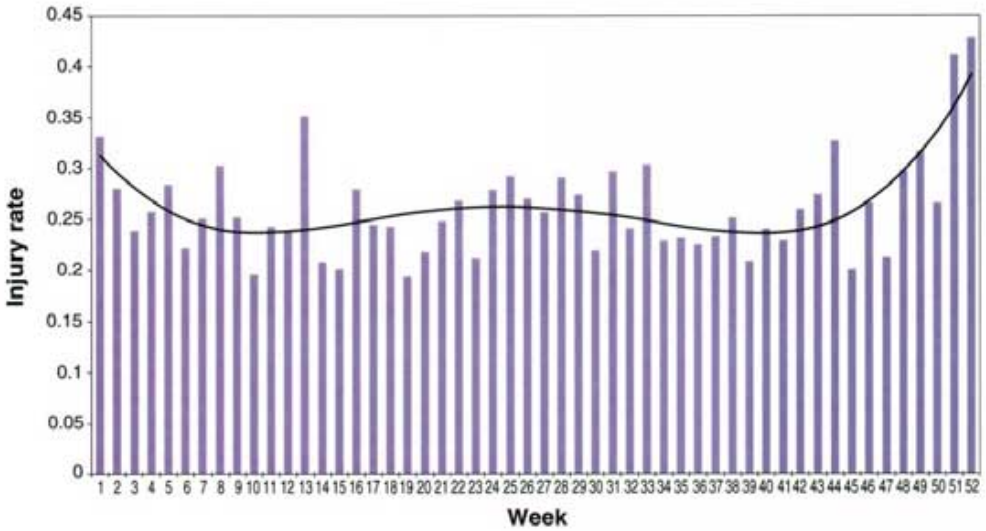

Figure 12 Injury rate per week in 1995 on the national road network. (VTI-report 435A)

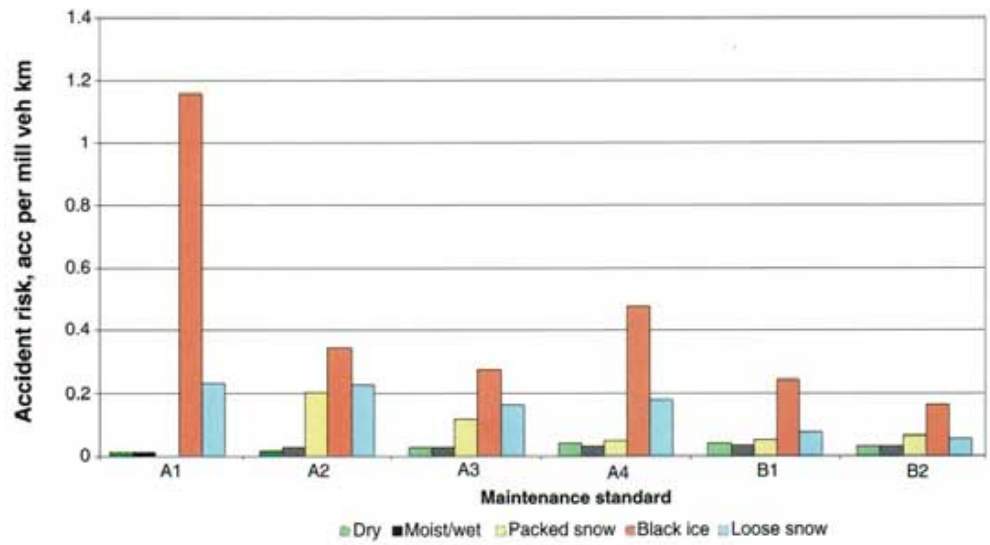

Figure 13 Accident rate at different winter maintenance standard and road contions in central Sweden (VTI-Notat 60-2001)

SWITZERLAND

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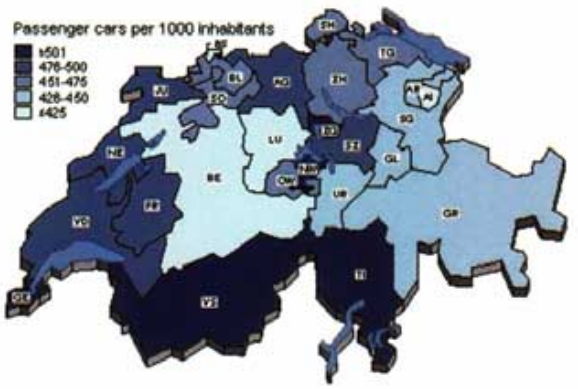
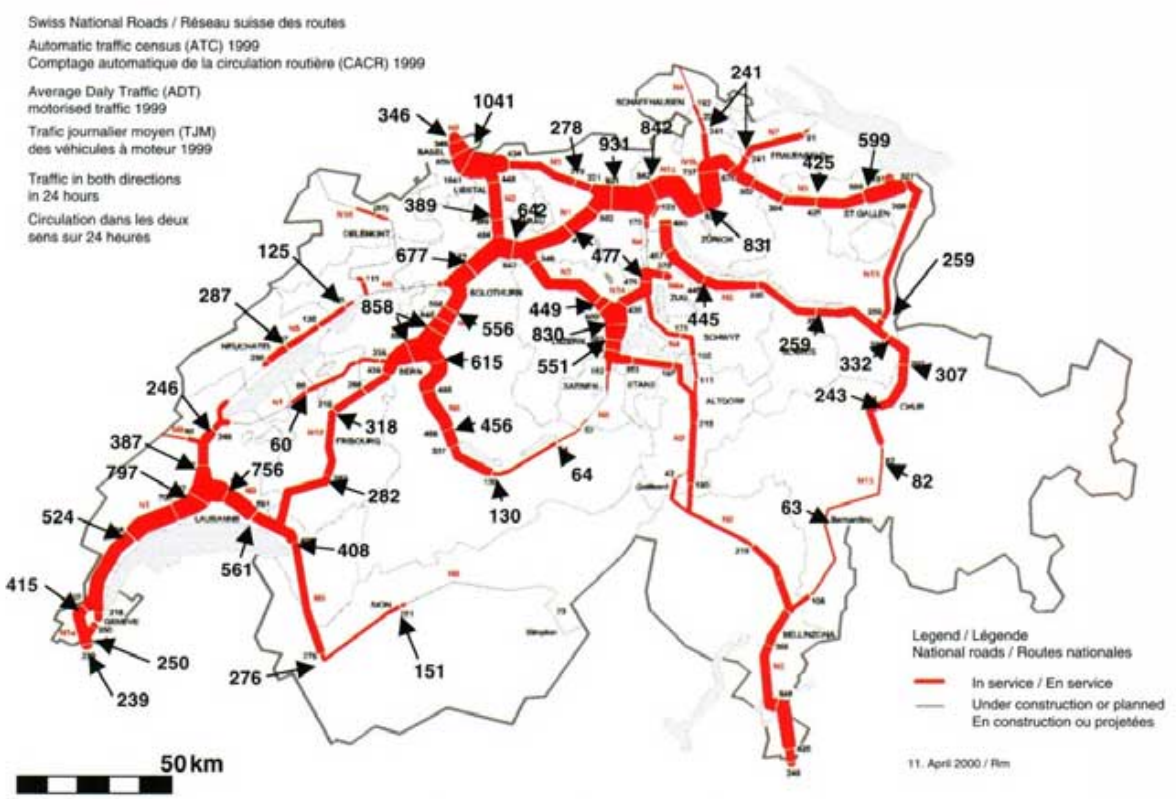
Demographics and Roads

Area	41,284 km²	
Latitude	45°50' N to 47°50' N	
Population	7.097 million	
Population density	172 / km²	
Length of road	Total	71,000 km
	National roads	1,710 km
	Cantonal roads	18,190 km
	Communal roads	51,100 km
Number of passenger cars (2000)		3,545,247
Number of utility vehicle (2000)		278,546



Traffic Volumes (Average Daily Traffic, ADT)



The numbers in the map indicate the ADT in hundreds (example: 120 = 12,000)

Climate

Switzerland have a climate influence by the alitude (above sea level).

Switzerland is divided in 4 climatic regions (see Figure) with the following characteristics:

Jura

High-precipitation with frequent strong winds. Raw winter climate.

Precipitation averages between 120 and 180 cm on 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 widespread driven snow.

Midlands

Well-balanced precipitation distribution. Great variation of snow quantity from winter to winter. In winter fog is a frequent phenomena.

Precipitation averages between 90 and 140 cm on 120 to 140 precipitation-days a year. Strong winds reach peak speeds up to 170 km/h.

Alps

Pre-Alps are generally rich in precipitation.

Precipitation averages between 140 and 200 cm on 140 to 160 precipitation-days a year. Strong winds with peak speed up to 270 km/h are possible in valleys. Foenstorms (hot and dry winds) are frequent in N-S oriented valleys.

South of the alps

High yearly precipitation up to 220 cm as a result of rain accumulation at the south side of the Alps in springtime and autumn. Wind-speeds up to 120 km/h.

A summary of the different Swiss climatic regions and their winter characteristics.

	Temperature		Precipitation					
Climate	number of days below 0° C air temperature	number of ice days (air temp. stays below 0°C)	number of days with rain	amount of rain (cm/year)	number of days with		max. precipitation of snow (cm/day)	amount of snow (cm/year)
					snow fall	snow cover		
Jura	121	30	157	140.6	64	123	55	317
Midlands	96	22	126	104.2	30	51	22	53
Alps	140	42	138	148.7	59	132	50-90	433
South of the Alps	45	4	107	184.8	14	19	63	43
Duration	1961 - 1990				1981 - 2000			

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Principal Policies Snow and Ice Management

Standards

The official road standards comprise 18 documents on winter maintenance. Besides these standards, the Federal Road Authority issued a directive describing the special requirements for National Roads.

Road classes

For snow removal and ice control, the following classes have been defined:

- Motorways, Highways
- Main traffic arteries, steep roads
- Roads used by public transport
- Roads leading to railway stations, hospitals, police stations, fire departments, industrial plants
- Public transport stations
- Important pedestrian and bicycle paths, stairs

Service levels

All road stretches are classified in one of the following service levels:

- Level A: black roads, complete snow removal and ice control
- Level B: avoid slipperiness on the runways, medium-term black roads
- Level C: practicable roads without the use of de-icers, white roads
- Level D: no winter maintenance

Priority levels

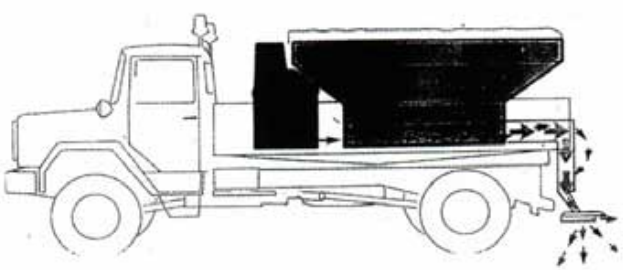
- Level 1: First passage of snow removal completed 3 hrs after mobilisation (2 hrs on motorways). First passage of spreading completed 2 hrs after mobilisation.
- Level 2: First passage of snow removal completed 4 hrs after mobilisation. First passage of spreading completed 3 hrs after mobilisation.
- Level 3: First passage of snow removal completed 5 hrs after mobilisation. First passage of spreading completed 4 hrs after mobilisation.

All road authorities are obliged to have route maps, where road classes, service levels and priority levels are indicated.

Winter maintenance and organisation

In general, the cantonal and communal maintenance centres are in charge of winter maintenance.

However private companies are frequently given contracts



Vehicle and spreader for wet salt technology

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.

The order for action is in most cases given by the maintenance centre.

Every maintenance centre has a stand-by organisation during the whole year. Every employee is obliged to work temporarily as stand-by.

Equipment

There are great differences between the road classes.

The national roads are covered by 45 maintenance centres. The average length of highways per centre is defined by the obligation to do the first round of winter maintenance within 2 hours.

The equipment includes: 2 ~ 3 lorries per direction, equipped with ploughs, width 3.5 ~ 6.0 m.

demountable spreaders, 4 ~ 6 m^3 for salt and 2 m^3 brine. 1 person per lorry. On mountainous stretches and on stretches where the snow can not be removed to the side, snow blowers are necessary to load the snow on lorries.

Salt is always stored under roof, either in barns (up to 4,000 tons) or in silos (200 tons 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 good disposition of the silos, 2 ~ 3 spreaders can be loaded at the same time.

Automatic de-icer spraying installations are in operation on specific stretches with a particular micro climate or which are particularly exposed. Two Installations are on high bridges, 1 installation (length 6 km) on a stretch with heavy traffic (80,000 vehicles per day) and particular micro climate.

Road heating is not used. There is however one exception. On a particularly exposed bridge a solar energy pilot application is in operation since 1995.

A heat exchange tube system embedded in the asphalt layer of a bridge, covering a surface of 1300 m^2, collects heat during summer and utilises it during frost periods in winter, to heat the bridge surface, thus preventing the formation of ice. The liquid is stored in an underground heat store.

Materials

Salt consumption varies and depends on the winter intensity. The average consumption on highways is 600 grams per m^2 a year. The dosage of de-icing agents and abrasives is defined in the standard.

Certain surface conditions may require a higher salt dosage. The use of the wet salt technique (salt and brine are mixed on the spinner of the spreader) is progressing. In 2000 this technique is used by 85 % of all highway maintenance centres.

For high road levels, a preventive salting (10-20 g/m^2) is done under certain weather conditions such as: forecast of snow or freezing rain, road surface temperature below 0 °C. Abrasives are mainly used on mountain roads and in winter sport resorts (white roads). In urban areas, abrasives are also used on pedestrian paths.

Spreading	Temperatures °C	
	0°C to -8°C	-8°C to -20°C
	g / m^2	g / m^2
dry salt	7 — 15	10 — 20
pre wetted salt (wet salt technique)	7 — 15	10 — 20
brine in automatic spraying installation	5 — 10	5 — 10
abrasives	≤ 200	≤ 200
mixing ratio	only NaCl	2/3 NaCl 1/3 $CaCl_2$

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 phenomena regularly occurs.

In some winters avalanches cause a severe problem for the road authorities. In all mountainous regions, a special avalanche task force is organised.

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. On some locations, automatic warning devices are installed.

Measurements of efficiency

All the maintenance centres for national roads and some for communal roads have a cost accounting system. Therefore the total cost of winter maintenance, as well as the cost factors personnel, vehicles/engines, material etc. are exactly known.

Based on this cost accounting efficiency measurements are made after every winter.

A system for road maintenance quality assurance is actually in the preparatory stage.

Meteorological Information

MeteoSwiss provides information for winter maintenance on several levels:

- A general road weather forecast, available to the general public on internet and radio. Free of charge.

- A 24 hrs specially designed road weather forecast for maintenance centres. This forecast is done separately for over 20 areas with different local climates. The information is distributed by phone lines and computer network and arrives directly on the RWIS-computer in the maintenance centre. The contract is established between MeteoSwiss and the maintenance centre. The accuracy lies between 86 % and 89 %.

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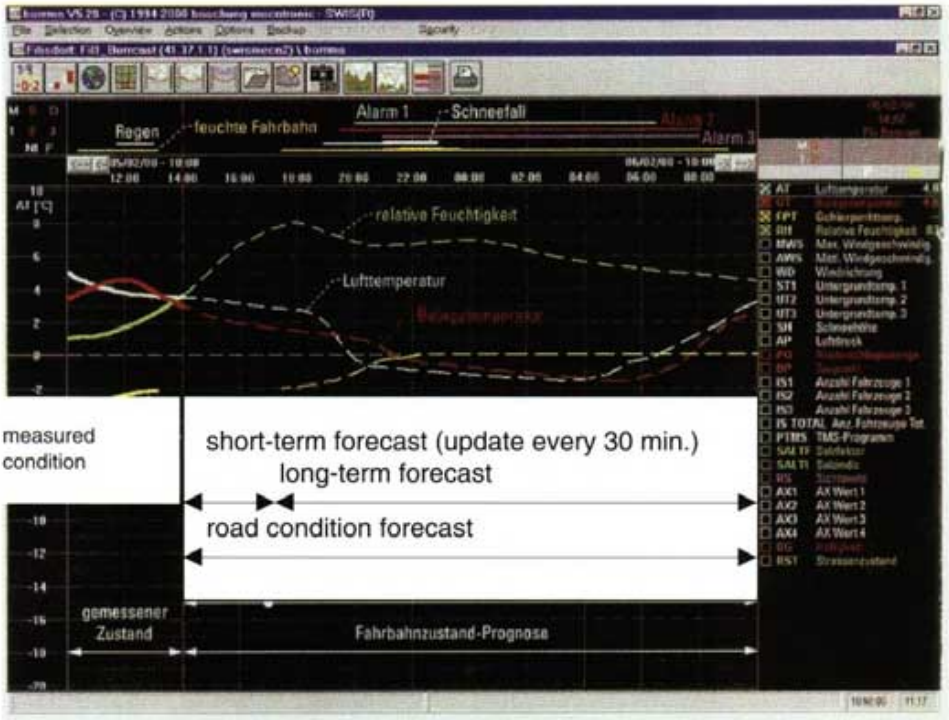


- Weather warnings are issued for special occurrences or situations, general or local, which have not been announced in the general weather forecast. They are delivered directly on the RWIS-computer in the maintenance centre and actuate a warning signal. Free of charge.

The MeteoSwiss road weather forecasts rely on a network of automatic weather stations (ANETZ) and several forecast models. A verification is usually made with selected road sensors.

RWIS-system

All maintenance centres for the national roads and some of the larger communes dispose of a RWIS-system. The system combines measurements and warnings from road sensors and road weather stations and the local road weather forecast issued by MeteoSwiss.

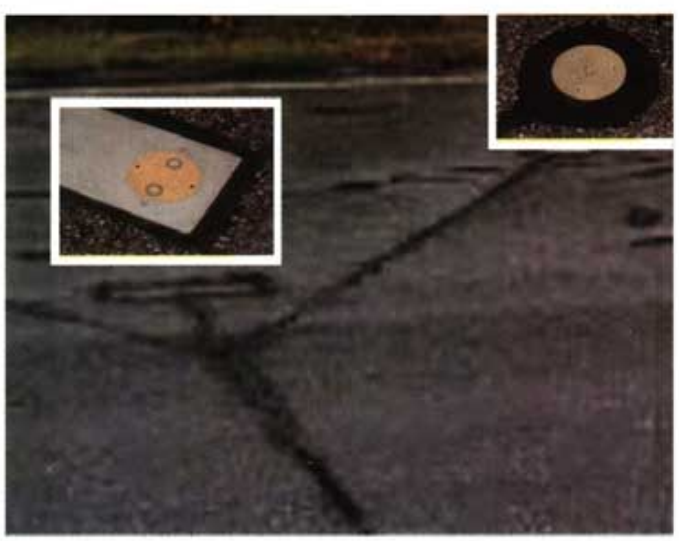
Road sensors and road weather stations generally provide the following parameters: air temperature 2 m above ground, surface temperature, humidity, dew point, freezing temperature, precipitation, wind: direction and intensity, state of the road: dry or wet, residual salt (when wet).

The RWIS local weather forecast is issued every day at 15 hrs and covers 24 hrs. It provides: air temperature 2 m and 5 cm above ground, humidity and dew point, precipitation: type and quantity, limit of snowfall, wind: direction and intensity, sky covering, state of road surface.

The forecast is updated, if a change occurs within 24 hrs.

Ice detection system

The national road network is equipped with an ice detection system. A total of ca. 400 road sensors are installed, which measure the surface temperature and the freezing point by



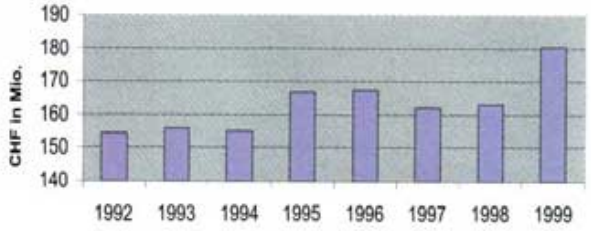
cooling down the sensor surface. The medium distance between road sensors is approximately 6 km.

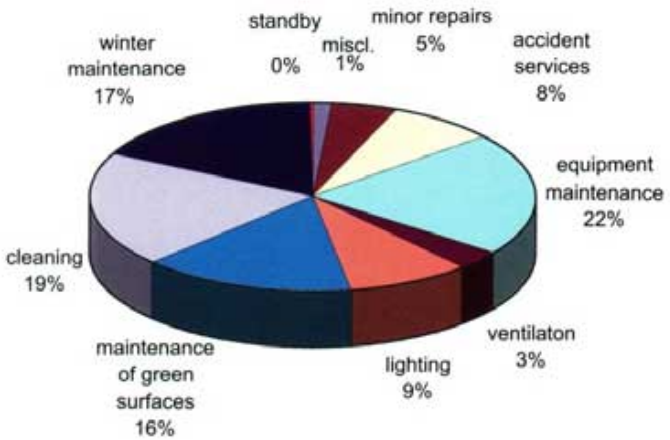
The most widespread system is the Boschung system. In a few cases, the Vaisala system is installed. The road sensors are generally combined with roadside measuring stations.

The location of the sensors was determined by experience. Usually the most dangerous spots were chosen. Additional locations are on bridges, on particularly exposed and on shady stretches.

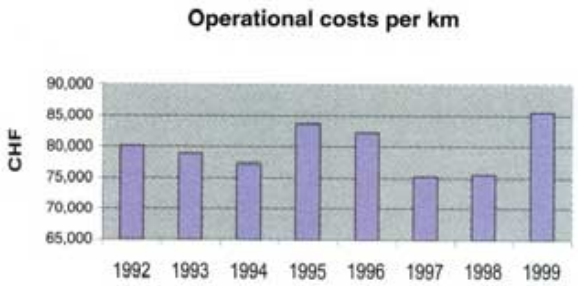
Costs

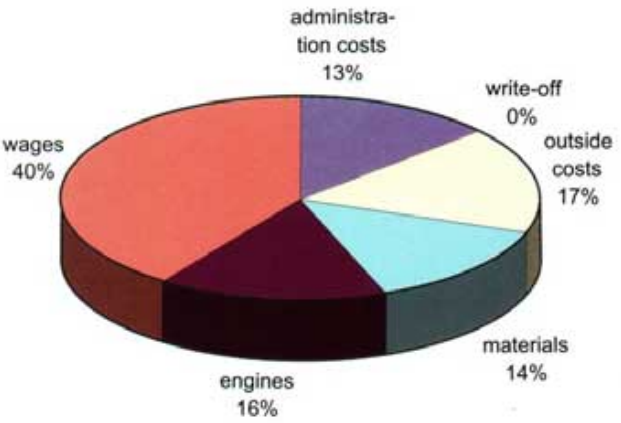
Operational costs – National roads open stretches and tunnels



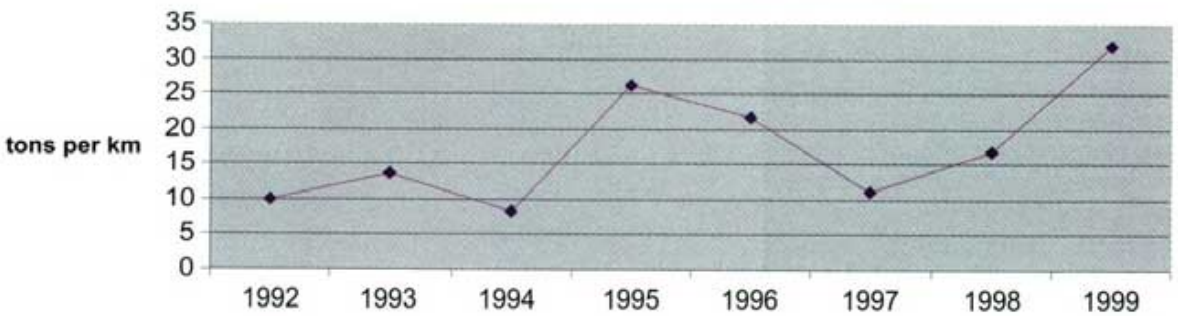


Operational costs – National roads open stretches





Salt consumption – National roads open stretches



Federal Highway Administration, Road Weather Management Program HOTO-1
400 Seventh St. SW, Washington, DC 20590 USA, Tel: +1-202-366-1301 Fax: +1-202-366-3225

Demographics and Roads

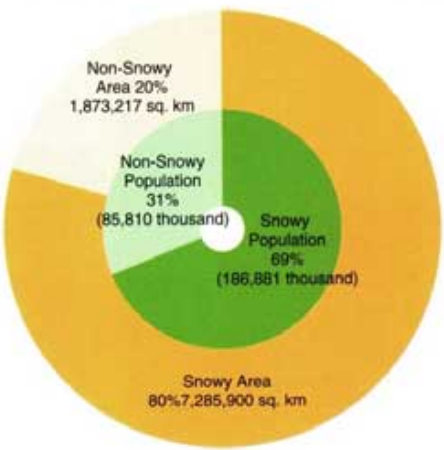
Area	Total	9,159,117 km²
	Snowy regions*	7,285,900 km²
Population	Total	272.691 million
	Snowy regions*	186.881 million
Length of road	National Highway System	255,910 km
		Snowy regions 190,491 km
	Other federal-aid roads	1,280,428 km
		Snowy regions 929,506 km
	Non federal-aid roads	4,816,523 km
		Snowy regions 3,615,668 km
Latitude (capital)		39°N

*defined as >13 cm average annual snowfall

Near Denver, Colorado: Snow storm on the eastern slope of the Rocky Mountains

Area of U.S. with >13 cm annual snowfall

Population and area of snowy regions



Climate

Selected U.S. cities (see map)

	Daily min. temperature [°C]				Snowfall (5-year average) [cm]			Precipitation (5-year average) [mm]				
	Dec.	Jan.	Feb.	Mar.	Daily Maximum Snowfall	Maximum Snow Depth	Cumulative Depth of Snowfall	Dec.	Jan.	Feb.	Mar.	Total
New York City	-0.7	-3.7	-2.8	1.6	67	77	62	99	87	83	104	1,200
Buffalo, New York	-5.1	-8.3	-8.1	-3.4	64	174	236	93	69	59	68	980
Washington, DC	-0.2	-2.9	-1.6	3.2	47	78	42	79	69	69	81	981
Chicago, Illinois	-7.2	-10.6	-8.2	-1.9	46	90	99	63	39	35	68	910
Minneapolis, Minnesota	-12.1	-16.2	-12.7	-5.2	53	119	146	27	24	22	49	719
St. Louis, Missouri	-3.3	-6.2	-3.8	1.9	35	67	57	77	46	54	91	953
Denver, Colorado	-8.1	-8.8	-6.6	-3.4	60	99	158	16	13	14	33	391
Boise, Idaho	-5.3	-5.8	-2.5	-0.1	33	67	52	35	37	27	33	308
Seattle, Washington	2.1	1.8	3.0	3.6	54	145	30	150	137	101	90	945
Anchorage, Alaska	-12.5	-13.3	-11.5	-8.2	40	119	182	28	19	21	15	399

Policy of Snow and Ice Management in the United States

The United States is a federal system of the national, state and local governments. The Federal Highway Administration (FHWA), within the national executive branch, neither operates nor builds highways, but administers $21 billion per year* of federal-aid highway funds to states and localities, primarily for capital expenditures. The total expenditure for highways is $102 billion per year, mostly funded by state and local governments. State and local capital expenditures are $48 billion; maintenance and services are $27 billion, of which costs for winter road maintenance are $2 billion per year.

Because of the allocation of maintenance to state and local governments, there is no uniform policy for winter road maintenance in the U.S. States and local governments may operate their own maintenance equipment or hire contract services, and they establish their own Level of Service (LOS) goals. Higher classes of highways generally receive more attention. Routes on the National Highway System, a 256,000 km network, mostly of interstate expressways and primary roads, will be cleared more completely and quickly. Critical areas like mountain passes will have snow-chain requirements for vehicles, and many local streets are "snow emergency routes" that must be cleared of parked cars.

Parking lot and sidewalk snow removal is mostly the responsibility of property owners. The most common treatment is snow removal by plowing, with chemical and grit application. However, anti-icing strategies prior to plowing are used increasingly.

*All expenses from Highway Statistics, FHWA, 1998.

Winter Maintenance Improvement Programs

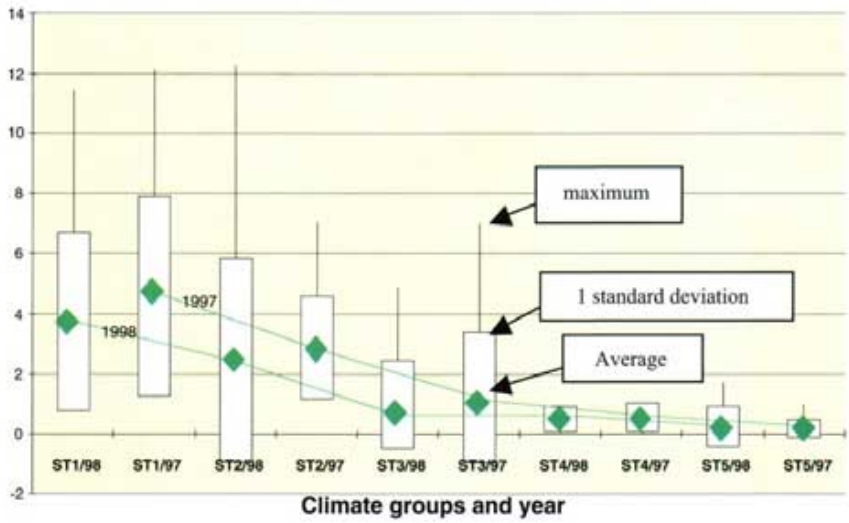
The state and local governments fund and perform snow removal and ice control, so improvements primarily have been a state and local effort. The states coordinate through the American Association of State Highway and Transportation Officials (AASHTO) that operates the Snow and Ice Cooperative Program (SICOP) for research and training. The FHWA has funded and initiated research in ice control and snow removal techniques for many years. 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 works with the Office of the Federal Coordinator for Meteorology (OFCM) in projects that involve other federal agencies, especially the National Weather Service (NWS). The Program mobilizes partnerships of highway operators, federal laboratories that perform meteorological research, university researchers, and private sector vendors of services and equipment. The Program's goals are to develop:

a) Improved road weather information systems that meet the demands of all users and operators;
b) Improved maintenance technologies for winter mobility; and,
c) Traffic operations/incident management procedures under all weather events.

The Program has a five-year target of ten comprehensive, statewide, road weather information systems, five of these using Intelligent Transportation System (ITS) standards, and three of these using advanced decision support technologies developed under the Program.

Winter maintenance costs ($1,000/mile), States 1998 and 1997



This figure shows the variation in winter maintenance expenditure, per route mile, between the years 1997 and 1998 and between climatic groups of states. The state climatic groups (ST1-5) start with more average snowfall on the left. The variation between years (e.g., ST1/98 and ST1/97) shows the effect of varying annual snowfall. The variation by year and among states in one group reflects important budgeting uncertainties.

UNITED STATES

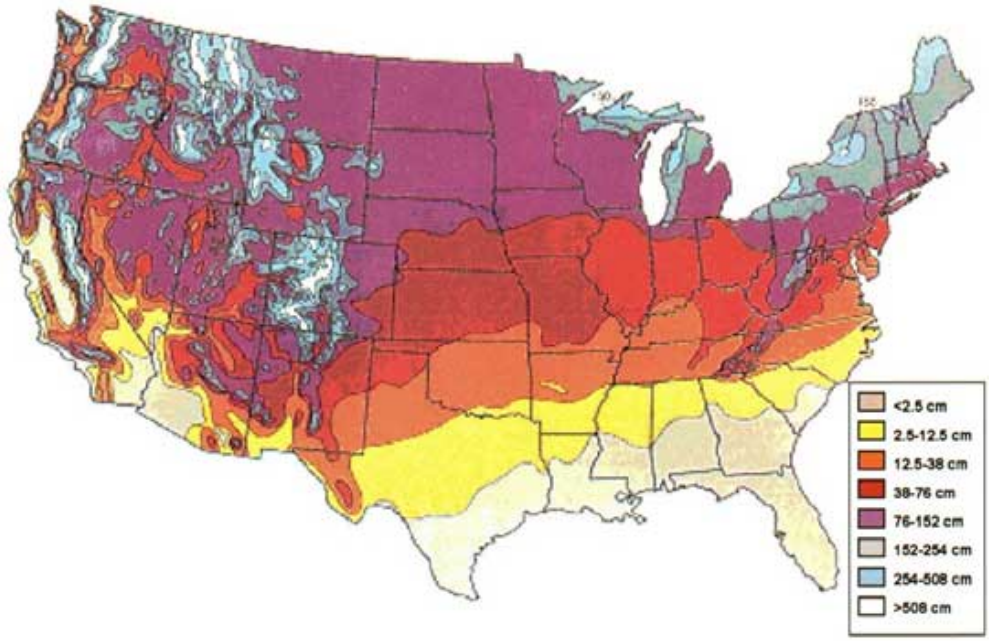
Federal Highway Administration, Road Weather Management Program HOTO-1
400 Seventh St. SW, Washington, DC 20590 USA, Tel: +1-202-366-1301 Fax: +1-202-366-3225

Snow Climatology

The United States has a great variety of climates due to different thermal influences over the large land mass, a large range of latitudes, and elevation differences. The 48 contiguous United States (CONUS), shown in the maps, are climatically different from the northerly State of Alaska, and the semi-tropical State of Hawaii in the Pacific Ocean.

The geographical factors create a large difference in average annual snowfall. However, all states experience significant snowfall at some locations and times. The difference between average and extreme snowfalls creates differences in how road maintenance responds to snow, from continual and routine treatment to occasional and emergency response to infrequent events. Ice without snow also forms on roads, especially in more temperate and coastal areas, and requires careful detection and treatment. The snow extremes in the CONUS are mostly in mountainous areas with low population density and few roads, but many critical passes. But there are large metropolitan areas in all zones, and the northeast and midwest have both large population and large snowfall.

Especially severe are the lake effect snows on the eastern shores of the Great Lakes. Approximately 187,000 thousand people live in areas with >13 cm average snowfall per year, amounting to 80% of the national area. Only the southern tier of the CONUS around the Gulf of Mexico, the southwestern deserts, and Hawaii receive little regular snow fall.



Mean annual snowfall for the United States, 1961-1990

Snowfall extremes, by state, in the U.S.
The differences between these amounts and the averages also reflect the climatic extremes that can occur in each state, including lake effects and mountains

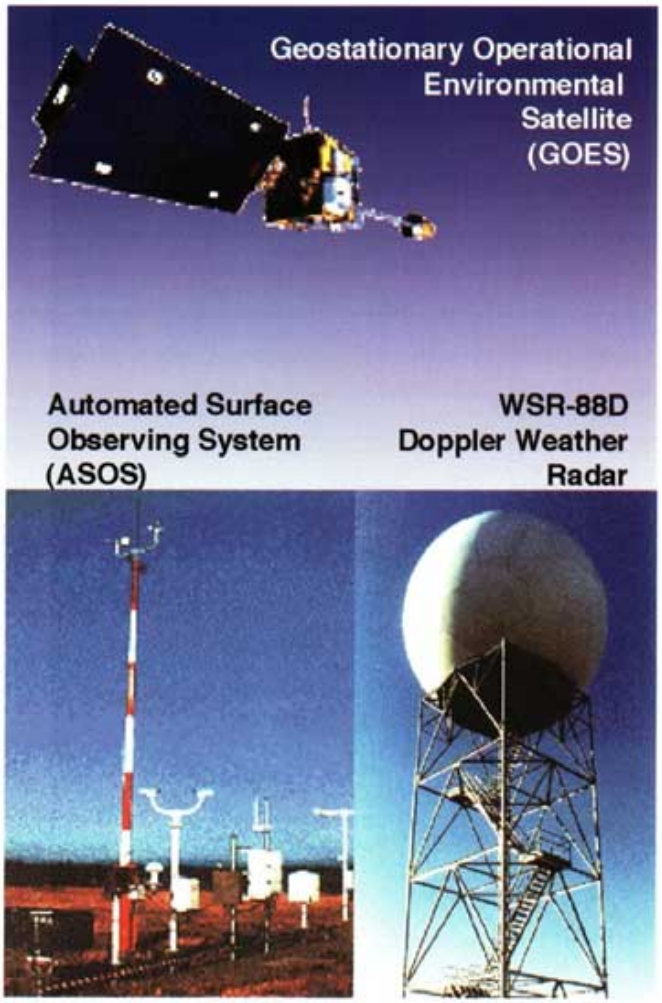
Project and Program Highlights

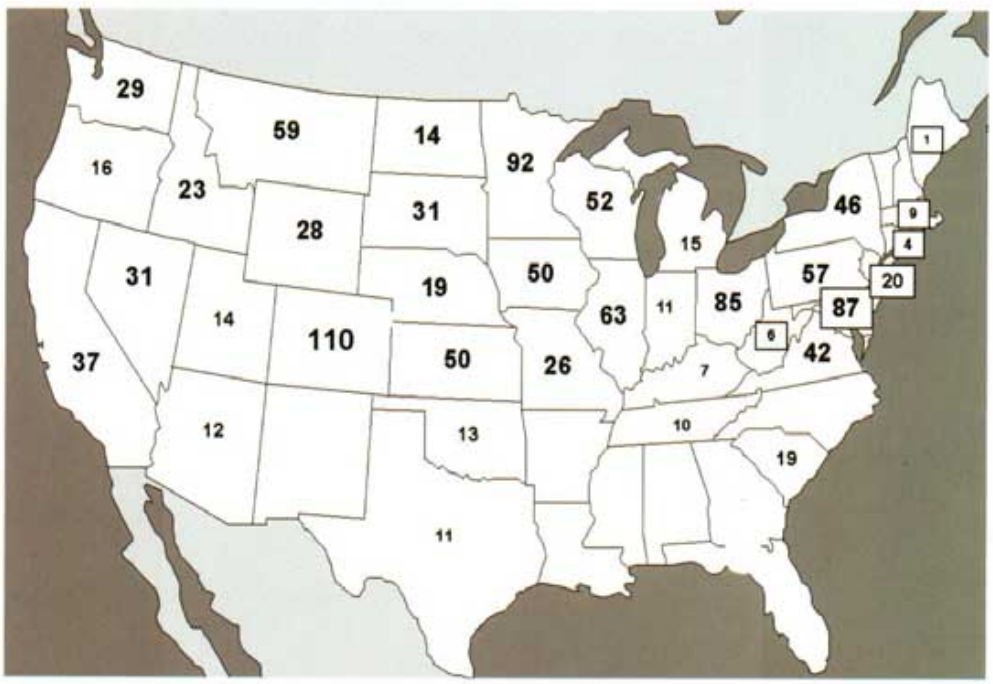
The National Weather Service (NWS): Information infrastructure

The NWS is a federal agency operated under the Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA). The NWS is chartered for the "...forecasting of weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce and navigation and the taking of such meteorological observations to record the climatic conditions of the United States..."

In practice, the NWS provides general weather information and warnings for public safety, and works closely with airspace operations. The tailoring of weather information for various economic interests, including surface transportation, is largely given to private value-added meteorological services (VAMS). But all users are directly or indirectly dependent on NWS products, including:

- Observations from surface sensors (ASOS), Doppler radar and satellite (geostationary and polar).
- National forecasts from the National Centers for Environmental Prediction (NCEP).
- Regional forecasts and warnings from 124 Weather Forecast Offices and 13 River Forecast Centers.





An Environmental Sensor Station (ESS).
Remote Processing Unit (RPU) with surface and pavement sensors.
(Left) **A census of ESS RPUs** operated by state highway agencies.

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The Observation and Prediction of Road Environmental Conditions

The observations provided by the NWS generally are inadequate for characterizing details of the road environment, including surface freezing, local visibility, and chemical concentrations (surface freezing point). Private vendors have been providing the ESS equipment, and associated prediction services called Road Weather Information Systems (RWIS). There are about 1,200 ESS RPUs now installed in the U.S. The FHWA has been active in trying to integrate the ESS observations with NWS surface observations. This will be aided by an ESS data communications standard developed under the ITS program.

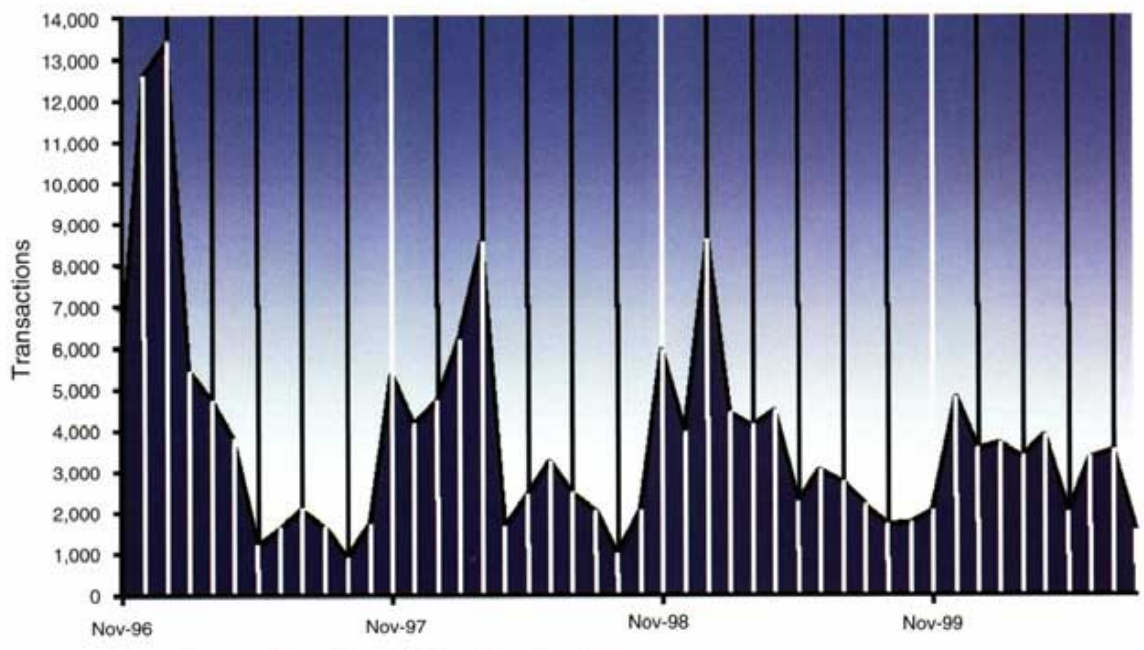
Predictions of road conditions, especially surface freezing, are being provided by correlating point ESS measurements with other locations through thermal mapping, time series prediction at individual ESS, and heat balance methods based on high resolution (meso scale) numerical weather prediction combined with road thermal/radiation surveys.

Advanced Decision Support Systems

The FHWA Road Weather Management Program has identified decision support as a missing link between environmental information and better transportation system performance. In winter road maintenance, the integration of RWIS with treatment tracking and dispatching has only begun. At present, there are many environmental information sources that must be fused manually and then applied to treatment decisions. There are no capabilities for dealing with uncertainty in predictions and decision risk. Through cooperative efforts of the federal and local governments, with meteorological researchers and the private sector, problems of better decision support are being addressed.

The Advanced Traveler Weather Information System (ATWIS) program

The ATWIS program began in 1995 with federal funding at the University of North Dakota. The primary product has been the #SAFE™ service, via cell phone, to travelers in the Dakotas, Minnesota and part of Montana. It is expected that the underlying road condition observation and forecasting will be applied to highway maintenance and management



The daily transactions of the #SAFE system show clear peaking on occurences of severe road weather.

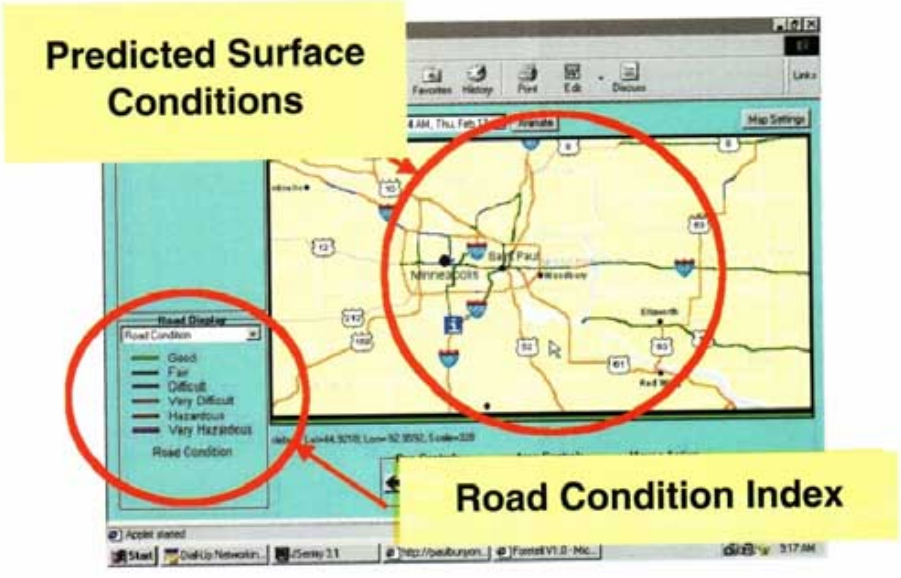
functions. The system merges state-of-the-art technologies in weather analysis and forecasting, telecommunications, and road condition monitoring and reporting to produce short-term route-specific forecasts. Currently, the system covers all state trunk highways and over 27,000 road miles across multiple states.

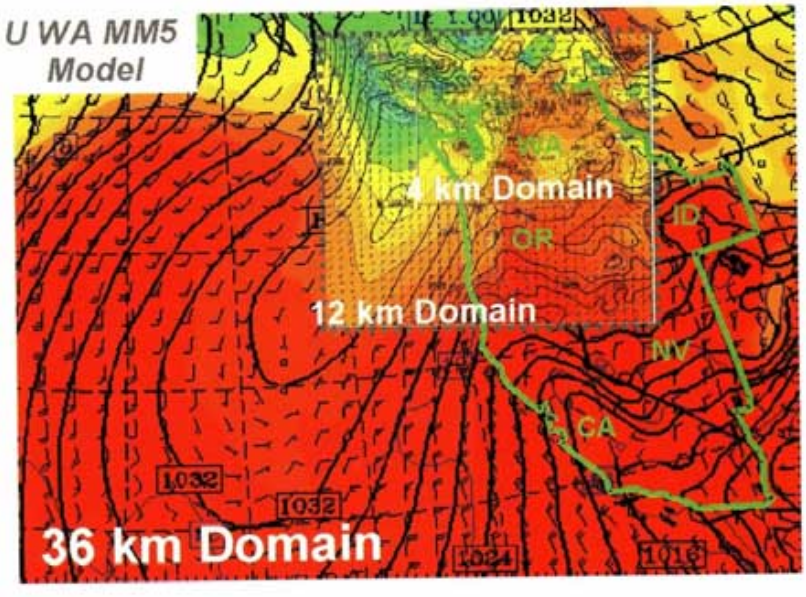
The Foretell™ program

The Foretell program was the first operational test funded by the Road Weather Management Program, starting in 1997. It is a cooperative project between the FHWA, state DOTs and a private vendor. Foretell will be in full operation for the winter of 2000, covering Iowa, Missouri and Wisconsin. The program is focusing on advanced road condition forecasting and decision support fusion for maintenance and traveler information, over a variety of media. An advanced meso scale numerical weather prediction model supports road condition forecasting and a heat balance model for road freezing. The program is expanding into a general highway information system. Results of the operational test will be validated through a three-year evaluation sponsored by the ITS program.

Washington Weather System

Washington State DOT and the University of Washington are working with federal funds to develop high resolution road condition predictions for traveler and maintenance use. The picture (below) shows nested domains run by the high-resolution numerical weather model of the project.





Maintenance Decision Support System (MDSS)

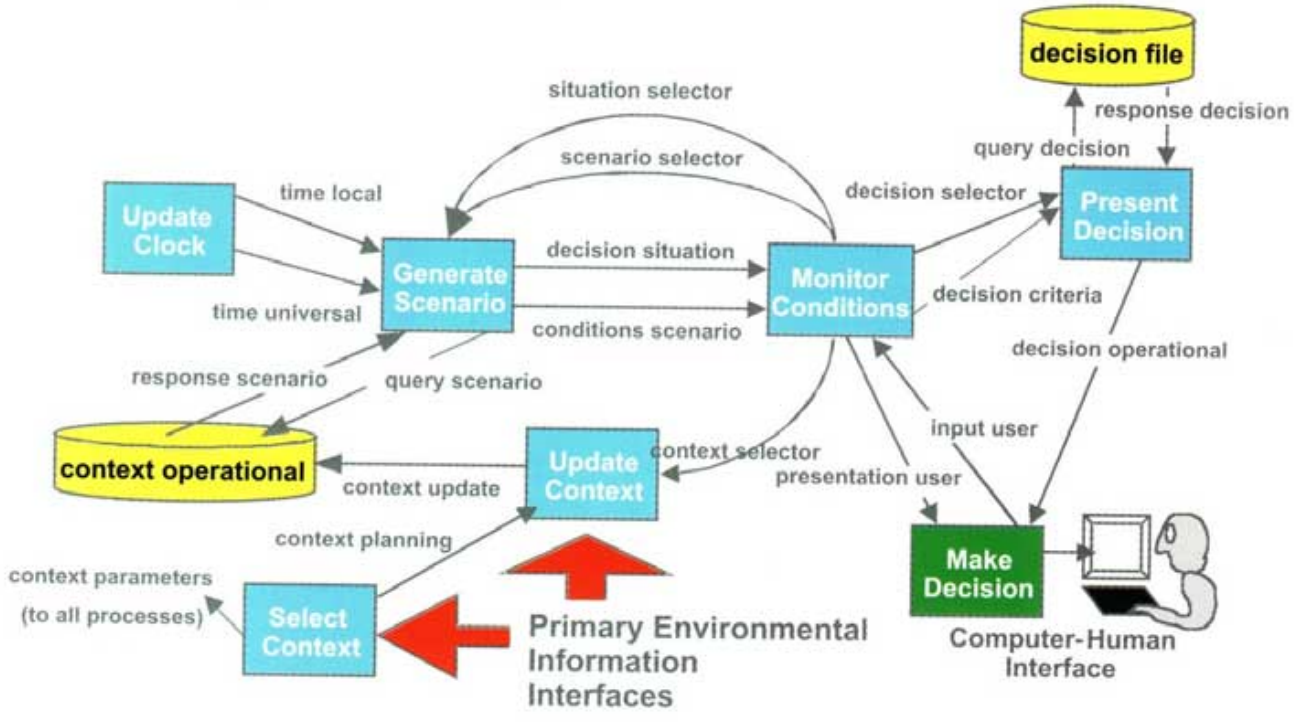
To get to the next generation of decision support, the Road Weather Management Program is sponsoring requirements research and prototype development for the MDSS. The emphasis is on fusion of existing environmental information and integration with operational risk-decisions. An operational test of developed technology is expected in 2002.

Treatment Technology and Technique Development

Along with better decision support, the need is for improved techniques for treating threats from weather. For winter road maintenance, this involves a combination of vehicle-related technologies and chemical applications for anti-icing/deicing. The vehicle technologies for communications, navigation and tracking are closely tied to the Intelligent Vehicle Initiative and other components of the ITS program in the U.S. Anti-icing has been the most significant addition to technique, and this has depended on the simultaneous development of RWIS.

Anti-Icing

Formal research interest in the U.S. on anti-icing dates to a 1990 project of the Strategic Highway Research Program (SHRP), under the National Research Council. That project, follow-ons and deployment guidance continued through the 1990's. Surveys by the Lead States Program under the American Association of State Highway and Transportation Officials (AASHTO) indicate that at least 37 states use anti-icing. The combination of improving icing prediction, expanding options in chemical types/prewetting, environmental impact concerns, and location-based/road-sensing control capabilities continue to make anti-icing an active research area.



Operational Concept Description: Maintenance Decision Support System

Maintenance Vehicle Technology

In 1995 the Iowa, Michigan and Minnesota State DOTs formed a consortium to develop an advanced winter road maintenance vehicle. In partnership with private vendors, each of the three states has been testing a prototype vehicle for three years. The requirements derived from user focus groups emphasized economical operation, mobile sensing of road conditions (temperature, friction, chemical), communication of vehicle activities, and adaptable material dispensing. Geo-location is essential to vehicle tracking and location-based treatment control (e.g., for environmentally sensitive areas). With Differential GPS, which is being deployed nationwide, navigational assistance in poor visibility and on snow-covered roads becomes possible. In addition to the adaptive treatment control on the vehicle, the technology ties the vehicle into the larger ITS for dispatching and reporting of road conditions. Since Iowa is also participating in the Foretell decision support project, it has been active in developing an ITS architecture involving maintenance technology and is using its Concept Vehicle as a recipient of, and input to, the Foretell information.

Fixed overpass anti-icing spray installation. Photo courtesy of CRYOTECH Deicing Technology

IOWA DOT Next-generation maintenance concept vehicle

Interior view of the Concept Vehicle, showing application controller and mobile data terminal