

SNOW AND ICE DATABOOK 2018



**Poland
2018**
AIPCR-PIARC

**XVth International
Winter Road Congress**
20-23 February 2018

PIARC TECHNICAL COMMITTEE B.2 WINTER SERVICE
2019 FINAL EDITION



INTRODUCTION

Even though climate change is closely associated with global warming, under the present circumstances it also translates into more extreme weather events. This effect can result in a very mild winter one year followed by a frigid and snowy season the next. Consequently, winter maintenance is very difficult to manage given a context of ever-increasing mobility and declining budgets. We must continue to do our best but with less money.

Road network managers must ensure infrastructure remains open so that economic activity is not disrupted while guaranteeing road user safety.

Different types of road users and means of locomotion and transport are affected by winter road service, i.e. pedestrians, cyclists, public transit services, automobiles, and freight carriers. It is important therefore to propose a comprehensive response as regards winter maintenance.

This becomes a real challenge, especially in urban environments, and significant resources (both human and equipment) are typically allocated.

Sustainable development and environmental protection are fundamental topics, providing the input to regularly reflect on defining better strategies and improving our practices. To advance along these lines, experience-sharing has become essential.

The ambitious goal of the "Snow and Ice Data Book" (SIDB) is to report on experiences in winter maintenance from some 30 countries. This tool was launched more than 15 years ago and its updated version, published every 4 years at the time of the International

Winter Road Congress, is always a huge success.

The SIDB features a consistent format, with the same sequence of chapters contributed by each country. This document successfully provides an overview of winter maintenance practices across roughly thirty countries, which is three countries more than for the previous edition.

The XVth International Winter Road Congress, held February 20-23, 2018 in Gdansk (Poland), offers the opportunity to release this fifth version of the SIDB.

The 2018 version of the SIDB has been coordinated by a working group within Technical Committee B.2 on Winter Service, composed of Anna Arvidsson, Tuovi Päiviö, Odile Coudert, Alan Chambers and Didier Giloppé, not to mention all the other Committee members who make it possible for the SIDB to be updated along with many external participants.

We would also like to thank the Polish Organising Committee, in particular Aleksandra Cybulska, who has very actively contributed to both the SIDB publication effort and coordination of this XVth International Winter Road Congress.

We hope that this databook will constitute a practical and user-friendly reference for all actors involved in winter service: contracting authorities, project managers, stakeholders, and road users.

**ON BEHALF OF THE ENTIRE COMMITTEE
DIDIER GILOPPÉ,
CHAIRMAN OF PIARC TECHNICAL COMMITTEE
B.2 WINTER SERVICE**

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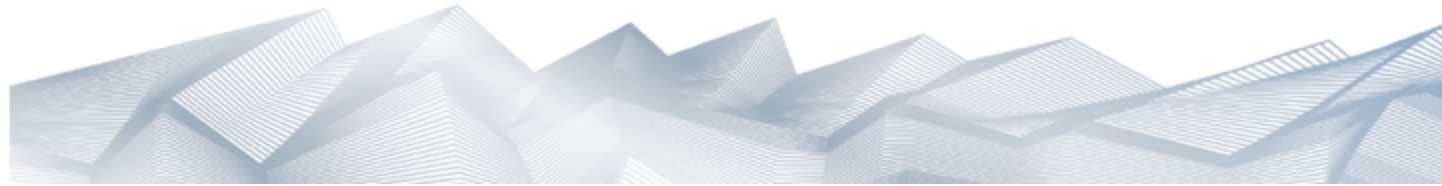
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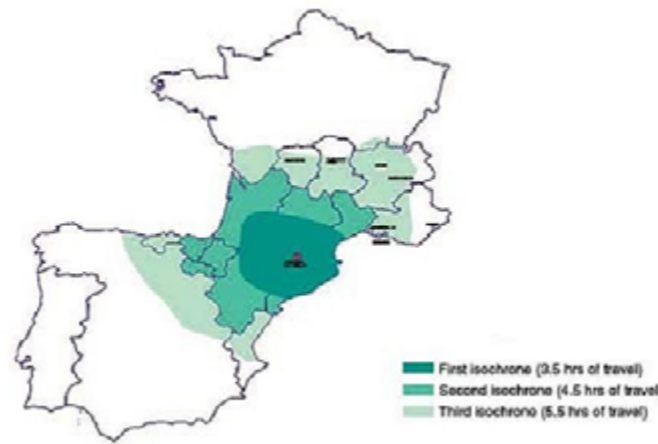
1. DEMOGRAPHIC AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

The Principality of Andorra is a microstate (468 km²) located between Spain and France, in the middle of the Pyrenees mountain range. The current population is over 85,000 inhabitants, with a density of 182 inhabitants/km², with the majority of the population concentrated on the valley floors. The key economic sectors are construction and its derivatives, the financial sector, and above all the restaurant industry and trade. Every year more than 11 million tourists visit the country (approximately 80% leave the same day and 20% stay at least one night in the country), attracted mostly by the retail offerings and mountain sports, particularly in winter (the Principality of Andorra has the highest concentration of ski resorts in the Pyrenees, 315 km of trails)

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

1.2 ROAD NETWORK AND TRAFFIC



ACCESS ISOCHRONES FOR THE PRINCIPALITY

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

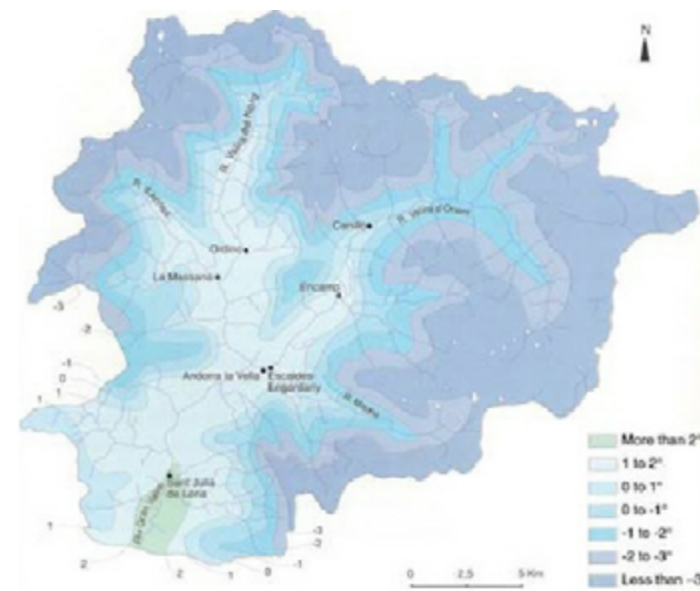


OFFICIAL ROAD MAP

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

2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS



3- AVERAGE TEMPERATURES IN THE MONTH OF JANUARY IN ANDORRA (RASO, 1999)

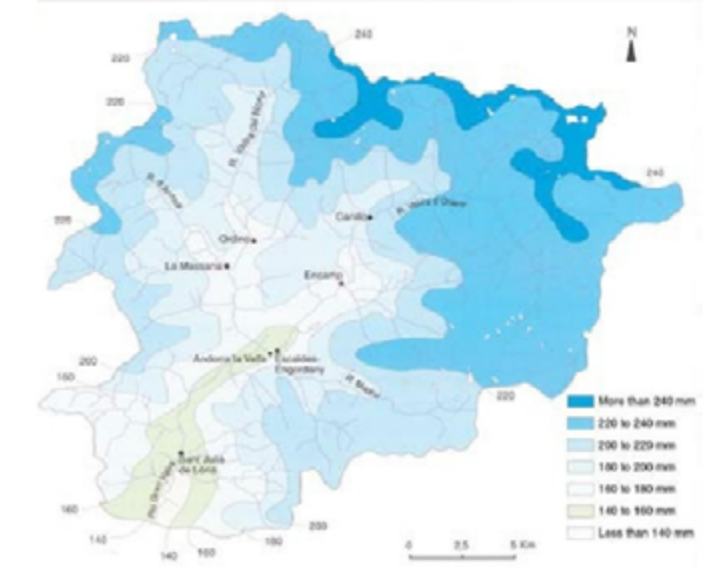
From a regional point of view, the Principality of Andorra can be said to fall within the sphere of the Mediterranean climate; however, a set of geographical factors influencing the climatic behavior in particular must be taken into account: first the relief and significant altitudinal climate present in the Principality of Andorra. Most of the country is at 2,000 m, and accordingly falls within the realm of mountain climates where precipitations are higher than in the valleys, temperatures lower, the temperature range greater, and the wind more present. From 2,000 – 2,200 m, snow is likely to fall on a regular basis from December to April. The situation changes in the warmest part of the year, especially summer, when the convective activity generates intensive precipitation, often in the form of storms lasting a short time.

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

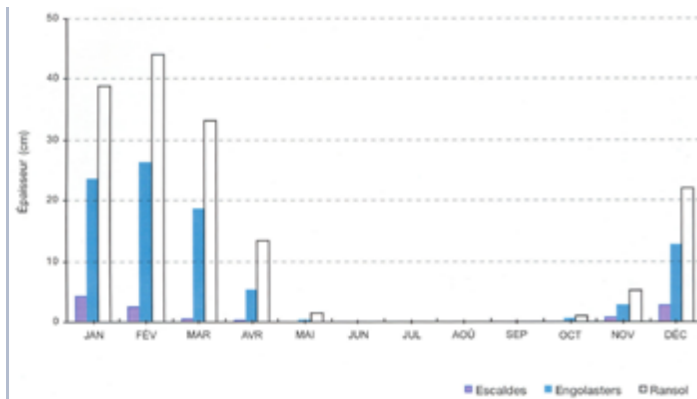
2.2. NOTEWORTHY CLIMATIC DATA

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

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



4.- AVERAGE PRECIPITATIONS IN THE MONTH OF JANUARY IN ANDORRA (RASO, 1999)



5-MONTHLY DISTRIBUTION OF THE AVERAGE DEPTH OF SNOW IN ESCALDES (1,100 M), ENGOLASTERS (1,600 M / SUNNY) AND RANSOL (1,600 M / DARK) (RASO, 1999)

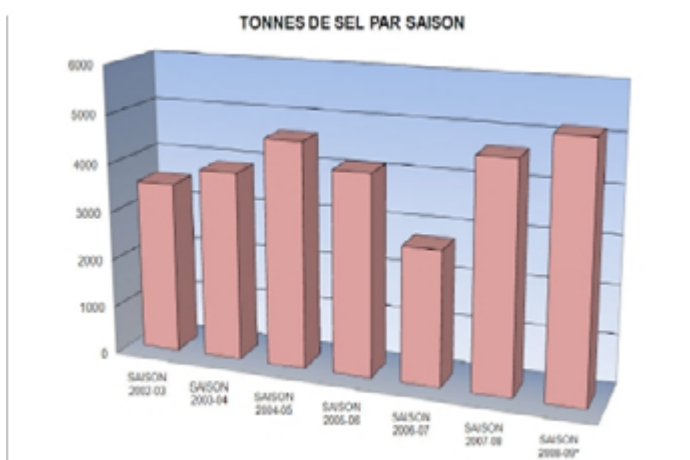
the maximum amounts of snowfall accumulated in 24 hours in the 1986-2003 period were 85 cm at 2,100 m (Pas de la Casa), 56 cm at 1,600 m (Ransol) and 40 cm at 1,100 m (Escaldes).

2.3 WINTER INDICES USED IN THE COUNTRY

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

3. Winter Road Management

3.1 STANDARDS AND RULES



6.- GRAPH OF TONES OF SALT PER SEASON

Classification of roads.
Roads are classified into two types:

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

LEGAL OBLIGATION

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

LEVELS OF SERVICE

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

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

Removal with neighboring countries by assisting them in extreme situations. This was the case when Catalonia (Spain) saw major snowfalls in 1962 and 2001.

In terms of winter maintenance, all road maintenance is managed by government crews. Communal crews are responsible only for roads within agglomerations. However, the effective collaboration between



7.- COL D'ENVALIRA, 1960

the seven communes and the central government in this area should be noted.

3.2 SECTORAL ORGANIZATION OF SNOW REMOVAL

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

- The North Valley Sector, with a network of 130 km of roads;
- The South Valley Sector, with a network of 70 km of roads;
- The East Valley Sector, which only has a network of 70 km, but which must make sure that the Col d'Envalira, at an altitude of 2,408 m, permanently remains open.

STAFF LABOR PROGRAM

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

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



8.- SNOWPLOW



9.- SNOWPLOWER

staff are present from morning until evening every day of the week. At night, we have on-call staff that can be called depending on weather conditions.

INSPECTION AND WINTER CONTROL

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

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

SNOW REMOVAL EQUIPMENT

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

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

AVALANCHE PREVENTION

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

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

1. Monitoring the snow cover and weather forecasts during snowfalls
2. „Expert“ estimates of a localized risk when the situ-



10. PROTECTIVE BARRIERS, SCREENS, NICOLAU CANAL, EL SERRAT.

ation requires it;

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

3.3 ASSESSMENT OF SNOW AND ICE CONTROL MEASURES

Every year, all of the departments that take part in snow operations (government snow removal services, police department, traffic services and communal snow removal services) draw up an account of the season and work to make the necessary improvements in preparation for the next season. In our country's economy, there is a very strong link between winter maintenance, tourism and mobility, and the GDP. That is why it is im-



11.- GAZEX EN LES FONTS, ARINSAL.

portant for all officers assigned to these strategic sectors to work together to provide the tools needed to make structural decisions.

3.4 ROAD SAFETY AND INFORMATION INFORMATION SYSTEM

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



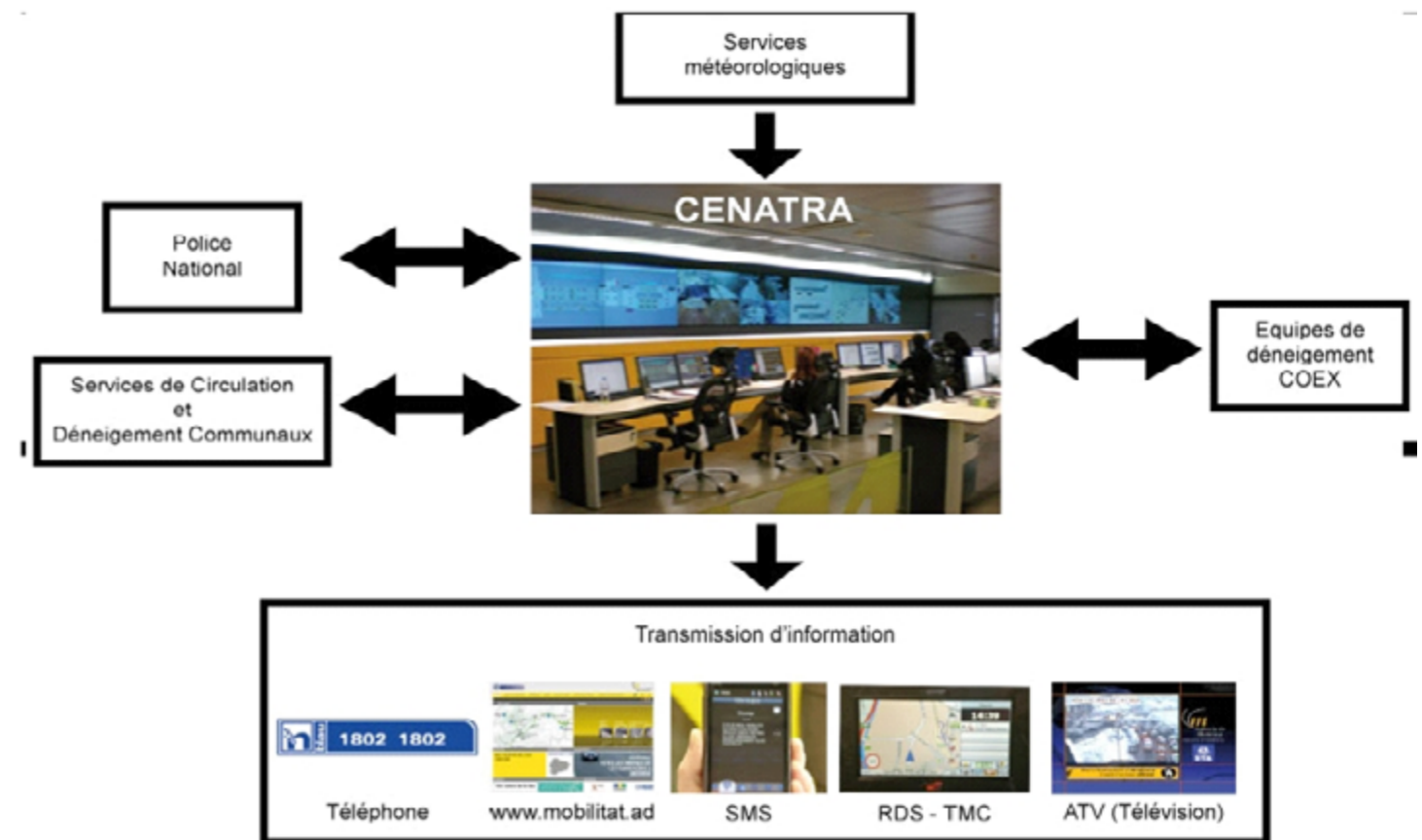
12-VARIABLE MESSAGE SIGN

of snow] campaign

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

4. ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

GREEN STARTING TO SNOW	YELLOW SNOW ON THE ROAD	RED ROAD COVERED WITH SNOW	BLACK ROAD IMPASSABLE
<ul style="list-style-type: none"> Traffic is undisturbed. Take more care. Do not exceed a speed of 80 km/h. Stay attentive to weather changes. Drive with care in wet areas and on clear nights because of the possibility of frost.	<ul style="list-style-type: none"> Use of chains or special tires at a maximum speed of 60 km/h. It is recommended that trucks and articulated vehicles not be operated. Slow down, particularly in turns and on banked roads. Avoid all unexpected maneuvers and increase your safety headway. Do not continue travelling if the weather starts to deteriorate and you have no special equipment (chains, warm clothes, etc.).	<ul style="list-style-type: none"> Use of chains or special tires at a maximum speed of 30 km/h. Use of chains mandatory on busses. The use of freight transportation vehicles with an authorized average weight of over 3,500 kg is forbidden. Unless absolutely necessary, it is preferable to postpone the trip. Do not stop the car on a hill or in places where you would be hindering traffic. Do not pass stopped vehicles if you are not sure you will be able to keep going.	<ul style="list-style-type: none"> Risk of being immobilized on the road for a long time. In the event of immobilization, conserve fuel and abandon the vehicle only if you are certain of finding shelter. Do not leave the car in places where it might become an obstacle to snowplows.



Ongoing projects:

- On-board communications equipment (TETRA system) for real-time data on the exact position of all snow removal vehicles and to obtain data from sensors analy-

zing the working conditions for each vehicle;

- Automatic laser stations on salt-spreading vehicles with relative humidity, surface temperature and air temperature measurement to calculate the exact rate

ANDORRA

of salt and brine;

- Road frost sensors;

Generalization of the use of brine

14- Brine production station

5. REFERENCES

Principality of Andorra website

www.govern.ad/

Agència de Mobilitat i Explotació de Carreteres

www.mobilitat.ad/

IEA Institut d'Estudis Andorrans

www.iea.ad/

CENMA

Centre d'estudis de la neu i la muntanya d'Andorra

www.cenma.ad/

El Clima d'Andorra

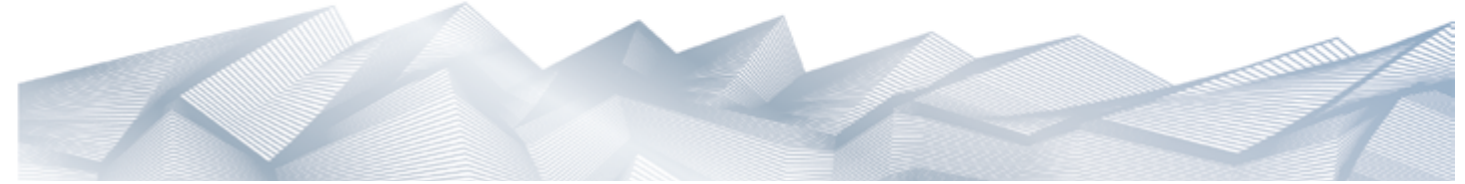
1.M.Raso Nadal, 1999

Ministeri d'Educació, Joventut i Esports

(Government of Andorra)



ARGENTINA



1. DEMOGRAPHIC AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

From the institutional point of view, Argentina is a democratic and Federal Republic, constituted by 23 Provinces and the Autonomous City of Buenos Aires, with an executive political system, constituted by a national presidential system and provincial governors, a Legislative system both national and provincial and an independent judicial system, with national and provincial jurisdictions.

The Argentine territory is located in the southern hemisphere in relation to Ecuador, in the western hemisphere if the Greenwich meridian is taken as a reference.

As for its surface, the territory of the Republic of Argentina is the second largest in South America after Brazil, second in Latin America, fourth in all America and the eighth in extension of the Earth. It is bordered by Chile, Bolivia, Paraguay, Brazil and Uruguay. Its geography is very varied, being mostly plains in the east, mountains in the center and mountains in the west. The country is crossed, in its western end, from north to south by the Cordillera de los Andes, which in good part marks the limit with Chile. The highest peak in Argentina is Aconcagua, at 6,960.8 meters above sea level.

The area under effective sovereignty has a great latitudinal development: 3,779 kilometers between the extreme North and the extreme South, from La Quiaca to Ushuaia, which makes it one of the longest countries in the world.

The continental surface of Argentina is 2,791,810 km². From here: 2,780,400 km² corresponding to the Federal Capital (Autonomous City of Buenos Aires) and 23 Argentine provinces. The rest is made up of the 11,410 km² of the Malvinas Islands. In turn, the An-

tartic continental surface comprises 969,464 km². Of these, some 965,597 km² correspond to Argentine Antarctica (claimed territory). This area also includes the South Shetland Islands and the South Oreadas Islands. The remaining 3,867 km² are made up of the South Georgias Islands (3560 km²) and the South Sandwich Islands (307 km²) which are part of the department of the South Georgias Islands (3560 km²) and the South Sandwich Islands (307 km²).

South Atlantic of the province of Tierra del Fuego, Antarctica and South Atlantic Islands, as well as the Antarctic sector (included as a department).

The total area thus amounts to 3,761,274 km².

2. POPULATION

Argentina has a population of 43,847,430 people, of this total the female population is the majority, with 22,389,000 women, representing 51.06% of the total, compared to 21,458,430 men who are 48.94%.

Argentina can be considered a country with a significant number of inhabitants, if we compare it with the rest of the countries, since it occupies the 32nd place in the ranking of 196 states that compose the world population table. Of the total 4.81% of the population of Argentina are immigrants although a large part of its population in the last century and a half was made up of immigrants from different regions of the world. Currently Argentina is the 82nd country in the world by percentage of immigration.

The composition of the current Argentine population is very influenced by the great wave of immigration, which took place between 1870 and 1930, and which provided contributions especially from Europe, the Near and Middle East and Japan. To this is added the contribution of the natives, Asians (from the Near, Middle and Far East) and the population of Africa (taken as slaves to the territory that today makes up Argentina).

Argentina is considered a „country of immigration” due to the massive migratory currents it received over time, mainly from the European continent, highlighting primarily Italians, Spaniards, Germans and Poles. Currently, it receives Asian immigrants (China and

POPULATION DENSITY

INHABITANTS PER KM², ALTHOUGH THERE ARE GREAT VARIATIONS ACCORDING TO REGIONS.



South Korea), a large number of nearby South American countries, especially from Paraguay, Bolivia, Peru and to a lesser extent Colombia, Chile, Uruguay, Brazil and Venezuela.

Being one of the largest countries in the world, it has a very low population density, with 16,000 inhabitants.

In contrast to the low population density mentioned above, there is the concentration in the Greater Buenos Aires Agglomerate (38.9%), and a large proportion of people over 60 (14.3%). It has high rates of life expectancy (75.3 years) and literacy (98.1%).

If to the agglomerate of Buenos Aires is added the Province of Buenos Aires and the population located in the axis of the agglomerate and the city of Rosario (fluvial port of great importance), almost 50% of its population is located less than 10% of the territory.

Geographical Situation

It borders Bolivia to the north, on the Cochincoca mountain range, on the Grande de San Juan, Bermejo, Grande de Tarija, Itaú and Pilcomayo rivers, and on Paraguay, from which the Pilcomayo, Paraguay and Paraná rivers separate it.

It borders to the east with Brazil (rivers Iguazú, San Antonio, Pepirí Guazú and Uruguay), with Uruguay, crossing the river of the same name, and the river of La Plata.

It is bordered on the west by Chile, whose common border is constituted mainly by the Andes mountain range. The southern borders were defined thanks to a 1984 treaty on the Beagle Channel and the Drake Passage, which links the Atlantic and Pacific oceans and in turn is the extreme south to where the effective sovereignty of Argentina reaches.

Argentina extends for more than 33° latitude between its northern end, at 21°46'S; and the southernmost point of the Argentine emergent continental territory in the island Grande de Tierra del Fuego, at 55°03'51"S. It extends from west to east by 20° longitude, from a point southwest of the Patagonian Andes in the province of Santa Cruz, at 73°38'0, to the town of Bernardo de Irigoyen, in the province of Misiones, at 53°35'0.

Regions

The country has a large number of geographical regions. The formal regions of Argentina are:



Northwestern region that includes an area known as the Altiplano.

- Pampean Sierras
- Region of Cuyo
- Platense Plain
- Subtropical plateau
- Patagonian Region
- Antarctica Argentina

Argentina's natural wealth is immense. The Pampean plain (part of the plains of La Plata) is suitable for the cultivation of cereals and oilseeds, as well as for livestock. Patagonia is rich in gas and oil, as well as spices. In the pre-mountain range there are minerals of different varieties, such as uranium, silver, gold, lithium, etc.

Weather

Given the enormous extension of the country, as well as its latitudinal and altitudinal development, Argentina presents an enormous variety of climates. As a general rule, it must be said that, since the ConeSurrounded by enormous oceanic masses, the variations between summer and winter are low in relation to numerous regions in mid-latitudes of the northern hemisphere.

- Subtropical without dry season
- Subtropical with dry season
- Tropical serrano
- Wet pampeano temperate
- Temperate pampeano semi-arid
- Ocean Temperate
- Temperate Serrano
- Árido de Sierras y Bolsones (Aggregate of Saws and Bags)
- Semi-arid
- Patagonian arid
- Andean-Puneño Arid
- Wet cold
- Polar cold

Argentina has two rainfall regimes, the Atlantic and the Pacific. The first penetrates from the east and northeast and covers most of the north and center of the country, and having greater penetration in summer, causes greater rainfall at that time. The Pacific regime comes from the west, and produces rainfall in the mountains and Patagonia, preferably in winter. As the Andes act as a barrier, rainfall is very low in the region the eastern slope of it. In the same way, the enormous extension of land that separates the northwest and

BIOMES



- MISIONES JUNGLE
- MESOPOTAMIAN PARKLANDS
- CHACOAN PARKLANDS
- TUCUMANO-SALTEÑA JUNGLE
- ANDEAN-PUNA STEPPE
- MOUNTAIN
- PAMPEAN STEPPE
- PATAGONIAN STEPPE
- PATAGONIAN ANDES-TIERRA DEL FUEGO FOREST
- SOUTHERN PROVINCE AND ANTARCTICA

Cuyo regions from the Atlantic also means that there is little rain there. Then we can talk about two main sources of precipitation, one that advances from the northeast, with precipitations higher than 1500 millimeters in Misiones, and another from the west of Pa-

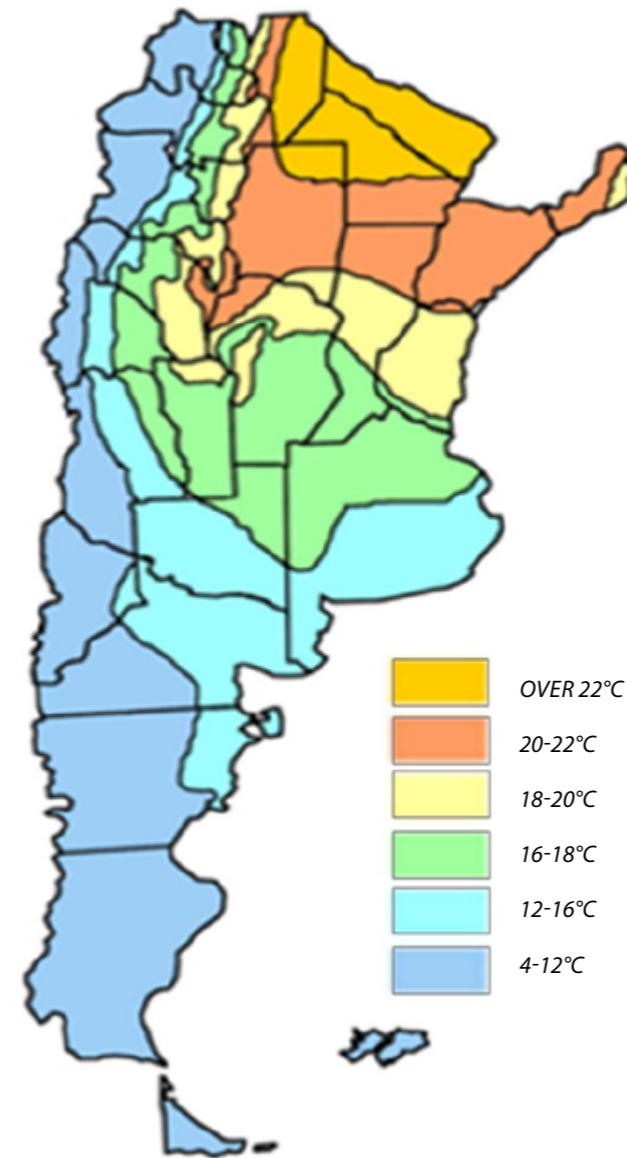
tagonia, with precipitations that reach 3000 millimeters in the southwest of Neuquén. From the province of Misiones, the decrease in rainfall towards the west and south occurs slowly, with values of around 1,000 mm still in the north of Buenos Aires and the center of the Chaco. In Neuquén, due to the barrier of the mountain range, a few kilometers to the east, rainfall drops to less than 300 mm. A third focus of rainfall occurs in the northern sub-Andean zone, where eastern winds „collide” with the mountain range and discharge into a thin strip (where the provincial capitals of Jujuy, Salta and Tucumán are located) amounts of about 1,000 mm annually, much more than the surrounding regions. In addition, they occur with a strong seasonality, during the summer.

In general, because there are large portions located in intermediate latitudes, which are located at altitudes close to the sea level, there are different varieties of temperate climates of the Pampean type, which are very suitable for both human life and for agricultural development, the basis of the country's economy.

With the increase in latitude the winter cold also intensifies. In areas of the Patagonian plateau, the lowest temperatures in South America occur at low altitudes (-33.0 °C). Already in the Fuegian archipelago the temperature is cold all year round, although the intensity of the winters is tempered by the tempering effect produced by the gigantic southern oceanic masses. A similar increase in cold occurs with the increase in altitude, this being especially noticeable in the northwest and center-west of the country, consistent with the presence there of plateaus and mountain ranges of the Andes of considerable height.

This determines that, in all winters, the routes that cross the Andean chain towards Chile suffer, during some weeks, the interruption of the transit, because of the copious snowfalls. As a benefit, these allow the existence of a tourist industry based on winter sports.

However, this phenomenon is very exceptional in the northeast of the Chacopampeana plain, in the Litoral up to the north of the province of Buenos Aires, and even more so in the Gran Buenos Aires, whose winters are tempered by the cooling action of the Río de la Plata and the island of heat that the megalopolis develops (which also rarefies frosts). Snowfalls are more frequent towards the west (as the altitude increases) and towards the south, at the same time as their annual



AVERAGE TEMPERATURES IN THE AMERICAN SECTOR OF ARGENTINA

nitored and studied by the National Meteorological Service (SMN).

Seasonal regime

Although the northern climate of the Argentine country is usually simplified as „warm”, the center as „temperate” and the south as „cold”, in practically all of Argentina there are the four seasons, obviously with higher average temperatures in the north (Tropic of Capricorn for example) and much lower average temperatures in the south (zone of influence of the Antarctic polar circle), and before these latitudinal differences the singularity of the altitudinal cooling in all the elevated

region of Argentina, especially notable to the west of the Sierras Pampeanas and very notorious in the high altitudes of the great mountain range of the Andes.

It must be taken into account that since the whole territory of Argentina is in the Southern Hemisphere, the cyclical regime of the seasons is symmetrically inverse and complementary to that of the seasons of the Northern Hemisphere, that is to say (for example) when in Argentina summer begins in Europe, the United States, China, Japan, etc. winter begins and vice versa, when in the Northern Hemisphere winter begins in almost all of South America, part of Africa, in Oceania, and in all of Antarctica, summer clearly begins.

In the same way, the solanas in Argentina usually occur in the mountain range facades that „look” to the north and the umbrías in the mountain range facades or faldeos that „look” to the south.

On the other hand, it must be taken into account that Argentina, together with Chile, all of Uruguay and the region south of Brazil, the south of Australia and all of New Zealand are the only continental and insular territories in the Southern Hemisphere with the four well-differentiated seasons (in a similar way to that which occurs in Europe and the United States).

Regions affected by winter phenomena

Beyond specific phenomena there are regions and sub-regions affected by winter phenomena. One of them is the one affected by the high summits of the Andes Mountain Range, which includes seven provinces, which have mountainous populations and international crossings linked to Chile, affected by these phenomena.

The other Region is Patagonia, made up of 5 provinces, which have areas of lower mountains than the northern Andes, but coexist with non-mountainous areas of low temperatures and snowfalls that affect the movement and production of those areas.

Region of Patagonia dominated by snow and cold
The Argentine Patagonia is subdivided climatically (without counting the microclimates) in two great regions: the western Andean Patagonia around the Andes mountain range and west of the Patagonides mountain range and the southern third of the island of Tierra del Fuego, in such a zone of cold and humid peri climate (2.The precipitation gradient decreases abruptly to less than 500 mm/year due to the effect exerted by



the Andes mountain range, since much of the humidity carried by the winds blowing from the southwest quadrant condenses and precipitates in the form of snow (especially from April to early October) and then in the form of rains in the Andean-Patagonian mountain ranges. Therefore, the climate of the eastern extra-Andean Patagonia tends to be semi-arid or directly arid although with great thermal amplitude and icy winters that in the southern winter may cause intense rainfall and levels with temperatures averaging - 40°C.

In the arid steppe climate in northern Patagonia, average annual temperatures of less than 15°C, very frequent frosts and scarce rainfall (400 mm per year) can be appreciated. However, rainfall increases in the northwestern end of the Patagonian mountain range, being more abundant during the winter. In the south of Patagonia the climate is very cold, the average temperature is below 5°C and rainfall of 300 mm and in the Patagonian coasts during certain summers can have high temperatures.

Rainfall is around 2,000 mm up to 4,000 mm on the border with Chile and drops sharply to the east, up to 200 mm and winter snowfalls are frequent.

South of the Colorado River begins Patagonia, whose plateaus descend down to 1500 and 2000 meters high, at the foot of the Andes, to a marine coastline rugged by cliffs and with wide sinuosities (gulfs of San Matías and San Jorge, Bahía Grande, peninsula Valdés, Cabo Tres Puntas, etc.). These Patagonian plateaus are cut by deep canyons, where the rivers coming from the Andes Cordillera flow.

One of the characteristics of Argentina is towards the West, the presence of the Andes Cordillera. The Andes Cordillera extends from Venezuela to Tierra del Fuego, through 7500 kilometers. They are characterized by

their high altitude, their grandiosity and width in Bolivia, by the vigour with which they rise over the Pacific to the West and over the central plains to the East. Several sectors of different characteristics can be distinguished the geography of the Andes.

Region of the Andes Cordillera Lacordillera de los Andes is the mountain range that occupies the western part of South America. It occupies an area of approximately 3,370,794 km² that borders the western Pacific coast and part of the Caribbean Sea along 7,240 km, making it the longest mountain range on Earth. The Andes lie between 11° N latitude and 55° S latitude, forming part of the territories of Argentina, Chile, Bolivia, Peru, Ecuador, Colombia and Venezuela. The Andes are home to the highest volcanoes on the planet. At the southern end, the Andes sink into the Atlantic Ocean east of the Isla de los Estados, (an island contiguous to the Argentinean part of the Isla Grande de Tierra del Fuego.

In its southern part, it serves as a natural border between Argentina and Chile, an area where the continent's highest mountains are found.

The highest summit of the Andes is the Aconcagua, with 6,960.8 m, besides being the highest summit of the southern and western hemispheres. It is located in Mendoza, Argentina. Argentina and Chile share the highest peaks of the Andes, including the Nevado Ojos del Salado, the world's highest volcano and the second highest summit on the continent. Of the ten highest volcanoes on the planet, six are shared between Argentina and Chile, three are in Argentina and one in Bolivia.

The relief of Argentina is fundamentally determined by the strong opposition between the great plains to the East and the Andes Mountains to the West.

Extended longitudinally north-south along the border with Chile, the Relief of Argentina in the Andes region offers a variety of aspects. In the extreme North, it is the tip of Atacama, vast desert plateau of 4,000 meters of height, crossing by the mountain ranges that surpass the 5,000 meters, and with numerous closed depressions; denominated salares. This impressive desert, dominated by volcanoes such as the Lullaillo, 6,723 meters high, and shared with Chile, loses altitude to the South to make way for older and more uniform mountain ranges, cut by narrow transverse valleys, called quebradas, which serve as a natural pass between the two countries. The most important is the Quebrada de Humahuaca. In the Andes, the tip is frag-

mented into short solid chains divided by arid depressions. Towards the 36° latitude, the mountain range loses height again.

Argentina's highway network

This implies that the road system is constituted centrally by a national network of roads, administered by the National Direction of Roads, and a system of provincial networks, administered; The functional objectives are, in the National case, to unite all the provinces and the production zones, ports and urban conglomerates, in addition to attending to the territorial organization of the country. In the case of the provincial networks, the functional objective is the internal communication of the provinces.

Different cities and production centres and the social organisation of the territory.

Despite the concentration of population in a relatively small area of its territory and most of the productive activities located in the central region of the country, Argentina over time was constituting an integrated road network. The development of the network has been balanced throughout the country, allowing a significant level of integration, beyond a paving insufficiency especially in the provincial networks.

The national network consists of 40,039 km of which more than 90% are paved, of which 2800 km are highways and highroads. For its part the Provincial network and roads amounts to 198,288 km of which only 44,861 or 23% are paved.

National network		Provincial networks	Total
Paved	36,235	44,861	81,096
Gravel	2,764	39,234	41,998
Dirt	1,040	114,193	115,233
Total	40,039	198,288	238,327

Winter road maintenance

In this territorial and climatic context, there are activities centralized in the national management of roads and provincial and municipal management of the attention to these situations. Given that the border with Chile is the Andes mountain range, it is a national policy to develop jointly with that country, a system of integration of border crossings. There are currently 26

prioritized border crossings, beyond the existence of many others that serve development between border localities of both countries.

In general, all these passages are affected by winter road maintenance phenomena. The system of attention to winter road maintenance is subdivided into different estates.

- Border crossing systems with Chile
- Systems of attention of roads of high mountain.
- Status of Routes reached by winter effects
- Urban and peri-urban systems affected by winter road maintenance

Border crossing systems with Chile

In spite of the fact that during part of history different links were developed through the Andes Mountain Range, for different motives, bordering and political, it begins to give a systematization in the attention of the same ones from the decade of the 90.

Since 1996 the border crossings agreed and prioritized with Chile were thirteen (13) of which twelve (12) were on national routes. At that time the Christ the Redeemer Pass on NR 7 was the only one that had associated winter maintenance activities within its daily operations.

Currently, the border crossings with Chile, which have been prioritized by both countries, are twenty-six (26). Of these, fourteen (14) on national routes (1,300 km) and twelve (12) on provincial networks (280 km).

Of the 26 steps 9 are paved on the Argentine side and 8 on the Chilean side.

For years the National Direction of Roads participates in four (4) GTI (Winter Working Group) by instruction of the GTM (Joint Working Group) of both countries that relates the operational activities between them.

These GTIs are the north, center, south and south, which annually define the POI (Winter Operation Plan) of the prioritized steps, which include, among other aspects, the resources to be committed. Given that the climatic realities in relation to Winter Roads are dissimilar, as well as the transits and inconveniences of the infrastructure, these four groups have been defined to face the winter problems.

Based on the operation with joint policies with the Republic of Chile, service levels are defined, which fundamentally tend to a system of warnings prior to winter events, a clearing activity of the network, and a policy

of planning human and material resources. The crossings in some cases are high mountain and in others relate border towns of both countries.

From these steps, the Cristo Redentor System stands out, Mercosur's communication axis, which is a bioceanic communication system, given that it is the most used transit solution from Sao Paulo (Brazil), Montevideo (Uruguay) and the central areas of Argentina, both for interregional trade and for the land linkage of the Atlantic and Pacific oceans.

Given the binational importance, the operation of this step is fundamental to the trade and transit of people in the winter season.

Border crossings

Name	Height (MASL)	Surface
Jama	4,200	Paved
Sico	4,092	Gravel
San Francisco	4,726	Paved
Pircas Negras	4,160	Gravel
Agua Negra	4,780	Paved
Cristo Redentor	3,186	Paved
Las Leñas	2,570	Dirt
Pehuenche	2,553	Paved
Pichachén	2,060	Gravel
Pino Hachado	1,884	Paved
Icalma	1,298	Gravel
Mamuil Malal	1,253	Gravel
Carirriñe	1,223	Gravel
Hua-Hum	625	Gravel
Cardenal Samoré	1,305	Paved
Río Manso	350	Gravel
Futaleufú	335	Gravel
Coyhaiqué Alto	728	Gravel
Huemules	650	Gravel
Ibáñez	327	Gravel
Jeinemeni	305	Paved
Mayer	270	Dirt
Don Guillermo	260	Gravel
Laurita Casas Viejas	90	Gravel
Austral integration	164	Paved
San Sebastián	20	Gravel

In that sense Argentina, Brazil and Uruguay have developed important ports on the Atlantic Ocean, and

Chile has built important port infrastructure on the Pacific Ocean. For this reason, beyond the commitments of forecasting, warning and cleaning the corridor, Argentina has developed a winter system to attend to the enormous problems that winter generates in the area.

El Paso Cristo Redentor links the Republic of Argentina with the Republic of Chile and is the main commercial outlet to the Pacific Ocean. The Corridor also serves a significant number of vehicles originating in the Republics of Uruguay, Brazil, Bolivia, Peru and Paraguay.

The passage is made through a tunnel 3 km long, located at an altitude of 3200 m.a.s.l. Winter conditions affect the route generally from 2,000 m.a.s.l., which impacts five villages: Polvaredas, Punta de Vacas, Puente del Inca and Las Caves. On the route there are 2 Sky centers various winter recreation centers The international traffic is approximately 2,800 vehicles/day. During the month of July 2016, for winter holidays local traffic exceeded 100,000 vehicles, which overlapped with 85,000 international transit vehicles.

Infrastructure:

The Cristo Redentor Andean Corridor has:

- A main camp in Uspallata. 2,080 MASL
- Three high-mountain camps:
 - Punta de Vacas at 2,400 MASL
 - Puente del Inca at 2,700 MASL
 - Las Cuevas at 3,200 MASL
- Two subcamps:
 - Potrerillos at 1,380 MASL
 - Polvaredas at 2,400 MASL

Operations

The corridor has a functioning system, conducted in terms of its opening or closing by the authorities of the National Gendarmerie of Argentina and Carabineros of Chile, who coordinate the information that affects the functioning of this important linkage step.

Also, the technical managers of the Roads of Chile and Argentina, maintain permanent contact, framed in the action plans defined in the Winter Operating Plans, with the activity planned in their territories and a system of collaboration of material, personnel and equipment for emergencies throughout the corridor.

In camps and sub-camps

the clearing teams and improvements of the corridor are prepared, operating with teams of snowblowers,



front loaders, motor graders and all winter equipment. It should be noted that in recent years there has been a re-equipment of all the machinery for the service of the corridor and new equipment is permanently incorporated to meet the operational needs.

The operational management of the winter maintenance of this corridor, as a leader in management, is based on five pillars:

- Meteorology
- Telecommunications infrastructure (Internet, information and real-time images)
- Traffic Maintenance and Rehabilitation Strategies
- Communication with other organizations and services
- User information

In terms of meteorology, a network of weather stations meteorological aspects, a Network of Meteorological Stations owned by National Roads has been installed. This makes it possible to capture information using a set of globalized models for the detection of winter phenomena. Along with this, local and regional forecasts are analyzed, which are dumped into a database to analyze the available information and prepare the set of operations to be developed. This allows operational decision-makers to make the relevant decisions.

This has implied a gradual improvement in the Telecommunications Infrastructure, so as to allow communications and image capture in real time.

As for the Strategies of Maintenance and Rehabilitation of the Transit a set of activities are carried out that are central to the operation of the winter roads. They are synthesized in:

- Routine Tasks - Various Conservation Tasks
- Preventive Tasks - (Proactive)

- Jobs during the storm
- Subsequent Tasks - (Reactive)
- Eliminate rocks or dense elements.
- Passive avalanche control
- Snow fences
- Optimal use of equipment and other resources

Accumulated precipitation during snowfall at road level (mm)	Equivalent height of snow (m)	Fresh-snow avalanche occurrences
30-50	0.3-0.5	Small avalanches occur during storms in some sectors between Puente del Inca and the border. The roadway is not affected.
50-150	0.5-1.5	Avalanches occur during storms between Punta de Vacas and the border. They reach the edge of the roadway between Punta de Vacas and Puente del Inca and moderately affect the roadway between Puente del Linca and the border.
150-250	1.5-2.5	Avalanches are produced during and after storms (in the first 24 hours) and affect the roadway from Punta de Vacas to the border with a significant impact on the road.

It is also planned a system of works in the coming years to modify the infrastructure of the corridor, such as expansion of roads, new tunnels, sheds to avoid avalanches and a set of works to prevent accidents caused by winter phenomena.





the Christ the Redeemer system, but that also have an important transit and commercial relations are the Cardenal Samoré Pass between the Province of Neuquén in Argentina and Osorno in Chile, a paved pass at more than 1300 meters above sea level, which links a wide Patagonian region and which, for orographic reasons, also serves as the regional trade route for vehicles from Chile in internal transit in that country.

There, in the context of the same Winter Operations Plans, a permanent coordination task is carried out between the control and technical authorities of both countries, with similar levels of action commented on in the Christ the Redeemer System, given that this step constitutes the second important step in the mountain range passages system.

A similar situation occurs in the so-called „Paso de Integración Austral” which has the particularity that not only links Argentina and Chile, but also the crossing of the Strait of Magellan in Chilean territory is the link between mainland Argentina and the Big Island, in which there are territories of Argentine and Chilean sovereignty.

In the North of the country the other important step is the one of Jama that links the Province of Jujuy in Argentina, with San Pedro de Atacama in Chile. This pass at 4,200 meters above sea level in the Puna, a low humidity territory, receives transit from Argentina and Chile as well as from Paraguay, Brazil and Peru.

In some short periods it has situations of cuts by winter problems, which forces an action of the fulfillment of the operative plans to avoid the closing of the passage. In addition this step is offered as an alternative to the central steps when the winters are very severe that although it is not permanent throughout the winter,



As for the tasks related to the Antifreeze, the step has 3 Plants of preparation of antifreeze solution: which use Mixes of : Sodium Chloride (ClNa) Calcium Chloride (Cl-2Ca) Cane Stillage (agricultural fertilizer).

In the corridor there are recurrent avalanche production areas and preventive measures are being developed in conjunction with research institutes in these areas to prevent uncontrolled avalanches. For this purpose, there are passive avalanche control actions and active actions, such as the construction of a set of fences.

This runner has 32 teams assigned to the tasks in it. It is therefore very important to make optimal use of the equipment.

For operational purposes the equipment is classified according to: The aspect of interaction with the Other Services Organisms is vital because it points towards a permanent coordination of information and plans of the same.

The operation and relationship is completed with the development of an information network that is manifested in: Emission of Parts of transitability, and Information to the user through the National Roads Web Page, and with a permanent action on the media of massive information.

All this aims to provide the user with the most reliable information on the situation and prospects of transitability along the Corridor.

Given the importance of road traffic in the Corridor, from the point of view of winter road maintenance it is the central corridor in the development of winter system operations in Argentina.

The other important steps that are alternatives to

requires an effective team to release the trace.

In the rest of the steps, prevention and snow clearing tasks are carried out, but given that the transits are smaller, the parameters for releasing the traces is less rigorous than in the four main steps of the system.

The basic equipment for the border crossing system to date is as follows, with a major requirement foreseen for 2017-2018.

Steps	Number of teams affected
Coyhaique	3
Huemules	6
Don Guillermo	3
Dorotea	3
Laurita-Casas Viejas	3
Monte Aymond	8
San Sebastian	24
Rio Encuentro	3
Futaleufu	7
Cardenal Samore	16
Huahum	3
Carirrine	0
Mamuilmalal	4
Icalma	4
Pino Hachado	8
Pichachén	0
Cristo Redentor	23
Jama	13
Sico	6
San Francisco	10
Pircas Negras	8
Total	155

Systems of attention of roads of high mountain.

In addition to the routes linked to the system of border crossings, there is a set of national and provincial routes, known as high mountain routes, where by virtue of existing populations or different types of production, whether agricultural or mining, it is necessary to maintain the roads in traffic conditions.

In general, the Provincial Highways Directorates have adequate equipment and personnel for emergency tasks in which to incorporate winter environmental phenomena.

The prevention system works with warnings from the populations or establishments in the area, together

with the parts of the National Meteorological Service, and the activities are developed on the basis of general and particular protocols of each of the Provinces.

Status of Routes reached by winter effects

Although this sector is related to the previous two, there are situations of snow or ice on the roadway on routes that are not part of the system of passes or high mountain roads.

It should be noted that the length of roads affected by winter phenomena is estimated at 6,400 km, mostly in the south of the country.

Part of the activities are developed by the National Direction of Roads, in some cases with own equipment (2.300km) and the rest with different mechanics of contracting with third parties.

As can be seen in the table, there are several ways of operating Winter Roads shares.

One part is done with its own equipment and personnel, another with a transfer of operational functions with the Provinces (TFO) and other systems such as Crema and Modular through the hiring of companies under the results control system. Since 1990 winter maintenance mainly in the South of the Country, it was through agreements with provinces under the modality of Transfer of Operational Functions, where conditions of transit and the corresponding measurements and payments are established.

This implied a rational use of equipment, given that in certain areas there are national and provincial routes and it would not make sense to have separate emergency teams. There is also a system for exchanging information and experience between the various network operators.

In summary in the entire national network of roads 1,300 km at border crossings and 6400 km in the rest of the network, make a total of 7,700 km of national network, where they assume winter road activities, this in 19% of network. In that length and percentage affect about 400 mobile equipment for winter road maintenance.

The growing importance of winter road maintenance within the strategy of maintenance and transmissibility of the network is complemented by tasks of new purchases of equipment for these purposes. In this sense, an important incorporation of equipment is planned for 2017-2018.



Urban and peri-urban systems affected by winter road maintenance

As in any network, the climatic winter phenomena affect not only the interurban routes of connection, but in certain zones they operate on the urban zones, causing innumerable inconvenient room normal life of the people.

In this sense we must distinguish those urban sectors with eventualities of climatic phenomena, in general of scarce presence, and those others with more daily life in the winter. For phenomena that eventually affect urban areas, in general the municipal and provincial authorities have a system of information to users on the facts and a system of attention with their own equipment for separate the average and all safe roads.

In the North of the country this situation occurs in localities that are served in the concept of routes of Alta Montaña

From the Province of Mendoza (zone of the Cristo Redentor Corridor) to the south there is an important group of towns and cities regularly affected by winter phenomena.

In general terms, Provinces and municipalities assign equipment and personnel prepared for these contingencies and in the most important cities they have equipment prepared for the attention during the whole winter. Cities such as San Rafael, Malargüe, in the Province of Mendoza, Chos Malal, Las Lajas, Zapala, San Martín de los Andes, Villa La Angostura in the Province of Neuquén, have winter operating plans, and protocols for liberating streets and roads in the shortest time possible.

Part of this zone is within the area of the National Parks of Patagonia and there is a system of collaboration between all the National Parks of Patagonia.



Mantenimiento invernadero (Nacional)	
Management	Total km
Administration	2354
Modular system	21
CREMA	1487
Service contract	409
TOF	1876
On-site	173
Total	6320

Incorporation of 2017-2018 teams

Motor grader, 200 HP	53
Front loader, 190 HP, 3m ³	21
230 CV 7m ³ flatbed truck with rear dump, Front loader, 190 HP, 3m ³	52
Pneumatic tractor 160 HP, 4x4 traction	54
Skid steer mini loader, 80 HP	22
Smooth drum combination vibratory compactor	7
Crawler-mounted backhoe 21-tonne, 140 HP	5
Front loader with backhoe, 90 HP	15
Crawler-mounted tractor with bulldozer and ripper, 190 HP	5
6x4 truck tractor, 420 HP	6
35-tonne capacity flatbed trailer	5
4-person mobile homes	5
Horizontal road-marking equipment, cold	1
Horizontal road-marking equipment, warm	3
Truck with full pothole equipment	3
Crack sealer	10
Total equipment	270



Important cities such as San Carlos de Bariloche, El Bolsón, Esquel, among others require and have a winter operating system and a system for cleaning and clearing their streets.

More to the South a group of localities in the Patagonian mountain range require the permanent attention in the winter and in that case the Provinces of Chubut and Santa Cruz, have mounted an operative system to support the clearing in these cities, with additional equipment of the own municipalities.

The same situation occurs in important cities such as El Calafate and Rio Turbio, with a large population and urban development that also serves the Province of Santa Cruz.

Finally, in the Province of Tierra del Fuego, there are two important cities, Rio Grande and Ushuaia, with a large population and the need for a permanent clearing of ice and snow.

There the cities together with the provinces develop the most developed programmed activity with clearing, use of salt and urea and a set of equipments that allow the daily life to work in spite of the low temperatures.

CONCLUSION

Winter phenomena affect a part of the territory, generating problems in the system of international passes, in high mountain routes, in routes in the South of the country and in a group of cities also located in the South of the country, especially in the mountain range area.

Given the system of management of road networks, a main system has been generated, for some important international steps and a system of technical collaboration between the national authorities and the different Provinces. In the last 30 years, this has made it possible

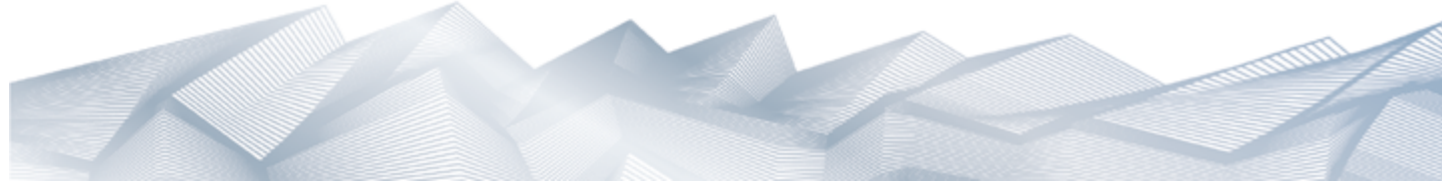
to improve attention to these phenomena and to reduce the cutting times of the main roads.

There is still the task of systematizing experiences, collecting specific data from each of the regions and cities reached, and a deepening of the operating protocols of the networks.

Among the future challenges it is necessary:

- Incorporate new technologies for the management of winter road maintenance, prioritizing by effecting service level.
- Decrease days of disguised transit interruption in winter maintenance, a common goal with the neighboring country.
- Works of road infrastructure friendly with winter maintenance
- The implementation of adequate logistics to optimize resources and make winter maintenance tasks efficient.
- Continue researching new antifreeze products, environmentally friendly, more effective, etc.
- ITS technology (variable signage, cameras, technology weather stations and sensors pavement, temperature and saline residue in roadway)
- Permanent coordination between border crossings and districts, with the aim of maintaining reasonable transitivity between countries.
- Training and exchange of knowledge and experiences.
- Improvements in the Communicational Theme.





1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY



and Hungary, in the south, Slovenia and Italy and in the west, Switzerland and Liechtenstein.

The size of the country is 83,879 km², with a population of 8.468.70 million. The topography is dominated by the Eastern Alps and the Danube area.

Vienna, the capital of the Republic of Austria, is on the eastern part of the country. The city comprises 414 415 km², with a population of 1.731.81 million.

Austria is a highly developed industrialized country with a significant tertiary sector. Chemical and electrical industries, agriculture and tourism are the main parts of the local economy.

The land has an extensive road and railway system. The Vienna International Airport is a central junction for flights between the western and eastern part of Europe.

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

- Wien (Vienna) (1.731.84 million people),
- Niederösterreich (1.621.65 million people),
- Burgenland (0.29 million people),
- Oberösterreich (1.421.45 million people),
- Salzburg (0.530.55 million people),
- Steiermark (1.211.23 million people),
- Kärnten (0.56 million people),
- Tirol (0.710.74 million people) and
- Vorarlberg (0.370.39 million people).

Motorways and federal highways are privately owned by the enterprise ASFINAG. There is a duty for all vehicles. Car and motorcycle holders have to buy a vignette for using the motorways.

Buses and trucks must be equipped with a so-called „go-box“.

The road network system is administered (planning, structural preservation and winter maintenance) by the regions.

FIGURE 1 – REPUBLIC OF AUSTRIA

Austria is situated in the southern part of middle Europe. The neighboring countries are in the north, Germany and the Czech Republic, in the east, Slovakia

1.2. ROAD NETWORK AND TRAFFIC

Area	83,879 km ²	
Population	8.468.70 million	
Length of roads	Motorway	2,1852,208 km
	Regional main roads	9,95910,345 km
	secondary & country roads	23,68023,681 km
	municipal roads	78,766102,463 km
Latitude (capital)	48° 13' 11" N	
Longitude (capital)	16° 22' 12" O	

TABLE 1

The network of the public roads comprises approximately 114,590138,696 km. There are 6.27.29 million vehicles with Austrian traffic certification. 4.54.75 million passenger cars driving an average 12,410 km per year.

2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS

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

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

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

fronts approach the country from Western Europe and the falling rain or drizzle freezes when hitting a thin layer of cold air close to the surface.

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

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

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

The traffic regulations are the legal foundation for all winter maintenance activities. Road operators are responsible to maintain a proper road condition which includes winter maintenance. The winter maintenance procedures on roads are divided in rural roads (table 2) and urban roads (table 3) with 4 (rural) or 7 (urban) different categories.

In case of snowfall or slipperiness sidewalks must be maintained between 6:00 (6:00 am) and 22:00 (10:00 pm). Responsible are the owners of the neighboring properties.

3.2. ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Motorways and federal highways are administrated and operated by the ASFINAG (Autobahn und Straßen Finanzierungs AG). Roads of the countries or municipalities are administrated by the regions (Lands of the Federal Republic), the cities or municipalities. There is no winter maintenance head office in Austria which is giving instructions to the road authorities.

Road Master

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

	Category A	Category B	Category C	Category D
Weather situation, road condition	Highways, Motorways and their junctions	Regional Roads with a daily traffic volume of more than 5,000	Regional Roads with a daily traffic volume between 1,000 and 5,000	Regional Roads with a daily traffic volume less than 1,000
2. Light Snowfall, snow and ice, light snow drifts	Trafficability of all lanes, junctions and access roads to service stations. Treatment with de-icing agents - Complete clearance. Snowy road might occur	Trafficability; Treatment with de-icing agents favoured. Snow depth up to 10 cm possible. Detractions between 22-6 cannot be excluded.	Trafficability; Treatment with de-icing agents or grit; Snow depth up to 10cm possible. Heavy detractions between 20-7 and on Weekend can't be excluded.	Trafficability; Treatment with grit or de-icing agents. Heavy detractions cannot be excluded.
3. Heavy Snowfall, snow drifts	Trafficability of at least one lane per direction, junctions and access roads to service stations between 0-24. Treatment with deicing agents - Complete clearance favoured. Snowy road might occur. Trafficability of parking lots and hard shoulder not ensured. Trafficability if necessary with snow chains.	Trafficability of at least one lane per direction. Treatment with de-icing agents favoured. Heavy detractions due do snow depths of more than 10 cm possible; Trafficability if necessary with snow chains.	Trafficability of at least one lane per direction. Treatment with de-icing agents or grit. Heavy detractions due do snow depths of more than 10 cm possible; Trafficability if necessary with snow chains.	Trafficability of at least one lane if necessary with snow chains. Treatment with grit or de-icing agents. Snow clearance from snow depths of 10 cm (8 to 20 clock).
4. Heavy snow drifts, avalanches, extreme ice (e.g. freezing rain)	Trafficability cannot be ensured. Temporary road closures might appear. Information of road users carried by media and police.			
Winter Maintenance service time	00 - 24 Treatment intervals as required	4 - 22 Treatment intervals as required	5 - 20 Treatment intervals as required	8 - 20 Treatment intervals as required
Time of circulation	max. 3 hours	max. 5 hours	max. 5 hours	-
Annotation	Time of circulation = Time between 2 Treatments, Trafficability = Use by vehicles with winter gear possible, Heavy Snowfall = More than 10 cm in 3 hours			

TABLE 2: WINTER MAINTENANCE CATEGORIES ON RURAL ROADS

	P1	P2	P3
	Inner-city main roads, access roads, roads with bus lines / trams, roads to access public hospitals and fire stations	Roads with minor traffic importance, feeder roads in residential and commercial areas, mountain roads	Roads with minor traffic importance, rural character
Sort of treatment	Ploughing and spreading	Ploughing and spreading	Ploughing and spreading
Service time	4-22	5-22	6-22
Max. snow depth	10 cm	10 cm, more at night	10 cm, more at night
Treatment interval	max. 5 hours	max. 12 hours	max. 12 hours
Treatment with	De-icer favoured	De-icer favoured, if applicable abrasives	Abrasives, de-icer if necessary
Surface condition after treatment	Wet or dry road, slight detractions possible	Wet or dry road, sporadically ice on road possible	Snowy roads and detractions possible

TABLE 3: WINTER MAINTENANCE CATEGORIES ON URBAN AREAS (WEATHER CONDITION: LIGHT SNOWFALLS)

	P4	P5	P6	P7
	Separated cycling lanes connecting neighbourhoods or with significance for commuter traffic	Separated cycling lane as a connection with a local access function or leisure travel	Designated sidewalks, pedestrian areas, school routes, paths in the area of hospitals, stops of public transport within the remit of the local authority	Parking spaces, parking areas, parkways, other trafficked areas
Sort of treatment	Ploughing and spreading	Ploughing and spreading	Ploughing and spreading	Ploughing after other Treatments
Service time	6-19	6-19	6-22	not specified
Max. snow depth	10 cm, more at night	Detractions possible	Detractions possible	Detractions possible
Treatment interval	max. 12 hours	as required	According §93 StVO or §1319a ABGB	none
Treatment with	De-icer favoured, if applicable abrasives	De-icing or abrasive	De-icing or abrasive	De-icing or abrasive
Surface condition after treatment	Dry road, sporadically ice or grit on road possible	Trafficability sporadically ice or grit on road possible	Dry road, sporadically ice or bumps on road possible	According to the possibilities. Restrictions due to snow deposition possible

TABLE 3: WINTER MAINTENANCE CATEGORIES ON URBAN AREAS (WEATHER CONDITION: LIGHT SNOWFALLS)

3.2.3 SPREADING TECHNIQUES

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

The application of prewetted salt (F 30 technology) is common practice (fig. 2). If trucks are not equipped





FIGURE 3 – SNOW CUTTER BLOWER IN THE AREA OF LILIENFELD (LOWER AUSTRIA)

with the necessary devices, it is possible to load a mixture dry salt (stone or vacuum salt) and grit.

With new developments in spreading technique and research projects higher brine rates (50% to 70%) are used in several regions starting 2015. Also combined spreaders capable of spreading pretreated salt or only brine are in use.

Figure 2 – Trucks with plow and F 30 equipment for urban or highway use – Combined spreader for pretreated salt and brine using spreading nozzles



FIGURE 4 – SNOW REMOVAL AT THE GROSSGLOCKNER HOCHALPENSTRASSE

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

Some high-altitude roads remain closed completely during the winter period. Snow clearing activities start in April. For the Großglockner Hochalpenstraße (fig. 4) 25 working days are necessary to remove



FIGURE 5 – TRUCK “FIRESTORM” WITH BRINE SPRAYING DEVICE

600,000 m³ to 800,000 m³ of snow. The snow walls have a height of up to 21 m.

3.2.4 ENVIRONMENTAL CONSEQUENCES OF DE-ICING AGENTS AND GRIT

The use of de-icing agents can have negative repercussions on the environment. On many roads in Austria the use of chlorides is prohibited due to environmental reasons. Some kinds of trees (for example, chestnut or plane tree) are very sensitive to salt or calcium chloride. To reduce the harmful effects to a minimum, it is necessary to use de-icing agents, which are less harmful. In some areas of Vienna potassium carbonate is used instead of sodium chloride.

This is necessary on roads where the spreading of grit is not sufficient to keep the roads safe.

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

3.2.5 ROAD WEATHER INFORMATION SYSTEM

The 9 Lands of the Federal Republic road authorities have special contracts with the weather service institutes. There are several weather forecasts for the whole country, but with consideration of the climate within a small area, a large number of special weather reports are required. Some of the most important weather institutes are:

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

The following weather values are common for road winter service:

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

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

The Austrian roads have over 370 500 ice forecasting systems installed mostly on highways. The measured values are transmitted by leased lines to the road administration. In exceptional cases selecting modems are used. Generally, the stations are set up at the coldest points of the roads and bridges. The determination of the location of new stations takes place through thermal mapping and the experience of the road master or drivers of snowplows.

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

3.2.6 TRAFFIC SAFETY AND ROAD INFORMATION FOR DRIVERS

The individual radio and television stations inform about the forecasted and current weather and the road conditions. Weather information is also available on the internet and for smartphones. Weather cameras are installed on certain points of the whole country. The weather situation can be observed both in the tourist region as well as in the urban areas. Since 2008 winter tires are compulsory on snowy or icy roads between November 1st and April 15th. Even though this



FIGURE 6 – SNOW STOCKPILE

regulation was made most handicaps are caused by insufficiently equipped vehicles.

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

3.2.7 SNOW STOCKPILES FOR URBAN AREAS

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

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

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

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

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

The comparison of typical winter maintenance situations with practical application rates shows a high potential of savings by preventing unnecessary salting. This leads to the question of optimized application rates and winter maintenance strategies for all typical situations that can still be applied in winter maintenance practice. To answer these questions the federal states of Austria, the Austrian highway operating company (ASFINAG) and the federal ministry of Transport (BMVIT) funded a research project at the

Vienna University of Technology. Based on extensive field and lab testing from 2010 to 2012 at the Institute of Transportation the complex mechanical and physical impact of all main factors and their influence on winter maintenance could be discussed with selected personnel completed the verification and implementation of the findings in a comprehensive winter maintenance model. Further results include a compact practical winter maintenance guide and training courses for winter maintenance personnel.

In addition to treatment principles, winter maintenance strategies, application rates, and driving recommendations for typical winter scenarios have been developed. These scenarios consist of clearly distinguishable road conditions and weather development scenarios according to their importance for winter maintenance and road users. These scenarios are given in Table 4 with pictures of typical road conditions and an overview of winter maintenance strategies. The winter maintenance recommendations do not replace local expertise and responsibility of the winter maintenance staff and adaptation of application rates for special requirements (e.g. on bridges, drain asphalt, etc.). However, they encourage a harmonized appraisal of the situation in order to achieve better winter maintenance results.

Based upon the results of this project a follow up projects have been conducted dealing with Current research projects considering new salt application technologies, new de-icing agents and the evaluation of sensor based winter maintenance possibilities decision making. will be finished in summer 2013. As a result, many road authorities use higher brine ratios for prewetted salting. Spreading machines and brine mixing plants are about to become adapted to the new requirements.

A research project funded again by the federal states of Austria, the Austrian highway operating company (ASFINAG) and the federal ministry of Transport (BMVIT) started 2016 and will be finished 2018. The scope of the project is the determination of the physical behavior of salt, brine and prewetted salt on the road. Also the effectiveness of anti-caking agents and the behavior of residual salt on the road are considered. In addition different type of snow ploughs are evaluated.




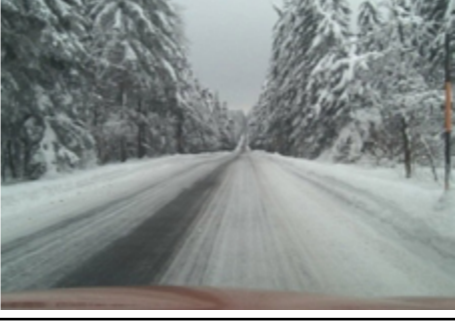

PICTURE DOCUMENTARY	ROAD CONDITION	TREATMENT RECOMMENDATION
	<p>Dry road:</p> <p>No slickness expected Surface temperature: -30°C to +60°C High skid resistance, $\mu = 0,6 - 1,0$</p> <p>Hoarfrost possible or expected (usually at 2 - 4 am)</p>	<p>Minimal salting only at hoarfrost:</p> <p>No treatment required</p> <p>Preventive treatment 5 - 10* g/m² with beginning hoarfrost</p>
	<p>Moist or wet road:</p> <p>Road surface temperature > 0° C Moderate skid resistance, $\mu = 0,4 - 0,7$</p>	<p>Salting at temperatures below 0°C:</p> <p>No treatment required (Watch temperature!)</p>
	<p>Road surface temperature ≤ 0°C Moist road Moderate skid resistance, $\mu = 0,2 - 0,6$</p>	<p>Preventive treatment with 5 - 10* g/m² Before beginning freezing</p>
	<p>Road surface temperature ≤ 0°C Wet road Very low skid resistance, $\mu = 0,1 - 0,6$</p>	<p>Treatment with 20 to 40* g/m² before freezing critical Warning messages if black ice forms!</p>
	<p>Snow next to wheel tracks:</p> <p>No snowfall Wheel tracks free of snow Moderate skid resistance, $\mu = 0,3 - 0,5$</p>	<p>Ploughing and salting:</p> <p>Ploughing and salting with 10 - 20* g/m², to remove remaining snow</p>
	<p>Snowfall less than 0,5 cm/interval Low skid resistance, $\mu = 0,2 - 0,4$</p>	<p>Ploughing and salting with 10 - 20* g/m²</p>
	<p>Snowfall more than 0,5 cm/interval Snow in wheel tracks Low skid resistance, $\mu = 0,2 - 0,4$</p>	<p>Ploughing and salting 10 g/m² (release coating!) until end of snowfalls, then ploughing and salting with 10 - 20* g/m²</p>
	<p>Snow in wheel tracks:</p> <p>No snowfall Road covered with snow Low skid resistance, $\mu = 0,2 - 0,3$</p>	<p>Ploughing and salting:</p> <p>Ploughing and salting with 20 - 30* g/m², to remove remaining snow</p>
	<p>Snowfall less than 0,5 cm/interval Low skid resistance, $\mu = 0,2 - 0,3$</p>	<p>Ploughing and salting with 10 - 20* g/m²</p>
	<p>Snowfall more than 0,5 cm/interval Very low skid resistance, $\mu = 0,1 - 0,3$</p>	<p>Ploughing and salting 10 g/m² (release coating!) until end of snowfalls, then ploughing and salting with 20 - 30* g/m²</p>
	<p>Very low skid resistance</p> <p>No precipitation Road surface temperature ≤ 0°C. Very low skid resistance, $\mu = 0,05 - 0,2$</p>	<p>Salting as required:</p> <p>Preventive treatment if possible, Maximum treatment at critical/icy Spots, Further treatments as necessary</p>
	<p>Black ice and further precipitation (Snow or rain) Very low skid resistance, $\mu = 0,05 - 0,2$</p>	<p>Maximum treatment until ice is cleared Closure of road sections as necessary. Opening after closure only if skid resistance is sufficient</p>

TABLE 4: WINTER MAINTENANCE RECOMMENDATIONS

5. REFERENCES

Magistrat der Stadt Wien, MA 48: Abfallwirtschaft, Straßenreinigung und Fuhrpark
 Amt der Niederösterreichischen Landesregierung
 Asfinag Service Gesellschaft, www.asfinag.at
 Anforderungsniveau für den Winterdienst
 Österreichische Forschungsgesellschaft Straße
 - Schiene - VerkehrDer Forschungsgemeinschaft

Straße und Verkehr

[http://www.grossglockner.at/de/grossglockner/Optimierung der Feuchtsalzstreuung](http://www.grossglockner.at/de/grossglockner/Optimierung%20der%20Feuchtsalzstreuung)
<http://www.bmvit.gv.at/service/publikationen/verkehr/strasse/feuchtsalzstreuung.html>
 Eignungskriterien auftauende Streumittel
https://www.bmvit.gv.at/verkehr/strasse/sicherheit/fonds/vsf/downloads/45_eignungskriterien_streumittel-v2.pdf



1. DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

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

1.2 ROAD NETWORK AND TRAFFIC

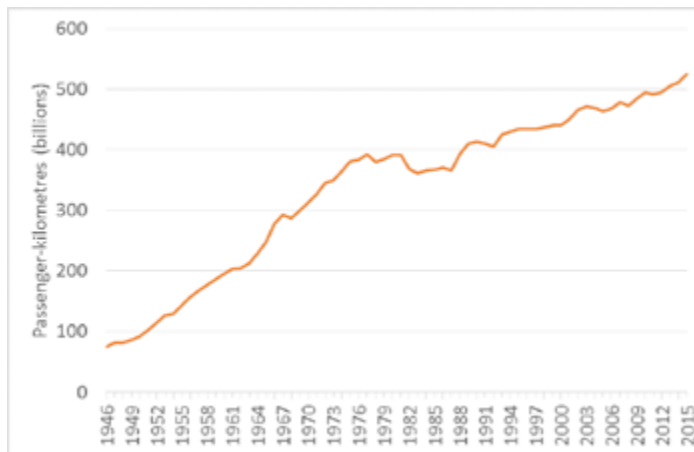
Land Area (2016)		8,965,589 km ²	
Population (2016)		35,151,728	
Population Density		3.92 persons/km ²	
Length of Road ('000 km) [2014]	1,207	Primary highways	100
		Secondary highways	523
		Local roads	584
On Road Vehicles, 2016 ('000s)	24,270	Passenger cars/light trucks/motorcycles	23,126
		Buses	91
		Vehicles over 4,500 kg	1,053
Cars/light trucks per 1000 persons		658	
Latitude (capital)		45°25'N	



Population & Density

2016 Census	Sq km 000s	Population 000s	Pop. Density
Canada	8,966	35,152	3.9
Newfoundland and Labrador	371	520	1.4
Prince Edward Is.	6	143	25.1
Nova Scotia	53	924	17.4
New Brunswick	71	747	10.5
Québec	1,357	8,164	6.0
Ontario	909	13,448	14.8
Manitoba	552	1,278	2.3
Saskatchewan	588	1,098	1.9
Alberta	640	4,067	6.4
British Columbia	923	4,648	5.0
Yukon	475	36	0.1
Northwest Territories	1,144	42	0.04
Nunavut	1,878	36	0.02

The following graph represents the general increase in passenger-kilometres traveled in passenger vehicles

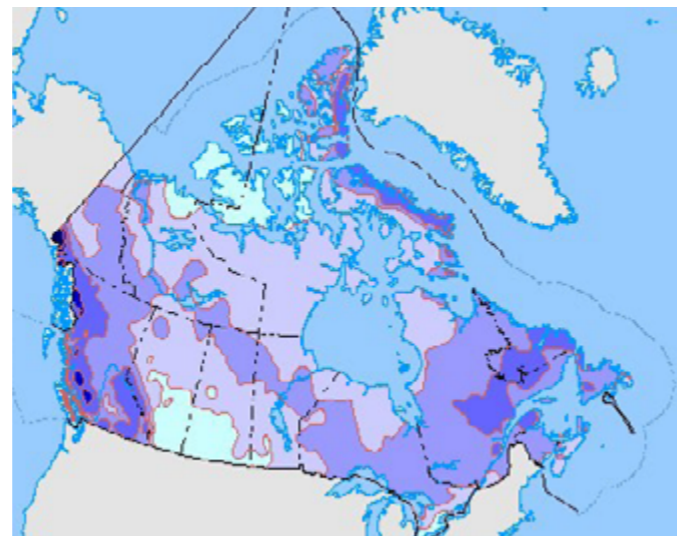


from 1946 to 2015.

2. CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

This map shows the average maximum snow depth in centimeters computed over 18 winter seasons (1979 to 1997). Over southern Canada this usually occurs in January or February, while the time of maximum accumulation occurs much later in mountain areas and in the



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

Arctic. The main features of the map are the pronounced maximum in snow accumulation over the western Cordillera, where snow depths can exceed several meters, with a secondary maximum over Québec and Labrador. These maxima are related to their proximity to oceans, which act as sources of moisture and winter storms, and to the orographic effect of the mountains in the case of western Canada. The two maxima are linked by a band of higher snow accumulation that follows the boreal forest zone; this is a preferred track for winter storms. To the north of this zone is the relatively shallow snow cover of the Arctic (low snowfall with extensive wind packing). To the south, the depth of snow is limited by the shorter accumulation season and the substantial sublimation of snow over the Canadian Prairies.

2.2 STATISTICS ON WINTER TEMPERATURE AND PRECIPITATION

AVERAGE MINIMUM TEMPERATURE (°C)

City	Nov	Dec	Jan	Feb	Mar
Whitehorse	-12.9	-16.5	-19.2	-17.6	-11.9
Yellowknife	-17.5	-25.7	-29.5	-27.5	-22.7



SNOWPLOWING IN CANADA'S MARITIME PROVINCES

Vancouver	3.5	0.8	1.4	1.6	3.4
Kelowna	-2.4	-5.9	-5.8	-5.3	-2.0
Edmonton	-10.6	-16.5	-17.7	-15.9	-10.0
Calgary	-8.2	-12.8	-13.2	-11.4	-7.5
Regina	-10.5	-17.7	-20.1	-17.0	-9.9
Winnipeg	-9.2	-17.8	-21.4	-18.3	-10.7
Toronto	-0.2	-5.8	-9.4	-8.7	-4.5
Ottawa	-1.5	-9.2	-14.4	-12.5	-6.8
Montréal	-1.7	-9.3	-14.0	-12.2	-6.5
Québec City	-4.2	-12.8	-17.7	-15.6	-9.4
Fredericton	-3.0	-10.7	-15.0	-13.7	-7.8
Charlottetown	-0.5	-7.0	-12.1	-11.7	-7.0
Halifax	-0.4	-6.4	-10.4	-9.7	-5.7
St. John's	-0.3	-4.7	-8.2	-8.6	-6.1
Goose Bay	-0.6	-7.6	-22.5	-21.3	-15.4
Iqaluit	-15.8	-25.5	30.9	-31.7	-28.1

BASED UPON CANADIAN CLIMATE NORMALS 1981-2010

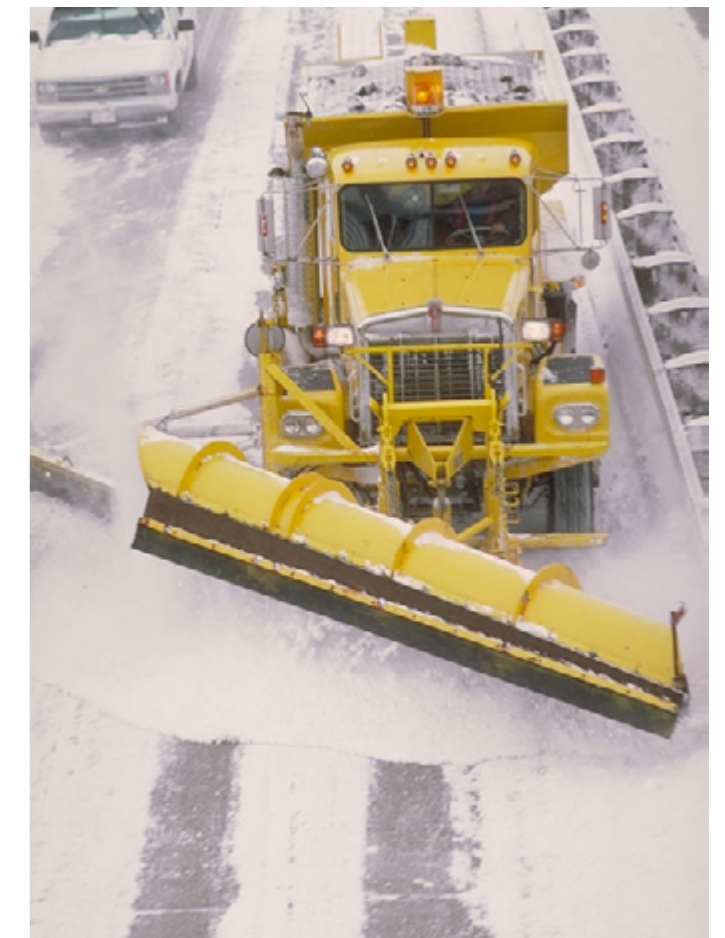
City	Mean Annual Snowfall (cm)	Mean Annual Days with Freezing Precipitation
Whitehorse	141.8	2
Yellowknife	157.6	11
Vancouver	38.1	1
Kelowna	89.0	2
Edmonton	118.1	8
Calgary	128.8	6
Regina	100.2	14
Winnipeg	113.7	13
Toronto	121.5	10

Ottawa	175.4	17
Montréal	209.5	13
Québec City	303.4	15
Fredericton	252.3	13
Charlottetown	290.4	17
Halifax	221.2	16
St. John's	335.0	38
Goose Bay	428.3	13
Iqaluit	229.3	6

BASED UPON CANADIAN CLIMATE NORMALS 1981-2010

2.3 WINTER INDICES

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



SNOWPLOWING IN CANADA © COREL CORPORATION 1994

relate the winter severity with respect to the use of road salts.

3. WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

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

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

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

TYPICAL CANADIAN LEVEL OF SERVICE GOALS

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



TYPICAL CANADIAN RWIS INSTALLATION

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

There are currently over 350 RWIS in operation in Canada. These stations were installed through a coordinated effort between the provinces and territories, Transport Canada and Environment Canada.

Transport Canada worked with key stakeholders, including Environment and Climate Change Canada, the Transportation Association of Canada and provincial and territorial jurisdictions to develop a core set of specifications for environmental sensor stations. This set of specifications ensures that data collection from these stations is consistent across Canada and provides a solid foundation for developing winter road maintenance policies and procedures. Transport Canada supported these specifications by providing matching funding for provinces and territories to install some of the 350 aforementioned environmental sensor stations that make up the cross-Canada Road Weather Information Systems Network.

The provinces/territories have collaborated closely with Environment and Climate Change Canada, and benefited from the support of Transport Canada and

Environment Canada on all aspects of the development of the national network: from the development (and acceptance) of common specifications for the RWIS equipment to common protocols for the exchange of data and metadata. Collaboration continues involving the university sector as well as non-government organizations like the Transportation Association of Canada for the development of winter severity indices and standardized definitions for pavement surface conditions.

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

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

3.3 ASSESSMENT OF SNOW AND ICE CONTROL MEASURES

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

Environmental Management of Road Salts: A Step Towards Sustainable Development

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

tonnes of road salts are used in Canada every winter.

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

CODE OF PRACTICE

On April 3, 2004, Environment and Climate Change Canada published the Code of Practice: road salts environmental management. This Code of Practice, developed with the participation of municipalities and road authorities, recommends that stakeholders compare their current management of road salts with the practices recommended by transportation experts, particularly the Syntheses of Best Practices – Salt Management Plans produced by the Transportation Association of Canada.

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



BRITISH COLUMBIA ANTI-ICING TRUCK

example, wetlands along the roadside).

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

Typical examples of vulnerable areas include:

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

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

The Code of Practice, developed in cooperation with municipal and provincial stakeholders, is a voluntary tool that allows the jurisdictions to implement solutions that are appropriate to their circumstances.

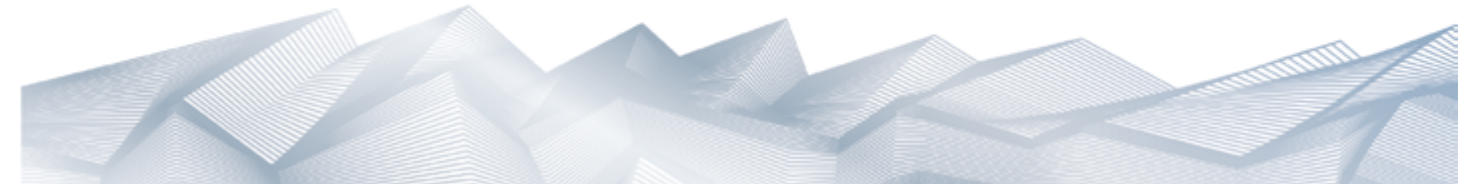
In December 2014, Environment and Climate Change Canada set seven Performance Indicators and National Targets for the Code of Practice for the Environmental Management of Road Salts.

The following results for 2013-2014 have been reported by federal, provincial, municipal and private road organizations that adopted the Code of Practice and are compared with the new National Targets set for 2019 (the last one is set for 2024):

- 196 road organizations including 8 provinces, 178 municipalities, 3 private roadways organizations and 7 national parks reported under the Code of Practice (target is 220).
- 58% annually reviewed their road salt management plan (target is 100%).
- 98% of their road salts are under a permanent roof and on impermeable pads (target is 100%).
- 65% of their treated abrasives are covered (target is 75%).
- 93% of their vehicles are equipped with groundspeed electronic controllers (target is 95%)
- 64% are using pre-wetting or pre-treated salts (target is 95%).
- 63% of their vehicles are equipped for pre-wetting (target is 75%).
- 20% of road organizations have identified their salt-vulnerable areas and have prepared an action plan (target is 95%). This target is set for later, in 2024.

While road salt continues to be the main de-icing medium, some jurisdictions are evaluating other products including beet juice and wood chips mixed with magnesium chloride. The use of these products can help to reduce the environmental concerns associated with road salt.

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



1. DEMOGRAPHICS AND ROADS

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

Geologically speaking, Québec can be divided into three major regions: the Canadian Shield, essentially composed of granite and ancient gneiss; the Lower St. Lawrence clay plain; and the extension of the American Appalachian Range, mostly composed of sedimentary rock. Québec's geography is relatively flat, rarely exceeding 900 meters in altitude. The northern portion of Québec presents tundra vegetation, with soil resting on more or less continuous permafrost. Further south is a taiga zone (299,900 km²), followed by the boreal forest, home to highly diversified wildlife and vegetation (761,000 km²).

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

The St. Lawrence River, which is 3,260 km long and



FIGURE 1 – QUÉBEC ROAD NETWORK

has an annual flow of 12,600 m³/s (near the city of Québec), is a true point of entry to the North American continent.

The St. Lawrence River, which is 3,260 km long and has an annual flow of 12,600 m³/s (near the city of Québec), is a true point of entry to the North American continent. It is on the shores of this river that most Québécois have chosen to live. Although Québec is a pluralistic society, where various cultures live in close contact, 78% of its population speaks French. The inhabited portion of Québec is less than 1,000 km from the major urban and industrial centers of the northeastern United States, constituting a pool of over 100 million inhabitants.

TABLE 1 – DEMOGRAPHICS AND LAND AREA

Population of Québec	8.3 million inhabitants
(80% live in cities)	Life expectancy at birth
Men – 80.2 years	Women – 84.1 years
Population of the Communauté métropolitaine de Montréal (greater Montréal area)	3.9 million inhabitants(1)
Land area of Québec	1,667,712 km ²
Population density	6.4 inhabitants per km ²

(1) 62% in the cities of Montréal, Longueuil and Laval.



In Québec, jurisdiction over transportation matters is shared by the federal and provincial governments. The road network is under the jurisdiction of the gouvernement du Québec, which entrusts the responsibility to the ministère des Transports, de la Mobilité durable et de l'Électrification des transports (the Ministère), while the marine, air and rail sectors fall mainly under the jurisdiction of the federal government.

The towns and municipalities of Québec (1,133 in all) are responsible for maintaining public roads that are used by local vehicles and pedestrian traffic, that is, the streets, avenues and boulevards serving their respective inhabitants.

TABLE 1A - QUÉBEC TOWNS OF 100,000 INHABITANTS AND OVER (2017)

Town/Municipality	Population (M inhab.)
Montréal	1.8 M inhab.
Québec	0.539 M inhab.
Laval	0.429 M inhab.
Gatineau	0.281 M inhab.
Longueuil	0.245 M inhab.
Sherbrooke	0.165 M inhab.
Saguenay	0.145 M inhab.
Lévis	0.145 M inhab.
Trois-Rivières	0.136 M inhab.
Terrebonne	0.113 M inhab.

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



The roads thus classified are used to link together the main concentrations of population, equipment and lands of national and regional importance (Table 2).

Except for the local network, for which Québec's municipalities are responsible (107,000 km), these roads (Table 3) all fall within the Ministère's jurisdiction.

TABLE 2 - THE MINISTÈRE'S FUNCTIONAL CLASSIFICATION

Classification	Characteristics
Autoroute network	All autoroute infrastructure.
National network	Interregional roads and those connecting major agglomerations (> 25,000 inhabitants).
Regional network	Links secondary agglomerations (5,000 to 25,000 inhabitants) and major agglomerations.
Local distributor network	Connects small agglomerations (< 5,000 inhabitants) to larger agglomerations.
Local network	Connects small agglomerations to one another and provides access to private property.
Network for accessing resources	Leads to logging and mining areas, hydroelectricity works and Crown recreational and conservation areas.

TABLE 3 - NETWORK MAINTAINED BY THE MINISTÈRE (2015)

Network	Length(1)	Mean
AADT(2)	Autoroute	6,019 km
13,689(3)	National	9,027 km
3,980	Regional	5,525 km
3,245	Local distributor network	7,835 km
1,590	Access to resources	2,385 km
260	Local	107 km
N.A.	Total	30,898 km

(1) Length: Weighted kilometer (two lanes)
 (2) AADT: Average annual daily traffic. The data do not take local urban traffic into account.

2. CLIMATE

From the 45th parallel along the south and up to the far north, Québec covers 15 degrees of latitude. Its cold, humid climate is largely due to its northern maritime location. Québec's 1,667,712 km² territory has



four types of climate, with wide temperature and precipitation variations.

The arctic climate in the far north is marked by a harsh, very cold, dry winter and a short thaw season. In Kuujuaq, for example, the duration of the frost-free period is only 82 days. Recorded precipitation is low and does not exceed 541 mm per year. This is the lowest in Québec.

The subarctic climate, between the 50th and 58th parallels, typically consists of long, very cold winters and short, cool summers. Precipitation is scarce. The average annual temperature in Chapais and Sept-Îles is close to the freezing point.

The most populous regions of Québec, which are south of the 50th parallel, have a continental climate, characterized by hot, slightly humid summers and cold, rather long winters. The thermal amplitude of this climate is approximately 30°C, and precipitation is abundant throughout the year, usually exceeding 900 mm annually.

The maritime climate of eastern Québec is shared by the Îles-de-la-Madeleine. This climate consists of long but fairly mild winters and short, warm, rainy summers.

OTHER CLIMATE CHARACTERISTICS

- The ground freezes for at least four months to a depth varying from 1.2 m to 3 m. In some areas, the frost period can even last from September to May;
- Winter is the longest season. It affects all of Québec's territory. Depending on the region, it can last on average 18 to 25 weeks, and the number of days of snowfall varies from 70 to over 120;
- Québec receives on average 280 cm of snow every

year. In some mountain areas, accumulation can even reach up to 6 m.

TABLE 4 - TEMPERATURE AND PRECIPITATION(1)

	Montréal (alt. 36 m)	Québec (alt. 64 m)	Baie-Comeau (alt. 21 m)	Fermont (alt. 600 m)
Ave. annual T° (°C)	6.6	4.6	2.7	-3.0
Ave. T° in January (°C)	-10.1	-12.0	-13.3	-22.1
Ave. T° in July (°C)	21.2	19.3	16.4	13.5
Days without frost (T° > 0°C)	213	192	178	118
Annual rainfall (mm)	833	900	787	535
Annual snowfall (cm)	172	272	297	291
Days with snow (n)	78.4	100.5	106.8	-

(1) Climate normals (1981-2010)

3. WINTER ROAD MANAGEMENT

3.1 LEGISLATIVE AND NORMATIVE FRAMEWORKS

The Act respecting Roads provides the framework that guides the Ministère in carrying out its mission. This framework addresses the sharing of road network management with the municipalities. In particular, it establishes the Ministère's jurisdiction over roads, decreed by the gouvernement du Québec, and defines the powers and obligations associated with the management of those roads.

SERVICE LEVELS

During snow removal operations in Québec's larger cities, priority is given to the larger roads (boulevards and main arteries) so that people can move around safely and public transit services can be maintained. After that, priority for snow removal operations is given to feeder roads, which connect residential streets with the main arteries, and to streets near schools, daycare centres, hospitals and public services. Snow removal operations are later carried out in residential and lo-

cal streets. As a general rule, snow removal operations start when the snow accumulated on the ground exceeds a predetermined threshold.

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

TABLE 5 – DETERMINATION OF SERVICE LEVELS

Functional classification	AWDT	Service level
Autoroute	-	Clear road(1)
National road	> 2,500 ≤ 2,500	Clear road(1) Partly clear road(2)
Regional road	> 2,500 ≤ 2,500	Clear road(1) Partly clear road(2)
Local distributor network and roads providing access to resources	> 2,500	Clear road(1)
	from 500 to 2,500	Partly clear road(2)
	≤ 500	Road with a hard snow base(3)

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

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

(3) Roadway whose traffic lanes and shoulders are on a hard snow base at most 3 cm thick. Under favourable weather conditions ($T^{\circ}\text{air} > 3^{\circ}\text{C}$ for more than 48 hours), the level of maintenance is brought up to partly clear road.

In order to deal with certain special situations, the Ministère designates some parts of its network as ecoroads. An ecoroad is a road that is maintained using an alternative form of maintenance during the winter in order to reduce the environmental impact of de-icers on areas sensitive to road salts. This form of maintenance gives precedence to increased scraping and limited used of abrasives in critical areas to ensure road network safety.

The establishment of a winter ecoroad is based on three general principles:

1. The primacy of road safety: the safety of all road users, no matter whom, must remain a priority.
2. Endorsement by the community: any initiative to es-

tablish and implement an ecoroad must be supported by the community (the population and elected officials).

3. The possible repercussions on one or more vulnerable areas.

QUALITY STANDARDS AND PERFORMANCE INDICATORS

The Ministère uses various measures to improve its performance in terms of winter maintenance. For example, it does an annual assessment focussing exclusively on the performance of private sector snow removal on sections of the road network (see 3.3). Also, he is using a winter severity index to establish an objective comparison of winter severity and the consequences on maintenance efforts deployed during a given winter. Based essentially on the weighting of certain climatic conditions (T° , rain, snow, etc.) with impact on maintenance operations in the network, the index makes it possible to compare certain operational data (amount of de-icer used, number of hours worked) and to measure performance.

MATERIALS

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

TABLE 6 – GRADING RANGE SPECIFICATIONS FOR DE-ICING SALT

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

630 μm		11
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TABLE 7 – GRADING RANGE SPECIFICATIONS FOR ABRASIVES

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

AB-5: Suited to abrasives composed of crushed stone.

AB-10: Suited to abrasives composed of sifted sand, crushed stone or crushed or uncrushed gravel.

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

Furthermore, when it adopted its Sustainable Development Act (2006), the gouvernement du Québec instituted, within public administrations, a management framework to ensure that powers and responsibilities would be exercised in the pursuit of sustainable development. That is the backdrop against which the Ministère drew up the Stratégie Québécoise pour une gestion environnementale des sels de voirie (Québec strategy for the environmental management of road salts), urging the various network managers (cities, municipalities and the Ministère) to draw up plans for the environmental management of road salts. The Ministère's plan specifies objectives and actions to be taken with regard to the environmental management of road salts.

MOTOR VEHICLES

In Québec, the Highway Safety Code (HSC) governs the use of vehicles on public roads and, in particular,



FIGURE 2 – PICTOGRAM IDENTIFYING A TIRE DESIGNED SPECIFICALLY FOR WINTER DRIVING

sets the framework for the use of chains and studs on tires on the road network. Their use is authorized from October 15 to May 1 and is limited to certain vehicle categories. In 2008, a regulation on the use of tires designed specifically for winter driving took effect in Québec. This affects all registered passenger vehicles in Québec, including taxis, from December 15 to March 15, inclusively. The tires of such vehicles must display a specific pictogram on their sidewalls certifying that they are designed for winter driving (Figure 2). Otherwise, they must be equipped with studs in accordance with the Regulation respecting the use of non-skid devices.

TABLE 8 – STUDS, CHAINS AND WINTER TIRES – AUTHORIZED VEHICLES

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

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

EQUIPMENT ASSIGNED TO NETWORK MAINTENANCE

Like all motor vehicles in Québec, the equipment assigned to winter road maintenance and its use is sub-

ject to the HSC and to various other laws and regulations:

- The Act respecting owners, operators and drivers of heavy vehicles establishes a framework for road transportation by introducing an administrative system for the registration of owners and operators of heavy vehicles, assigning safety ratings, as well as imposing penalties in the event of offences;
- The Regulation respecting the hours of driving and rest of heavy vehicle drivers forces the operators of heavy vehicles to submit to monitoring of the hours of driving and work performed. Accordingly, to ensure public safety, clear roads of snow accumulations and spread de-icers or abrasives, the driver of a snow removal truck may drive up to a maximum of 13 hours per work shift.

TABLE 9 – SNOW REMOVAL HOURS OF DRIVING AND REST MAIN MEASURES

Obligations	Rules
Driving prohibited if the total number of hours of driving is:	> 13 hours
Driving prohibited if the total number of hours worked is:	> 14 hours
Minimum number of consecutive hours of rest before starting a new work shift	≥ 8 hours

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

Hours of work: Period of time that includes the hours spent driving and performing various duties.

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



FIGURE 3 - LOAD RESTRICTION AREAS

condition;

- The Vehicle Load and Sizes Limits Regulation applies to road vehicles and combinations of road vehicles primarily to ensure the safety of road users and protect road infrastructures (bridges and roads). This regulation sets various standards limiting, among other things, the size and load of road vehicles operated on public roadways. In addition, in the spring, to take into account the reduced load-bearing capacity of the road network during the thaw period, it imposes load restrictions in accordance with three defined areas (Figure 3). Depending on changing weather conditions, the start and end of the load restriction period may be moved up or pushed back.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Ministère's organizational structure consists of an Operational Management Directorate, to which report 59 service centres, spread over 12 different territories of Québec (territorial branch). These territorial units benefit from significant autonomy in terms of resource management and they work together with the regional and municipal organizations in the community.

The responsibility for the network's maintenance falls directly on the service centres, which manage contractual agreements either with the private sector (for 66.1% of the network) or with the interested municipal corporations (for 13.7%). The Ministère and its teams maintain 20.2% of the network. For everyday maintenance work, the Ministère, like the private sector, generally prefers to use three-axle trucks. However, heavy (four-axle) trucks can be used to meet specific operational needs (increased de-icing autonomy, use of specialized equipment, etc.) while complying with the regulations applying to heavy vehicles.

TABLE 10 – SNOW REMOVAL TRUCK

Basic characteristics	Specifications	
	3 axle (6x4)	4 axle (8x4)
Rear axle capacity	18,000 kg	20,860 kg
Front axle capacity	9,000 kg	18,000 kg
Gross vehicle weight	30,000 kg	39,000 kg
Motor	Diesel: 305 kW minimum	Diesel: 330 kW minimum
Rear suspension	Pneumatic	Pneumatic

	Automatic	Automatic
Electronically controlled spreading system	Yes	Yes
Spreader	9 m ³	11 m ³
Snowplow wing	3,657 mm	3,657 mm
One-way snowplow	3,657 mm	3,657 mm
Front mount	Yes	Yes
Light signals	Yes	Yes

These vehicles are called "multifunctional" because they make it possible to (alternately or simultaneously) carry out both snow removal and de-icing operations on the network. This multiple functionality facilitates the synchronization of operations and ensures increased effectiveness. These vehicles are also equipped with an electronic spreading regulator and light signals specific to snow removal operations. These measures, designed primarily to increase the visibility of maintenance operations throughout the network, are also used on other types of maintenance equipment (such as graders and snow blowers) that can be found on the Ministère's primary network.

Naturally, snow removal contracts are awarded by the Ministère according to a regulated process. Such contracts are awarded either through a call for tenders from the private sector or through negotiations with municipalities, which are also network managers (107,000 km).

These contractual agreements, based essentially on performance measurement, are established for one year and include a renewal clause, generally for two additional years. Because the tendered (or negotiated) price is all-inclusive, efficient service providers (municipalities)



palities) can keep the contractual agreement with the Ministère for a maximum period of three years. This approach allows the contractor to better distribute the financial risks inherent to the performance of the contract and the severity of the winters. These agreements generally provide that the service provider will supply the materials necessary for the maintenance of the network (salt and abrasives).

For specific needs, the Ministère rents snow removal trucks with operators. At the operational level, the latter report directly and only to the Ministère and are integrated into existing maintenance teams. These contracts are based on a minimum number of operating hours and the successful bidders do not supply the materials.

OPERATIONAL MANAGEMENT

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

The Ministère monitors the entire network for which it is responsible to ensure compliance with the prescribed expectations. To structure and guarantee consistency in network monitoring practices, the Ministère, through its territorial branches, has a winter maintenance monitoring plan. It defines the guidelines given to the operational units and ensures uniform oversight of road network winter maintenance work, which is done by both service providers and Ministère employees (force account).

The Ministère uses the Guide des bonnes pratiques d'épandage (Guide to best spreading practices) and to the spreading charts in that guide. Those tools enable operational staff to make informed decisions in the context of materials spreading, and to standardize practices. The spreading charts (Figure 4) incorporate the principal road weather notions, and are based on the experience and empirical knowledge that the Ministère's maintenance personnel has acquired. They thus provide a solid foundation with respect to routine winter maintenance operations.

Niveau de service – Dégagée

T° surface	T° air	Trafic	Sécuriser		État de surface attendu
			DJMh > 10 000 véh./jour Circuit complet ¹⁾	Points critiques ²⁾	Circuit complet ³⁾
0°C et plus			Au besoin Sel 50 à 80 kg/km	Au besoin Sel 50 à 80 kg/km	Au besoin Sel 50 à 80 kg/km
0 à -7°C	↑ ↓		Sel 90 à 80 kg/km	Sel 90 à 120 kg/km	Sel 100 à 130 kg/km
			Sel 70 à 100 kg/km	Sel 100 à 130 kg/km	Sel 120 à 150 kg/km
-7 à -12°C	↑ ↓ ↑ ↓		Mix A 150 à 200 kg/km	Sel 120 à 150 kg/km	Sel 120 à 150 kg/km
			Mix A 175 à 225 kg/km	Mix A 200 à 250 kg/km	
			Mix A 200 à 250 kg/km	Mix A 250 à 300 kg/km	Sel 150 à 180 kg/km
			Abxsof 250 à 350 kg/km	Abxsof 250 à 350 kg/km	
-12 à -15°C	↑ ↓ ↑ ↓			Abxsof 250 à 350 kg/km	Sel 150 à 180 kg/km
					Sel 180 à 210 kg/km
			SÉCURISER POINTS CRITIQUES →		Mix A 250 à 300 kg/km
					Mix A 300 à 350 kg/km
-15 à -20°C	↑ ↓			Abxsof 250 à 350 kg/km	Abxsof 250 à 350 kg/km
					Abxsof 250 à 350 kg/km
-20°C et moins				Abxsof 250 à 350 kg/km	Abxsof 250 à 350 kg/km

1. Traitement sur le circuit au départ, au besoin.
2. Traitement des points critiques, incluant les sur-tours glorieux, au besoin.
3. Traitement sur tout le circuit à la fin des précipitations, selon les débits (C) ; traitement sur tout le circuit en cas de perte d'adhérence.
SEL de verre pour ABRASIF de type AB-12 ou AB-5. MIX A 1 : partiel de sel (25 %) pour 3 portions d'abxsof (25 %).
NB : les taux d'épandage et les méthodes sont proposés pour une intensité de précipitation, un temps de parcours du circuit et des vents moyens.

FIGURE 4 – EXCERPT FROM THE SPREADING CHARTS

ROAD CLOSURES

To ensure motorists' safety, the Ministère may decide to temporarily prohibit traffic from using its network. This decision is always taken jointly with emergency preparedness authorities, municipalities and the police forces concerned. The Ministère alone can decide on the right time to re-open roads to traffic.

COOPERATION BETWEEN NETWORK MANAGERS

The diversity of winter issues encountered across Québec and Canada, and the multiplicity of stakeholders involved, require ongoing coordination efforts. In order to promote the exchange of knowledge and training in this field, the Ministère works closely with other network managers facing similar issues. This cooperation gives rise to fruitful exchanges within various transportation associations, such as the Transportation Association of Canada (TAC), the World Road Association (PIARC) Technical Committee on Winter Service and the Association québécoise des transports (AQTr).

It is in this spirit of pooling knowledge and experience that the Ministère, in partnership with the AQTr, leads the Table d'expertise sur la viabilité hivernale. Members of this group come from different backgrounds (clients, industrial partners, educational institu-

tions, professional associations, etc.). Its purpose is to share practices in the field and in particular the results of the work of the PIARC Technical Committee on Winter Service.

ROAD WEATHER AND TRAINING

STATIONARY ROAD WEATHER STATIONS

Thanks to their open-architecture design, the stations, developed entirely by the Ministère, offer much flexibility regarding the selection of the various sensors of which they are composed. This type of station accurately measures the main meteorological and road parameters that have an impact on variations in road conditions. Using a 3m frost depth probe, also designed by the Ministère, the station provides data for the decision-making process related to the vehicle load restriction period on the Québec road network during spring thaw (see Figure 3). Two types of stations have been developed: one offers a complete

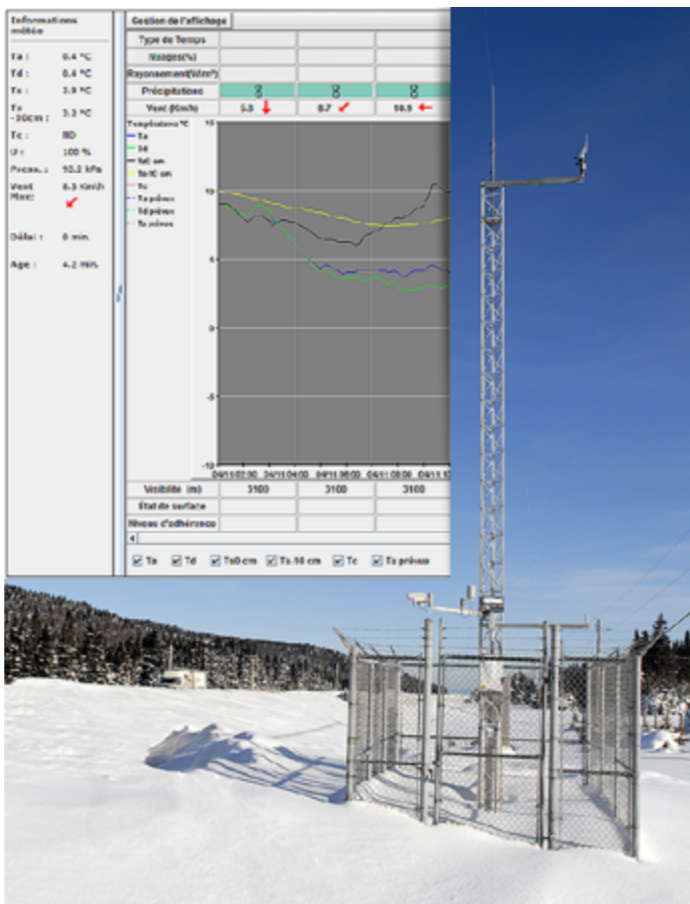


FIGURE 5 – STATIONARY ROAD WEATHER STATIONS AND THE RWIS SYSTEM



FIGURE 6 – MOBILE ROAD WEATHER STATION

range of measurements (see Table 11); the second is a streamlined, less expensive station limited to measuring only certain targeted road and weather parameters that are likely to be needed for specific operational problems.

Today (2017), the Ministère has a network of 53 road weather stations, nearly half of which are equipped with 24-hour cameras that relay weather and road conditions throughout the network to the maintenance staff. To make it easier to manage and interpret the incoming data, a computerized system (SMR) is available to back up the work of the staff assigned to operations. A forecasting segment (weather and road conditions (TS)) is displayed on the SMR system, even though weather forecasting is entrusted to the private sector through tender calls.

MOBILE ROAD WEATHER STATIONS

Also designed by the Ministère, mobile road weather stations (Figure 6) supplement the information collected by the stationary stations. This equipment, which is installed on the Ministère's some 230 patrol vehicles, provides an accurate portrait of the road surface's behaviour along the entire route travelled by the patrol vehicles. Interpretation of the various parameters that are measured allows vehicle operators to anticipate the formation of ice on the road and adjust the spreading strategy if required, based on the data collected.

Table 11 – Functionalities Stationary and mobile stations

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

(1) On some stations

To support the deployment, annual training sessions are offered to the staff assigned to operations within the Ministère, in particular through the intermediary of a network of road weather trainers. The Ministère has also developed a training program on winter road maintenance in cooperation with the Association québécoise des transports (AQTr); it contains a specific segment on road weather conditions. These technical training sessions are available to everyone working on winter maintenance in Québec.

3.3 EVALUATION OF WINTER MAINTENANCE MEASURES

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

TABLE 12 QUÉBEC'S ECONOMY IN NUMBERS

Value of exports (2016)	\$80.3 B
Largest trading partner	United States
Proportion of international exports to the United States (2016)	71% (\$57.1 B)

To ensure sustainability in the winter season, the Ministère allocates over \$260 million annually to direct operations on the road network under its responsibility. Aware of the economic and social issues associated with snow removal on the network and the challenge of managing such operations in the context of scarcity of resources, the Ministère undertakes:

- with the snow removal industry, to reposition and define a better balance with respect to the associated risk. This new balance consists in reducing contract lengths and using different contract management modes during the transition periods between seasons, as well as implementing technological tools, such as GPS, etc.;
- to measure the compliance of the services provided by contractors with the requirements and specifications set out in contractual documents. Accordingly, each winter maintenance route assigned to a private service provider under contract with the Ministère (≈ 66% of the network) is evaluated according to a grid containing 19 quality criteria relating to snow removal and de-icing, communication and collaboration, as well as compliance with the deadlines specified in the contract. Through this approach and those associated with the surveillance and monitoring of its network, the Ministère ensures that, in the field, the highway system's maintenance continues to comply with very high quality requirements so as to ensure safe, functional transportation. Accordingly, since 2005, the Ministère has integrated this indicator into its annual management report, a report that is tabled, in compliance with the provisions of the Public Administration Act, with the President of the Québec National Assembly.

TABLE 13 - INDICATOR - RESULTS ACHIEVED

Result	Rate of compliance with winter road maintenance requirements
2013-2014	89.7%
2014-2015	94.0%
2015-2016	96.6%

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

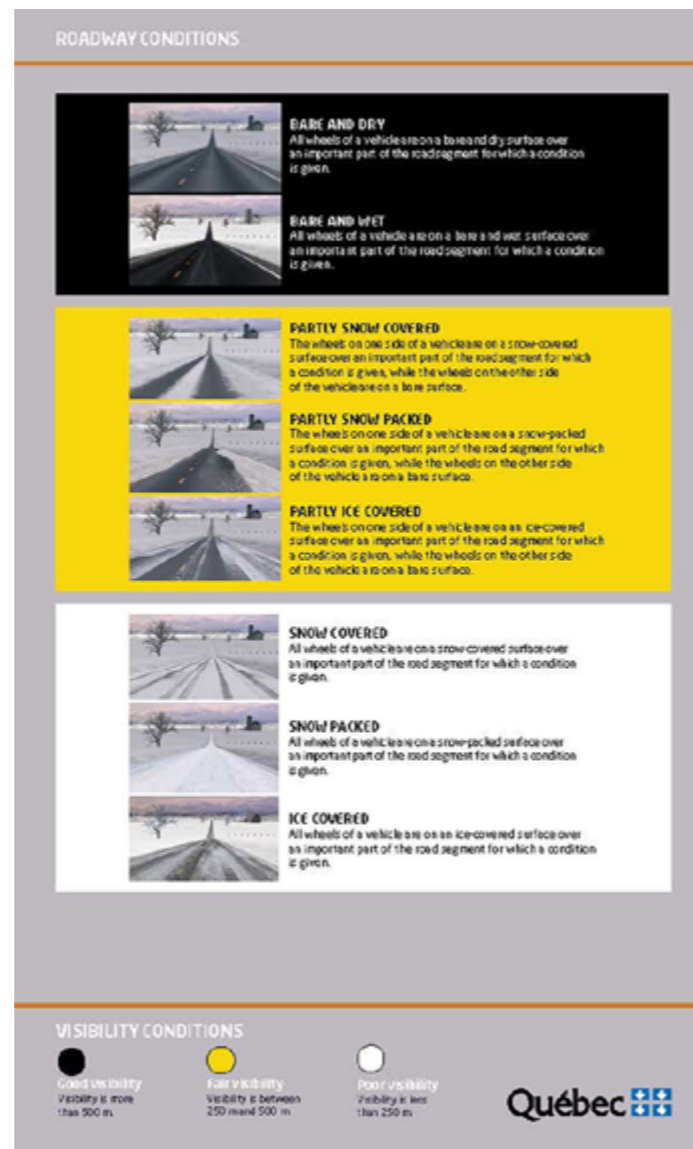


FIGURE 7 - TERMINOLOGY FOR ROAD WEATHER CONDITIONS

3.4 ROAD SAFETY AND USER INFORMATION

With the Ministère's participation, the Société de l'assurance automobile du Québec (SAAQ) conducts an annual awareness and advertising campaign on winter road safety. On the theme "in winter, slow down and keep a safe distance", the general goal of the campaign is to encourage road network users to be prudent by raising their awareness of the risks inherent to driving in the winter, which requires changes to habits. The means of communication include messages broadcast on the radio, news tickers on weather and traffic bulletins, animated banners on the Web and the signage on the whole road network. The Québec 511 website and Radio circulation are also tools that are used.

The Ministère also offers the public and users of the road network the ability to get information on the condition of the highways during the winter and on traffic obstacles. To facilitate access to that information at all times, it provides them with a mobile application, telephone service and the Québec 511 site.

The Ministère has also defined specific terminology to inform users of road conditions (Figure 7).

The terminology for winter road conditions describes road surface and visibility conditions separately. It also indicates the presence of snow drifts that are likely to affect traffic on the network. This approach provides more detailed information and more accurate

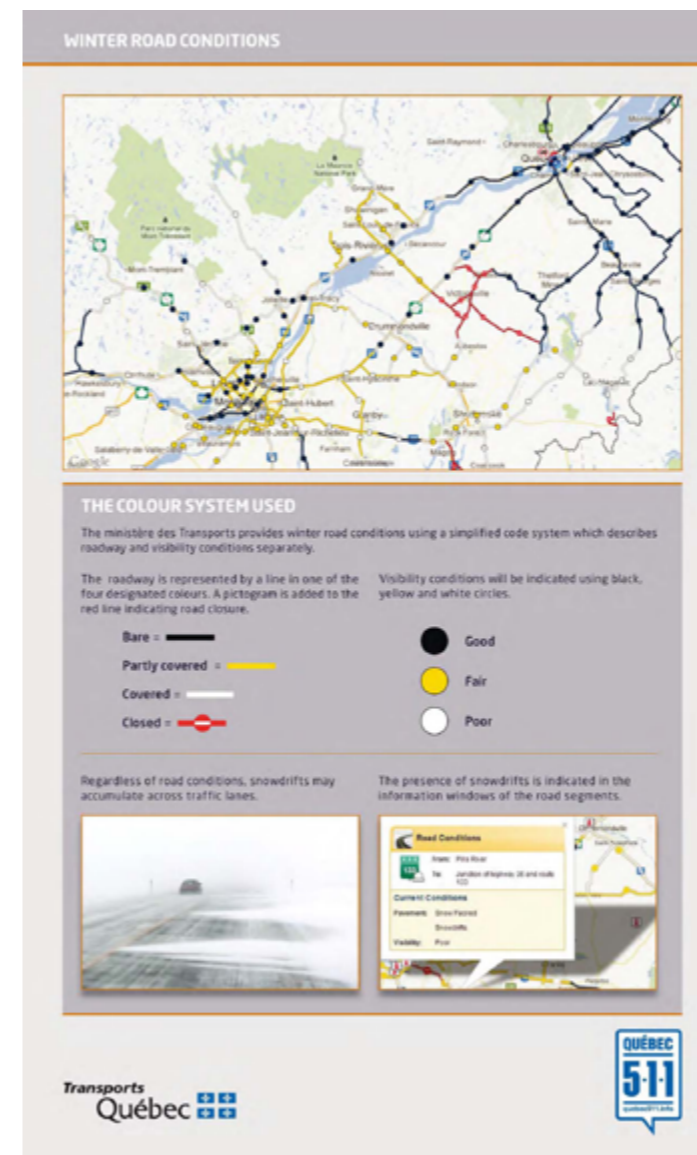


FIGURE 7A - TERMINOLOGY FOR ROAD WEATHER CONDITIONS

te descriptions of road conditions on the road network covered by the broadcast system. A four-colour code (black, yellow, white and red) provides a visual representation of the road conditions that drivers need to take into consideration before travelling.

On the 373 road segments located across the Ministère's network, information on road conditions is gathered using smart phone technology at least once a day and whenever a change in conditions is observed (Figure 7A). The mobile application feeds data into the winter road conditions system (système des Conditions routières hivernales (CRH)), which quickly redirects the information to users, as well as to the general population, through Service Québec 511 Info Transports, and to various specialized media outlets.

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

The Ministère is responsible for the highway system's operation and, as such, must assume a significant share of the responsibilities associated with the assistance to be given to users in trouble and management of the risks associated with such emergency situations. With this in mind, the Ministère has published a guide for members of its staff who are called upon to help road users in trouble, containing various tips on effective and safe ways to act in such circumstances.

INTEGRATED TRAFFIC MANAGEMENT CENTRES

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

As well, on networks with specific difficulties (e.g., high-volume and high-speed traffic; major wind corridor), a simple preventive approach with the user is possible

using pace vehicles or through the establishment of devices prohibiting access to portions of the network deemed risky.

4. ONGOING RESEARCH AND STUDIES

4.1 NEW TECHNOLOGIES

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

- the deployment and use of on-board equipment for vehicles used in particular for snow removal operations and network surveillance. The purpose of the latter is to record all road and/or operational information (geo-tracking, spreading, scraping, etc.), and to transmit that information in real or non-real time to an integrated network management system (vehicular data communication (VDC));
- the utilization of an experimental stationary, open-architecture road weather station to measure the full potential of various sensors and technologies applicable to the field and available on the market;
- development and testing of an automatic system for detecting slippery road surfaces so that warnings can be sent to users and operational teams;
- experimentation with the potential of various sensors for assessing road surface conditions;



FIGURE 8 – NON-INTRUSIVE SENSORS

- experimental use of an automatic brine sprinkling system;
- development of tools and guidelines concerning the use of humidified de-icing materials.

4.2 NEW MANAGEMENT APPROACHES

The Ministère is in the process of examining the management approaches currently used. To this end, it is trying out new contractual approaches aimed at sharing risks differing from those generally identified for snow removal and de-icing work on its network. In this way, using adapted technology, the Ministère hopes to better control maintenance costs on its network and foster the integration of new contractors entering the snow removal market.

For the Ministère, imagination and research constitute dynamic responses to the challenges presented by Québec due to the breadth of its territory and the harshness of its climate. It is by focusing on these elements in particular that the Ministère plans to improve the performance of transportation systems.

5. REFERENCES

- Gouvernement du Québec (www.gouv.qc.ca)
- Ministère des Transports, de la Mobilité durable et de l'Électrification des transports (www.transports.gouv.qc.ca)
- Société de l'assurance automobile du Québec (www.saaq.qc.ca)
- Développement durable, Environnement et Lutte contre les changements climatiques (www.mdelcc.gouv.qc.ca)
- Transportation Association of Canada (TAC) (www.tac-atc.ca)
- Association québécoise des transports (AQTr) (www.aqtr.qc.ca)
- Institut de la statistique du Québec (<http://www.stat.gouv.qc.ca>)
- Bourque, A., and G. Simonet. "Québec," in *Vivre avec les changements climatiques au Canada*, 2007 edition, D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush (eds.), Government of Canada, Ottawa (Ontario), 2008, pp. 171-226.
- Historical Climate Data – Environment Canada (<http://climat.meteo.gc.ca>)



1. DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY



FIGURE 1 - LOCATION OF CHINA

China is a socialist state under the people's democratic dictatorship. Monetary unit in China is Renminbi (RMB). One Dollar was 6.5480 RMB in September 2017. The basic information about China is following:

TABLE 1 – BASIC INFORMATION ABOUT CHINA

Area	Land area	9634057 km ²
	The sea area of jurisdiction	3 million km ²
Population	1354.04 mil. people	
Length of coastline	Continental coastline	18 kilo km
	Islands' coastline	14 kilo km
Geographic coordinates	Latitude (Beijing)	39.9°N.
	Longitude (Beijing)	116.3°E.

Source: <http://english.gov.cn/>; Annual Report of Economy and Development in 2012

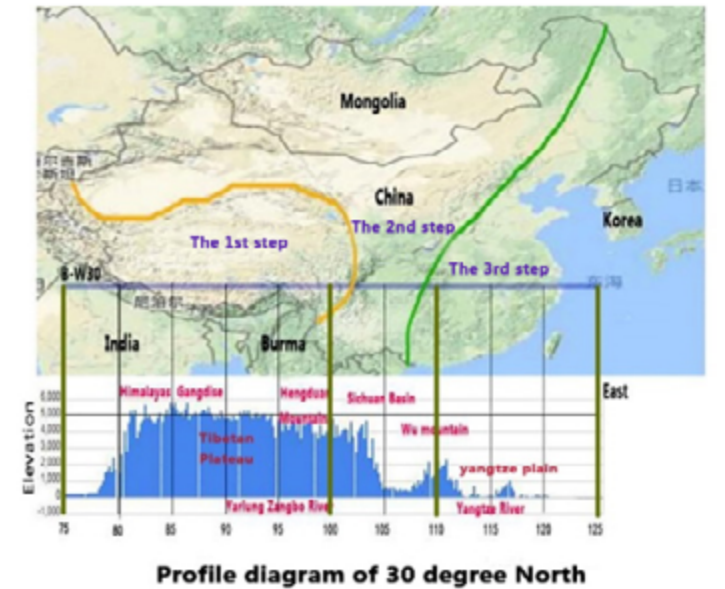


FIGURE 2 - MULTI-TERRAIN MAP OF CHINA

China is topographically high in the west and low in the east, showing the ladder-like distribution which gradually declines from west to east. Elevation of three steps are respectively above 4 kilometers, 1-2 kilometers and below 5 hundred meters (Fig. 2).

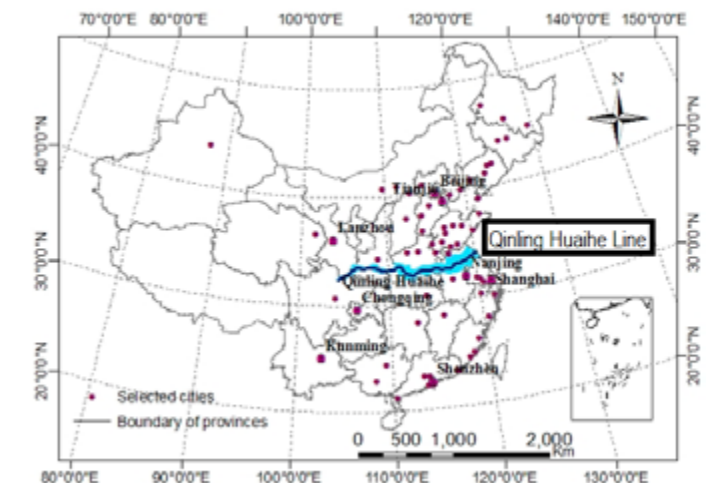


FIGURE 3 - THE QINLING HUIAHE LINE

China has the highest mount “Mount Everest” with the height of 8843.44 meters and the greatest plateau “Tibetan Plateau” with an average elevation above 4000 meters which is called “the roof of the world”.

The Qinling Huaihe line is a reference line used by geographers to distinguish between Northern and Southern China (Fig. 3).

China’s administrative unit is the government and National People’s Congress (NPC) with elections every 5 years. There are 23 provinces, five autonomous regions, four municipalities and two special administrative regions (SARs).

1.2 ROAD NETWORK AND TRAFFIC

In China, road levels are classified according to two different categories: Functional levels and Administrative levels. They are following:

TABLE 2 – ROAD TYPE 1— FUNCTIONAL LEVELS

Road Type	Length of Road
Freeway	4.7 mil. km.
Level 1 roads	98.6 kilo km.
Level 2 roads	371 kilo km.
Level 3 roads	422.7 kilo km.
Level 4 roads	3202.9 kilo km.
Gradeless highway	47.0 kilo km.

TABLE 3 – ROAD TYPE 2 — ADMINISTRATIVE LEVELS

Road Type	Length of Road
National roads	354.8 kilo km.
Provincial roads	313.3 kilo km.
County roads	562.1 kilo km.
Village roads	1147.2 kilo km.
Township roads	2250.2 kilo km.

Source: Ministry of Transport: The 2016 yearly National Statistic Gazette of the Ministry of Transport. (NSGMT)

As the length of highways is increasing, transportation volume is also growing rapidly. According to NSGMT, by the end of 2016, there have been 840 thousand passenger vehicles and 13.52 milo. freight vehicles, which contributed to 15.4 billion passenger capaci-

ty and 33.4 billion freight volume.

2. CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

China’s climate is dominated by dry and wet monsoons, which makes for clear temperature differences between winter and summer. In summer, influenced by warm and moist winds from seas, most parts of the country are hot and rainy. In winter, the cold and dry winds blowing from the continental land-mass towards the seas are prevalent, so most parts, especially north parts of the country, are cold and dry.

2.2 EFFECTS OF MAIN WINTER EVENTS

In ten years between 2005-2014, Chinese transportation construction was booming with the miles of traffic length leaping from 1.93 mil. km to 4.46 mil. km. Accompanied by increasing transport volume, the number of traffic accidents is increasing too. Variations in traffic safety parameters like road friction coefficient and driving sight distance are largely decided by the weather (Fig. 4). Bad weather has always been one of the main factors leading to traffic accidents (Guicai Ning et al, 2016).

The existing research conducted by Harold (1988) has explained that the possibility of traffic accidents on rainy days is 2-3 times higher than that on sunny days but in snowy days, it will increase to as much as 14 times. And the study conducted by El-Basyouny (2012) has shown that daily snowfall and precipitation has a positive correlation with car crash which can be seen in table 4.

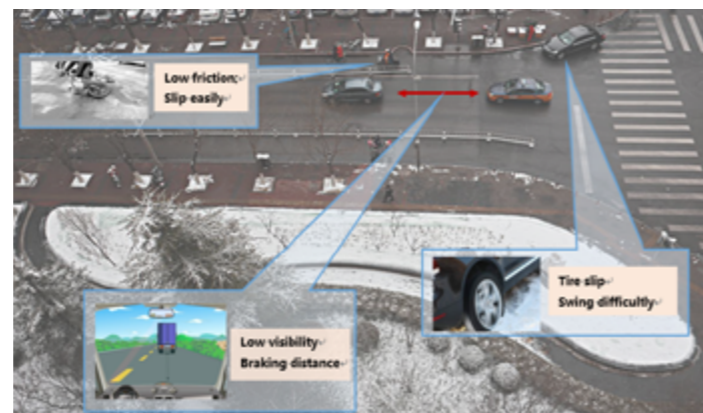


FIGURE 4 - POSSIBLE DANGEROUS ON ROADS IN SNOW DAYS

TABLE 4 – BAD WEATHER EFFECTS ON TRANSPORTATION

Index	Weather	Rain	Snow	Hail	Fog	Wind	Sand
TNTA		248939	19932	43	16742	1644	483
Ratio of TNTA (%)		86.5	6.93	0.01	5.82	0.58	0.17
TELTA/1 million RMB		1424.39	161.45		233.91	8.86	2.11
Ratio of TELTA(%)		77.8	8.82		12.78	0.48	0.12
AELEA/RMB		5721.85	8100.11		13971.40	5390.11	4367.33
TNIA		297737	24097	57	20497	1765	537
Ratio of TNIA		86.38	6.99	0.02	5.95	0.51	0.16
ANIEA		1.2	1.21	1.33	1.22	1.07	1.11
TNDA		67174	6198	19	7854	599	220
Ratio of TNDA		81.86	7.55	0.02	9.57	0.73	0.27
ANDEA		0.27	0.31	0.442	0.469	0.364	0.455

TNTA: The total number of traffic accidents
 AELEA: Average economic loss in each accident
 ANIEA: Average number of injuries in each accident
 ANDEA: Average number of deaths in each accident

TELTA: Total economic loss of traffic accidents
 TNIA: The total number of injuries in accidents
 TNDA: The total number of deaths in accidents
 (Guicai Ning et al, 2016)

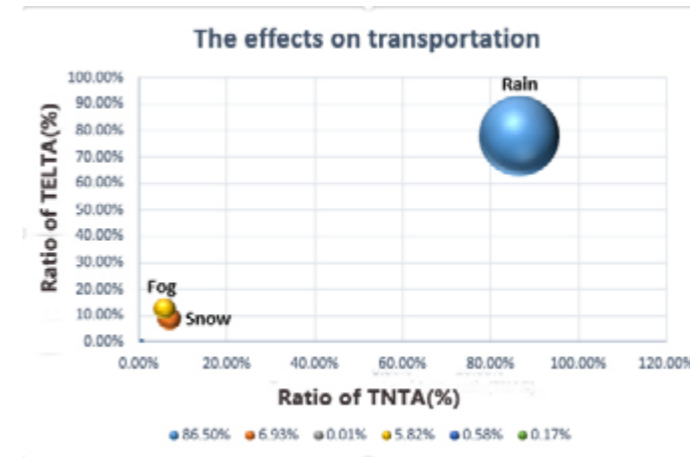


FIGURE 5 – WEATHER EFFECTS ON TRANSPORTATION

After analyzing the characteristics and economic loss of traffic accidents (Fig. 5), the meteorology department and traffic bureau cooperate with each other to reduce costs of the accidents.

From the Figure 6, we can see that the number of accidents decreased annually except 2008. Influenced by La Nina event in the Tropical Pacific Ocean in 2008, China experienced a once-in-a-century ice storm. The great freezing rains and snows in the south of China caused a countless economic loss and more than one billion people were affected. (Guicai Ning et al, 2016).

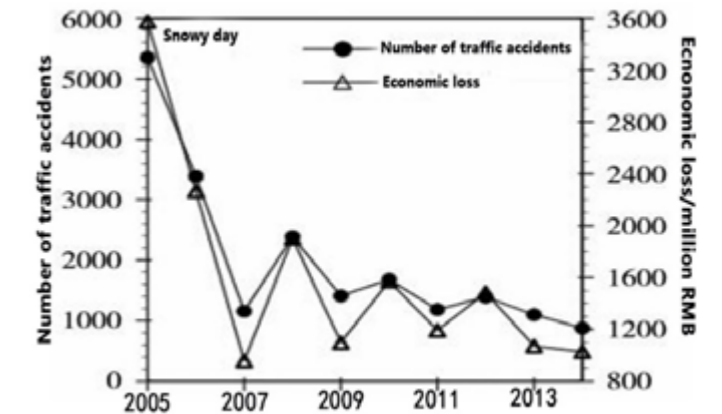


FIGURE 6 - VARIATION IN THE NUMBER OF TRAFFIC ACCIDENTS AND THEIR ECONOMIC LOSS

2.3 STATISTICS ON TEMPERATURE, ICING, PRECIPITATION

China has a large span of latitudes. The amount of heat from solar radiation received by a place in China depends on where it is. According to large amounts of temperature data, China is divided into 5 temperature zones (Fig. 7) and each of these zones has its own climate. We select 12 cities to give a brief but representative description of China’s climate. Different places have different amount of snowfall. The study conducted by Danwu Zhang et al (2016) has shown the distribution of snow in China during the past five decades.

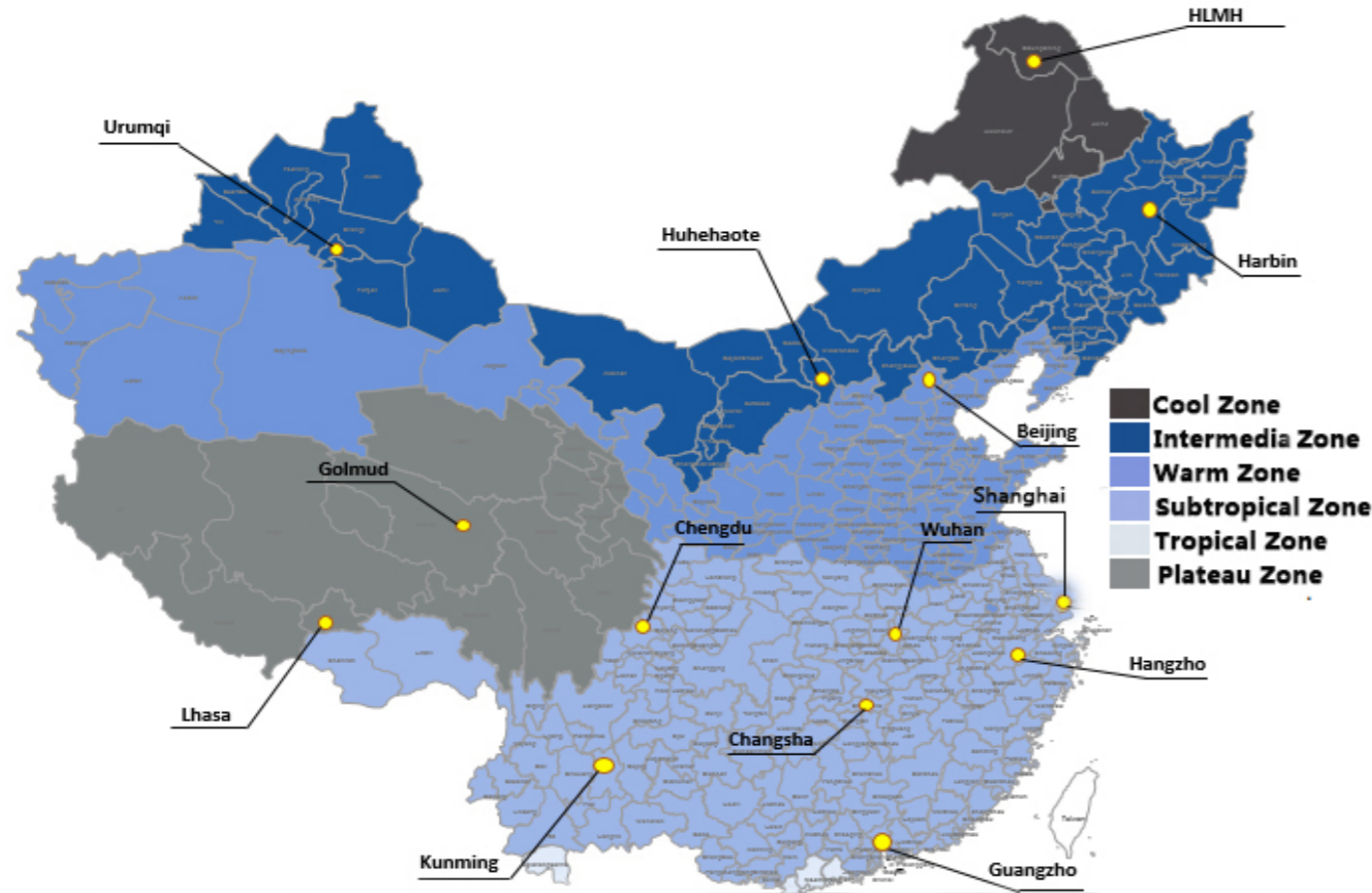


FIGURE 7 - THE TEMPERATURE ZONE OF CHINA

TABLE 5 -TEMPERATURES AND PRECIPITATIONS IN CHINA (34-YEAR AVG., 1980 - 2014)

Station	Temperature/°C		Precipitation/mm		Freezing Index/°C days
	TMAX	TMIN	PRCP	EMXP	AFIA
Mohe	25	-36	491	57	3575
Harbin	26	-23	558	43	1660
Beijing	32	-6	628	161	220
Hangzhou	33	6	1463	93	3
Wuhan	32	4	1364	140	5
Chengdu	31	6	628	82	0
Guangzhou	33	13	1920	166	0
Lhasa	23	-7	286	69	101
Urumqi	29	-15	186	72	1089
Huhehaote	28	-15	480	103	878
Shanghai	31	3	1194	125	3
Kunming	25	3	596	81	0
Changsha	34	4	1465	97	4
Golmud	24	-13	39	21	732

TMAX: THE MAX OF THE YEARLY AVERAGE TEMPERATURE TMIN: THE MINIMUM OF THE YEARLY AVERAGE TEMPERATURE
 PRCP: THE YEAR AVERAGE PRECIPITATION EMXP: THE MAX PRECIPITATION OF THE WHOLE YEAR AFIA: AVERAGE FREEZING INDEX

As we can see in Figure 8, there are four places which have more snowfall than others: the north and the east of northeast China, north of Tianshan Mountains, Tibetan Plateau, the middle and lower reaches of the Yangtze River (Danwu Zhang et al, 2016). In these areas, we should pay much attention to traffic safety during winter days.

3 WINTER ROAD MANAGEMENT

3.1 HISTORY AND BACKGROUND OF SNOW AND ICE CONTROL PROGRAMS

According to the latest Technical Specification of Maintenance for Highway in China, measures of preventing roads from being damaged by snow and ice should be based on local situations. When it comes to major engineering projects or some important roads vulnerable to ice and snow, emergency plans should be built up in advance.

Winter season in Heilongjiang province is cold and lasts a long time. Every year from the beginning of November to the following March, Heilongjiang province is covered constantly by snows (Bing Leng et al, 2015). Based on the specific situation in this province and combined with maintenance requirements on roads of some other areas in winter, the following article

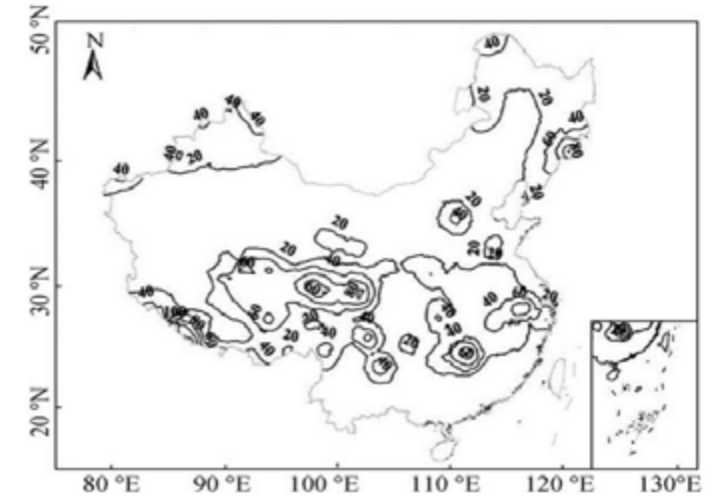


FIGURE 8 - THE SNOWFALL DISTRIBUTION OF CHINA (PICTURE REDRAWN FROM J TSINGHUA UNIV)

briefly summarizes China winter road management. The general process is shown in following flow chart: (Fig. 9)

3.2 BEFORE MAINTENANCE 3.2.1 ROAD SURFACE MANAGING

Road Surface Roughness (RSR) refers to the deviation of the road unevenness which is considered to be an

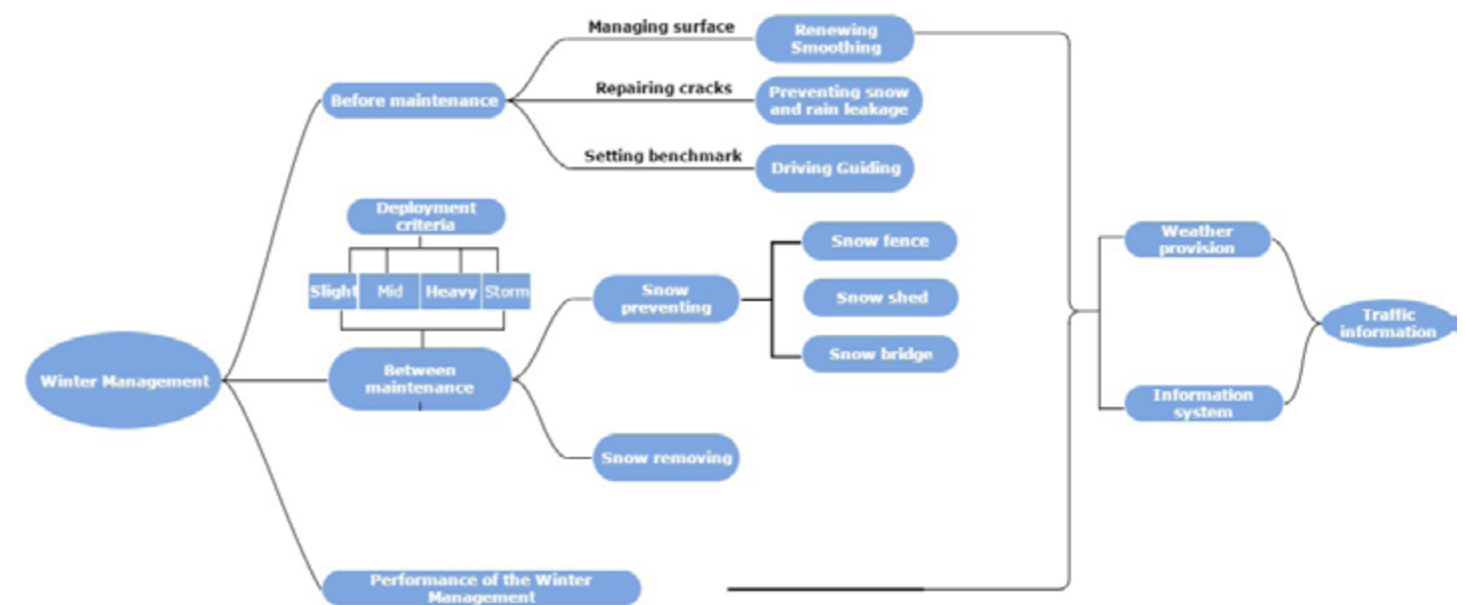


FIGURE 9 - FLOWCHART OF PROCEDURES FOR ENSURING ROAD TRAFFIC SAFETY IN SNOW DAYS



FIGURE 10 - TURNING OVER AND SIDE SLIPPING

important parameter in the road evaluation and road surface construction. It is closely related to traffic safety and comfort and determines the size of the impacting force on roads. If the road is uneven, vehicle vibration will occur, which increases driving resistance and affects driving speed and safety. Meanwhile, the effect of vibration can also exacerbate wear and tear between roads and vehicle tires.

Especially in winter, vehicles on roads are easily out of control due to vibrations and then accidents like roll-over and rear-end collision will happen. (Fig. 10)

To decrease the vibration effect, China takes some measures to ensure the pavement smoothness before winter road maintenance. These measures consist of controlling top elevation of roads, improving constructions of Asphalt Mixture Surface Course etc. (Fig. 11)

3.2.2 ROAD CRACKS REPAIRING

Crack is one of the most common damages to roads which cannot only affect road appearance and driving comfort, but also cause structure damages and short lives to roads. Especially on snowy days, melted water will flow into cracks among roads. Under the influence of thermal expansion and contraction effect, the expanding water will enlarge cracks and thus cause destruction of the whole pavement structures.



FIGURE 11 - GROUND LEVELING AND CONSTRUCTIONS OF SURFACE



FIGURE 12 - ROAD CRACKS REPAIRING

Crack tackling procedures will be divided into two stages: crack detecting and crack repairing. (Fig. 12)

3.2.3 BENCHMARK SETTING

In sections of roads that are susceptible to snow damages, guide poles are set on flanking sides of the roads as traffic guide signs. (Fig. 13)

3.3 DURING MAINTENANCE

3.3.1 LEVEL OF SERVICE (LOS)

According to classification of China meteorology



FIGURE 13 - ROAD GUIDE MARK

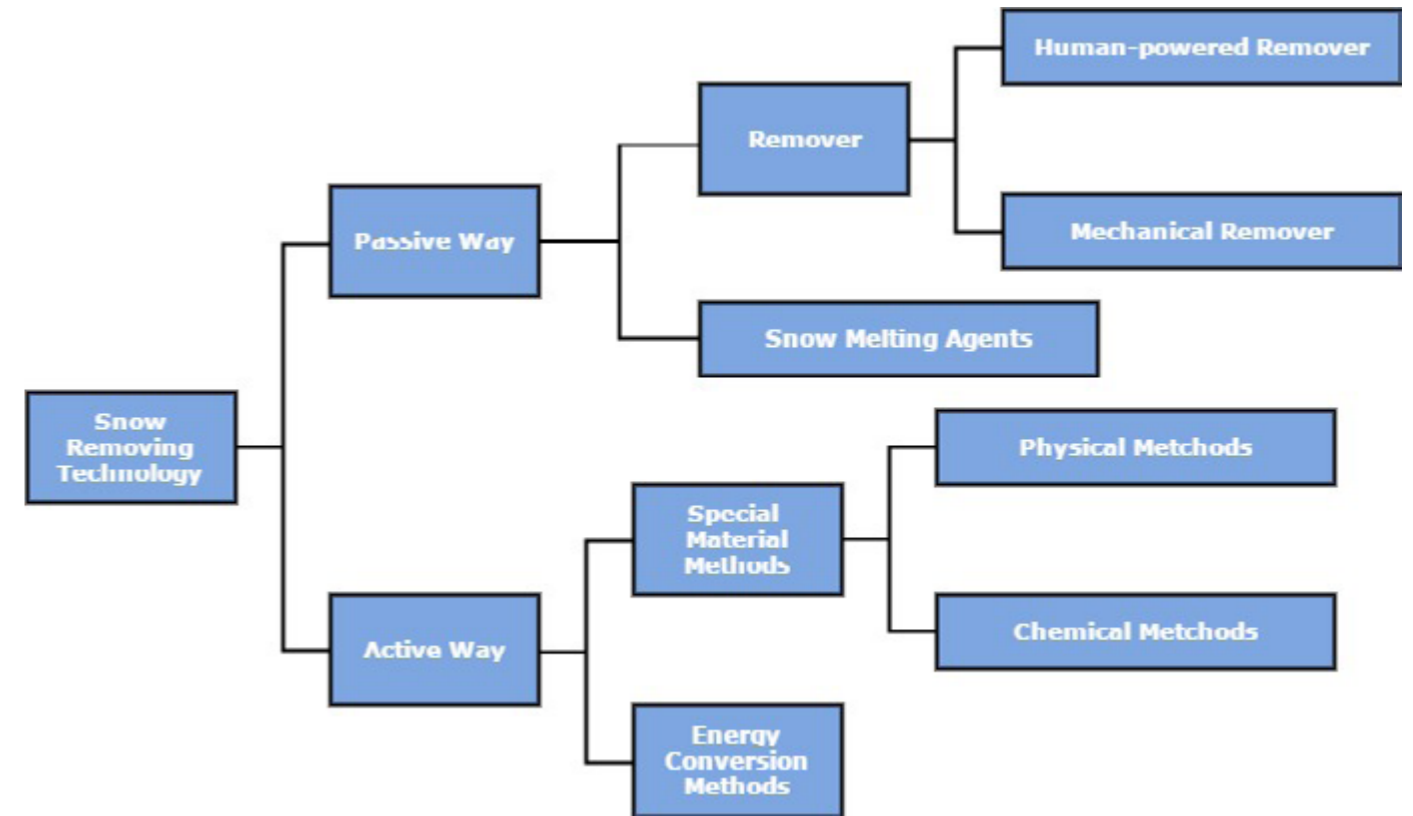


FIGURE 14 - PROCEDURES DURING MAINTENANCE (PICTURE REDRAWN FROM HIGHWAYS & AUTOMOTIVE APPLICATIONS, 2013)

department, the size of snow can be divided into four types: slight snow, moderate snow, heavy snow and blizzard. The depth, pressure, shape and density of snow can all be factors affecting qualities of road surface. Hence different level of snow causes different level of destruction. The Ministry of Transportation sets deployment criteria for each type of snow level. The LOS initiated in Shijiazhuang city is as follows (Table 7).

TABLE 6 – THE DEFINITION OF SNOW LEVELS

Snow level	Definition			Warning type
	P 12(mm)	P 24(mm)	SD(cm)	
Slight snow	(0,1)	(0,1,2.5)		Blue
Moderate snow	(1,3)	(2.5,3.5)	3.5	Yellow
Heavy snow	(3,6)	(5,10)	5.0	Orange
Blizzard	(6,∞)	(10,∞)	8.0	Red

P12: Precipitation in 12 hours P24: Precipitation in 24 hours SD: Snow depth

TABLE 7 – CRITERIA FOR DEPLOYING SNOW- AND ICE-CONTROL OPERATIONS

Snow level	Warning type	Emergency measure								
		EmA	EmB	EmC	EmD	EmE	EmF	EmG	EmH	EmI
Slight snow	Blue	█	█							
Moderate snow	Yellow	█	█	█						
Heavy snow	Orange	█	█	█	█					
Blizzard	Red	█	█	█	█	█	█	█	█	█

TABLE 8 – EMERGENCY MEASURES OF EACH LEVEL

Classes	Emergency measure
EmA	All the personnel and vehicles are in place.
EmB	The third department decides to start.
EmC	The second department decides to start.
EmD	The first department decides to start.
EmE	All the snow melting vehicles should load the snow melting agent in less than two hours.
EmF	Strengthen road cleaning, the inspection of bridge and drainage.
EmG	Professional snow melting group begin to implement snow melting in less than one hours.
EmH	The city's snow cleaning headquarters organize their personnel and machinery to carry out the snow clearance.
EmI	The governments, the snow control headquarters, the units at all levels pool the strength of all quarters into snow clearance.

(Bing Leng et al, 2015)

3.3.2 SNOW PREVENTING

SNOW FENCES

The speed of snow and wind drift will be blocked when it flows across snow fences, forming a weak-wind zone. In these zones, most of snow deposits before snow fences while only a little flows across the top of fences, which will reduce snow damages to the roads.

SNOW SHEDS

Snow shed is a type of rigid snow-supporting structure for avalanche control. It can be made of steels, pre-stressed concrete frames, or timbers.

SNOW BRIDGE

Snow bridges may superficially look similar to snow fences, but they act differently. Snow fences are built vertically and accumulate snow on their downwind side, while snow bridges are slanted or horizontal and hold snow on their top side.

SNOW-BREAKING WOODS

Snow-breaking woods (Fig. 15) slow down the snow drift and catch snow grains carried by winds, preventing them from blowing to roads. This snow-proof measure is cost-efficient and environmentally friendly. The



SNOW FENCE SNOW SHED
FIGURE 15 – SNOW CONTROL MEASURES



FIGURE 16 – PEOPLE ARE MOVING SNOW

location of woods and its planting numbers should be decided by wind direction and snow level.

3.3.3 SNOW REMOVING PEOPLE-USING REMOVERS

During every winter in Harbin, people use shovels to shovel snows, moving them from the middle of the roads to sides (Fig. 16). This way is flexible but also has some disadvantages: long operating time, low work ef-



PLOW SNOW REMOVER SNOW REMOVAL GRADER
FIGURE 17 – SNOW REMOVING MACHINES

iciency and consuming large amounts of manpower. Besides, traffic can also be affected by these working people.

MECHANICAL-USING REMOVERS

When temperature is low and snowfall is big, using mechanical devices to remove snow and ice is very efficient. From 1980 of the 20th century, the development of snow removers was started in China and today there have been three widely-adopted categories: plow snow remover, rotary snow remover and snow removal grader (Wei Hao et al, 2008) (Fig. 17).

TABLE 9 – DIFFERENT KINDS OF SNOW REMOVERS

Categories	Qualities and advantages
Plow remover	Low cost, high reliability
Rotary remover	Multifunction
Road grader	Small workspace

Except in winter, these devices will be put aside in the most part of the year and their short lifespans also need high maintenance costs.

SNOW MELTING AGENTS

Large grains of snow can be removed by mechanical devices but for those small ones, it doesn't work. Snow-melting agents are efficiently applied to reduce those small snow grains. These agents can lower freezing point of snow. The solid forms of snow grains turn into water and flow into drainage systems. Nowadays, common snow melting agents can be classified into three



FIGURE 18 – SNOW-MELTING AGENTS



FIGURE 19 – SPRAYING SNOW-MELTING AGENTS

kinds (Tab. 10).

TABLE 10 – DIFFERENT KINDS OF SNOW-MELTING AGENTS

Categories of anti-freezing agents	Advantages	Disadvantages
Chloride salts agents	Low costs; abundant sources;	Pollution and corrosion
Non-corrosive agents	Non-corrosion; non-pollution	High costs; Large amounts of oxygen
Organic activity agents	Non-corrosion; non-pollution; high efficiency; convenient; low costs	

USING SPECIAL MATERIALS

Snow melting technology of elastic road is to add some special materials in the laying periods of road (Zhibin Han, 2013). In winter, weight of cars and their pressure will stimulate those special materials, making them generate heat, thus melting snows. Though this way is advanced, these special materials cost so much. It's so difficult to maintain such roads and as time goes on, roads will be damaged and its effect of melting snow will disappear.

ENERGY CONVERSION METHODS

Melting snow by energy conversion is the way that we use other forms of energy (geothermal, solar and electric energy, etc.) to generate thermal energy (Zhibin Han, 2013). And this thermal energy can transfer



FIGURE 20 – SNOW-MELTING ROADS

up along underground pipes to road surface and then melts snows. This snow melting way can be divided specifically into two stages: energy saving and energy emitting. In summer, we can use energy storage device to gather thermal energy and in winter, these energies will be released.

3.4 PERFORMANCE OF WINTER ROAD MANAGEMENT

In December 2011, the completion of Dawu Bridge Group adopted the technology of conductive concrete deicing. The project was located in Hubei province, consisting of two closely tunnel bridges and wiring project, a total length of 3.7 km. It effectively prevented the bridge from icing and ensures the safety passing vehicles.

In November 2012, a viaduct of a highway in Hunan Province used anticoagulant ice material SMA-16 asphalt. It's 120 meters long with two ways and six lanes.



FIGURE 21 - THE BRIDGE WITH CONDUCTIVE CONCRETE DEICING TECHNOLOGY



FIGURE 22 - THE BRIDGE DECK WITH (LEFT) AND WITHOUT ANTI-ICING MATERIAL (RIGHT)

The width of a single bridge is 15.75 m.

It can be seen from the contrast of figure 2 and figure 3 that the effect of ice and snow prevention on the bridge deck with SMA-16 is obvious. The bridge without anti-icing material is covered with snow severely, which has great security risks.

3.5 TRAFFIC SAFETY & INFORMATION

Landscapes and climates in China vary from region to region and it's difficult to design any competent system that can accurately report current traffic information.

So each of the following two systems: weather information system and traffic information system has its own disadvantages which requires further development.

3.5.1 WEATHER INFORMATION SYSTEMS

Based on historical data and satellite cloud images, China meteorology administration has been running a portal website which is connected to personal mobile phones. This website can provide you some information about current temperature, precipitation, wind velocity, etc. According to this up-to-date weather information, drivers can change their driving behaviors to avoid accidents.

Due to the fact that traffic accidents always happen in snow days, early-warnings will be presented on this website and different warning colors will be used as a signal to remind drivers to drive carefully.

When it comes to some important routes vulnerable to snow damages, suggestions like driving slowly or choosing other routes will be given to drivers via internet and broadcast.

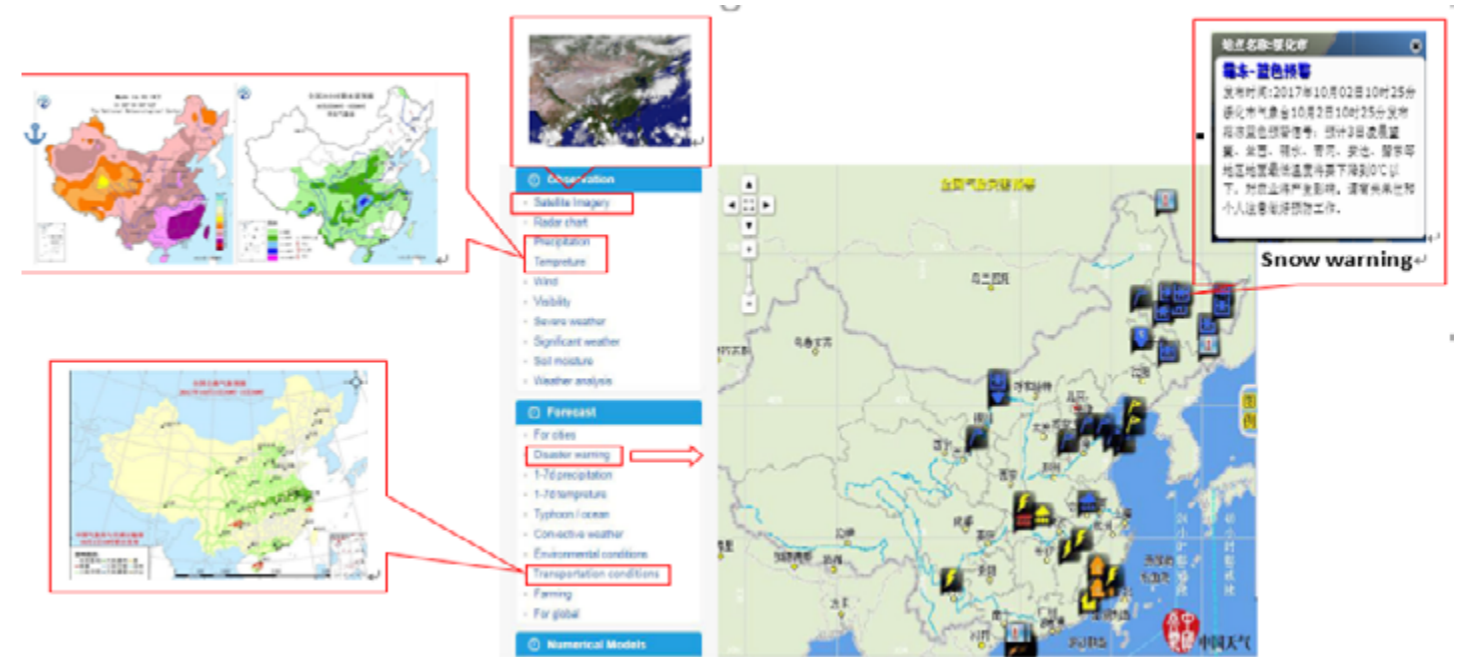
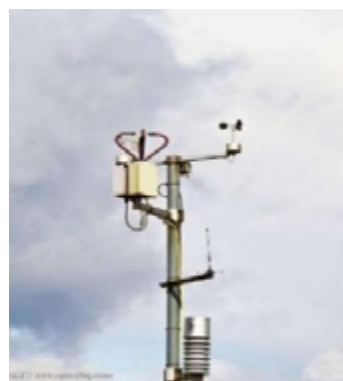
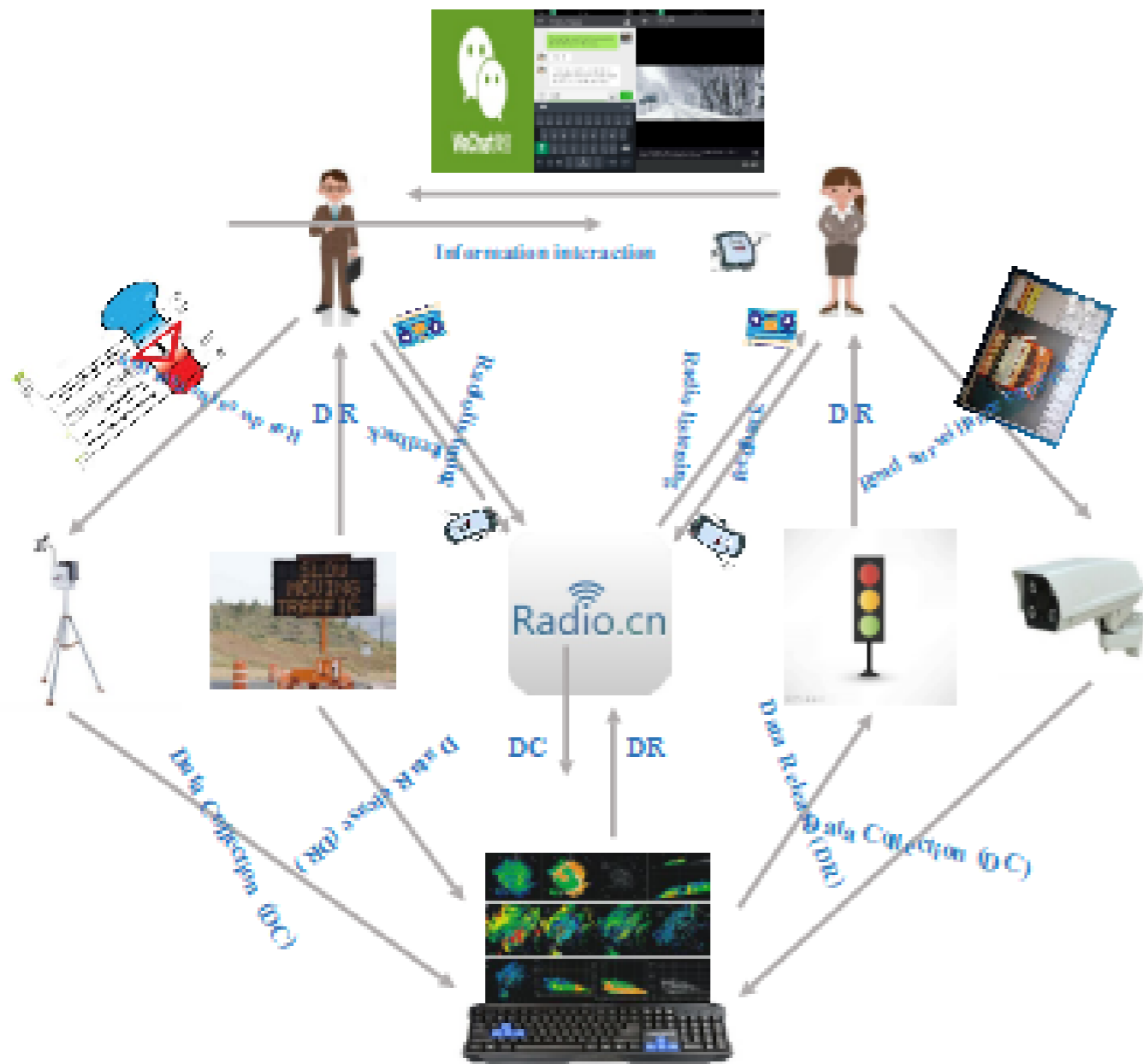


FIGURE 23 – WEBSITE FOR WEATHER AND ROAD INFORMATION IN WINTER (SOURCE: HTTP://WWW.CMA.GOV.CN/2011QXFW/2011QYJXX/, CHINA METEOROLOGICAL ADMINISTRATION)



FIGURE 24 – APP FOR WEATHER AND ROAD INFORMATION IN WINTER



ROAD WEATHER STATION



ROAD SURVEILLANCE CAMERA



ROAD INFORMATION DISPLAYS



VARIABLE MESSAGE BOARD

FIGURE 25 – TRAFFIC AND ROAD WEATHER INFORMATION SYSTEM

3.5.2 TRAFFIC INFORMATION SYSTEMS

In China, information can be conveyed between different objects: person and person, person and machine, machine and machine. With these three combined, an information network is built where people can get traffic information immediately.

In China, Wechat has been the most popular chatting software for some time. As you can see in the picture, information that there is a car accident on Songshan street is sent to your friends when you are chatting. Pictures of Huanghe road has also been uploaded online to warn that the traffic in this road has already been greatly affected by blizzard.

Listening to traffic radio is always an effective way for drivers to get current traffic information. In China, each province has its own radio station which offers abundant traffic information. Traffic radio is also an interactive platform where drivers can call in and report what they see and hear on roads.

4. ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 FURTHER DEVELOPMENTS OF SNOW-MELTING AGENTS

Composite types of snow-melting agents are produced by using inorganic and organic salts and a small amount of corrosion inhibitors. Compared with traditional snow-melting agents like sodium chloride, these snow-melting agents have high snow-melting efficiency and can protect the environment at the same time.

Study done by Meng Wang et al. (2014) showed that the organic salts are nearly noncorrosive which can be seen in following table:

TABLE 11 – CORROSIVE RATE OF DIFFERENT KINDS OF SNOW-MELTING AGENTS

Types	$\Delta M/g$	S/cm^2	$V/(l)$
SA	<0.0001	10.8258	<0.0001
CN	0.0103	12.0760	0.1983
SC	0.0131	11.5180	0.2644
CC	0.0120	9.9982	0.2790

SA: sodium acetate CN: calcium nitrat SC: Sodium chloride
 CC: Calcium chloride ΔM : Mass loss of metal during corrosion
 S: Metal surface area V: Corrosion rate(Meng Wang et al, 2014)

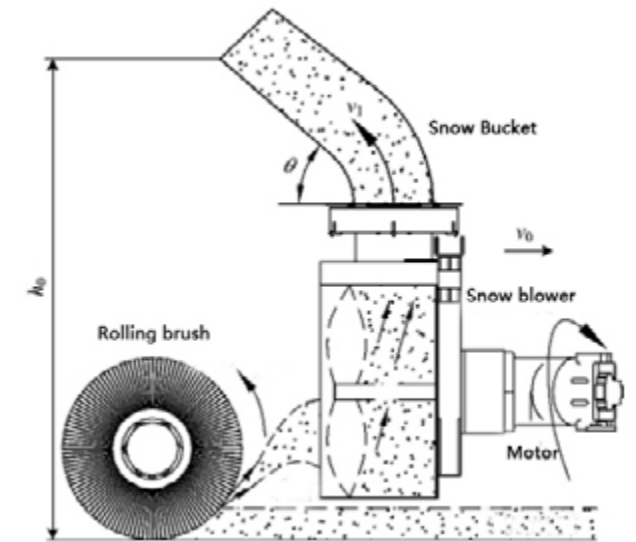


FIGURE 26 - TRACK SNOW REMOVING DEVICE (GUANZHU GUO, 2016)

4.2 ADVANCE IN IMPROVING SNOW REMOVING MACHINES

Snow removing ploughs and rotary casting snow removing devices are commonly used abroad. Limited by their structures, it's difficult for them to clean the snow from the rail surface to the following concrete slab sleeper surface.

Guanzhu Guo (2016) developed an autonomous track snow removing device which integrated the functions of rolling brush to brush snow and wind machine to suck snow. When it works, rolling brush will blow up snows and these snows will be sucked into the wind machine. The schematic diagram of the machine is as follows:

Snow-melting agent emulsion distributor is a new type of snowmelt device. In study conducted by Zhu-

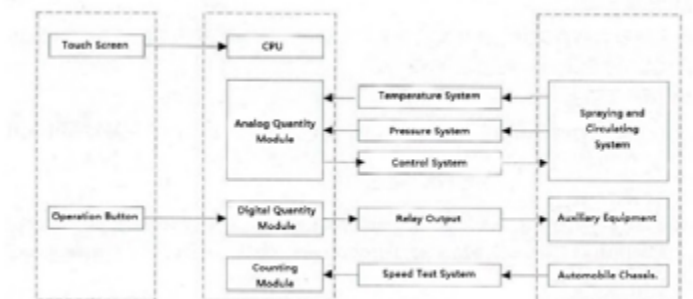


FIGURE 27 – SNOW-MELTING AGENT EMULSION DISTRIBUTOR (ZHU-ORU YAN, 2014)

oru Yan (2014), an intelligent snow-melting agent control algorithm is analyzed.

Based on this algorithm, ice and snow are melted more rapidly and efficiently. It can also protect the environment.

4.3 CURRENT DEVELOPMENTS ON ROAD MATERIALS AND STRUCTURES

Chemical treatments and mechanical removers have been widely used to remove snow on winter roads. However, both of these two methods have some inevitable problems: strong corrosion, serious pollution and low efficiency. To tackle with these problems, new types of road materials and structures are developed.

4.3.1 ROAD MATERIALS

In study done by Zhaohui Min et al (2017), a new asphalt mixture called epoxy asphalt mixture (EAM) was developed. It used epoxy resin as a modifier to change the thermoplastic characteristic of the binder. Three-dimension unsolvable crosslinking networks created by reaction between binder and curer can provide the mixture with excellent durability, high-temperature stability, fatigue resistance and moisture stability.

In study done by Zhenjun Wang et al (2017), asphalt mixtures incorporating with salt-storage aggregates (SSA) are made from mixing MgO, MgCl₂, salt-release materials (SRM) and hydrophobic silicone powder in certain proportion. The self-prepared SSA added to asphalt mixtures can greatly improve the property of asphalt mixtures which can be used in special areas of asphalt pavement, such as ramp and steep slope to

greatly overcome disadvantages of conventional snow-melting methods, such as severe environmental pollution and high economic consumption.

TABLE 12 – THE COMPARISON BETWEEN SSA AND AC - 13

Properties	Specification	Test result	
		SSA	AC 13
AD/(g/cm ³)	2.6	2.701	2.714
NPPC/%	15	7.2	10.15
ACV/%	26	18.4	15.02
LAA/%	28	21.8	7.5
WA/%	2.0	0.6	1.32
AWS	4	4	5

AD: Apparent density/(g/cm³)
 NPPC: Needle and plate particle content/%
 ACV: Aggregate crush value
 LAA: Los Angeles abrasion value/%
 WA: Water absorption/%
 AWS: Adhesion with asphalt
 (Zhenjun Wang et al 2017)

4.3.2 ROAD STRUCTURES

Nowadays, China has three types of pavement heating systems: hydronic system, electric heating system and infrared radiant heating system. They are as follows:

Most researches of hydronic system done in China have focused mainly on two aspects. One is to develop models to simulate the heat transfer pavement snow

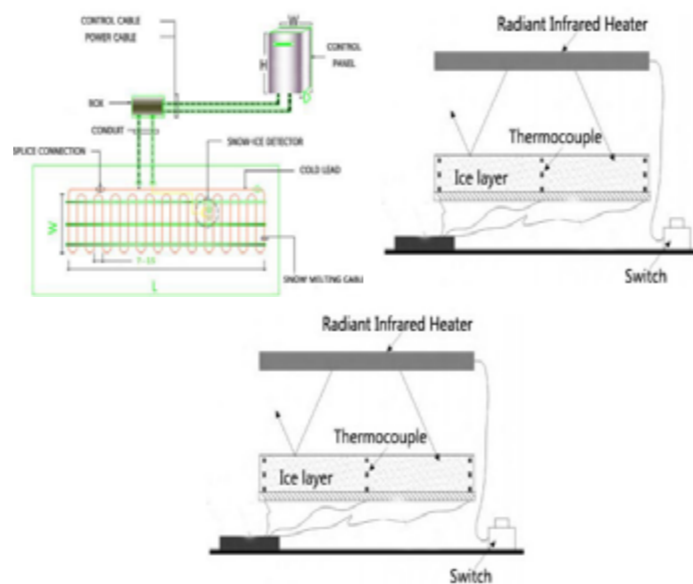


FIGURE 29 – THREE KINDS OF PAVEMENT HEATING SYSTEMS

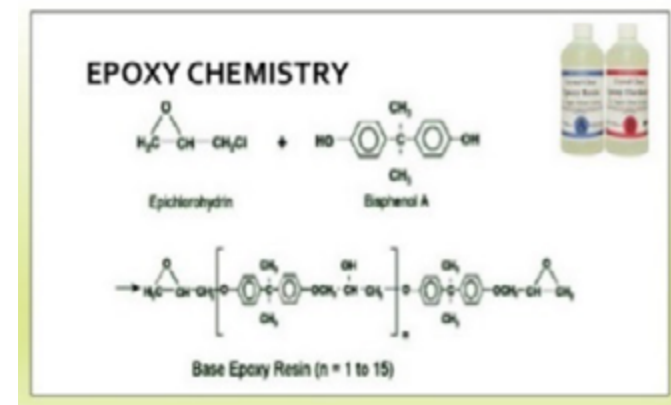


FIGURE 28 – MOLECULAR STRUCTURE OF EPOXY CHEMISTRY

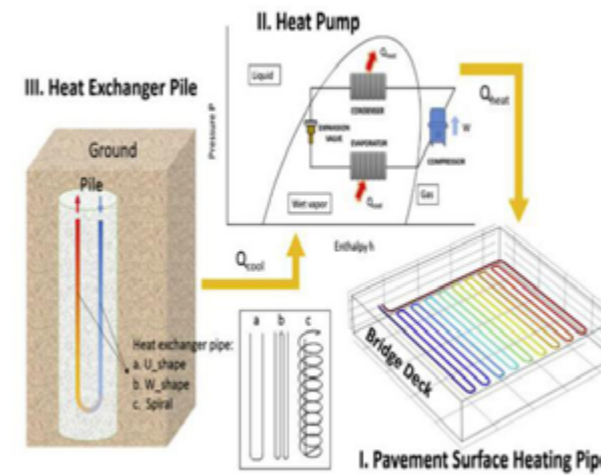


FIGURE 30 – SCHEMATIC DIAGRAMS OF WORKING PRINCIPLE OF GEOTHERMAL HEAT PUMP SYSTEM

melting process and evaluate its performance. The other one is to improve design of hydronic system to increase its work efficiency.

MODEL DEVELOPING

In study conducted by Huining Xu et al (2017), a two-dimensional heat and mass coupled numerical scheme is developed to modify the snow melting model proposed by Liu et al.

Chanjuan han and Xiong Yu (2017) carried out a validated computational model to analyze the amount of thermal energy extraction by a single thermal energy exchanger pile installed with different types of heat exchanger pipes.

DESIGN IMPROVING

Heat pipe technology used in melting snow is attractive because its features of environmental conservation and low maintenance.

However, the heat pipes need special anti-corrosion treatment against soil and the length should be long enough to reach isothermal layer which means that the prophase investment of these type systems are enormous. In addition, the transportation and installation of these heat pipes, over 50 m long, are inconvenient.

In order to overcome these defects mentioned above, Xiaoyuan Wang et al (2017) have designed an ice and snow melting system using super-long flexible heat pipes (SFHPs) based on thermally conductive polymer

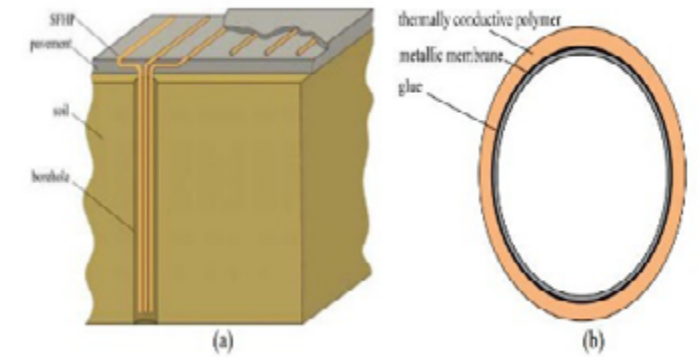


FIGURE 31 – (A) ICE AND SNOW MELTING SYSTEM USING SFHPs; (B) CROSS SECTION IN AN SFHPs

which will reduce cost and make it more convenient to be fabricated, transported, and installed.

4.4 INTELLIGENT SYSTEM OF VEHICLE BRAKE ON ICE AND SNOW ROADS

With the rapid development of artificial intelligence (AI), transportation system is facing a great revolution. The newly developed discipline including data communication, electronic sensing technology, computer science etc. will be applied to change the entire traffic and civil engineering industry.

Braking distance refers to the distance a car moved until fully stopping after braking. In snow days, sliding friction between tire and road surface is very low due to icy roads, especially when tires are totally locked when braking which will change sliding friction to rolling friction. And this rolling friction will inevitably increase braking distance and make drivers take corners sideways and thus cause traffic accidents. In order to avoid this phenomenon, anti-lock braking system (ABS) was devised.

In study done by Lei Zhang and Liping Lei (2017), a logic threshold PID controller is designed to improve

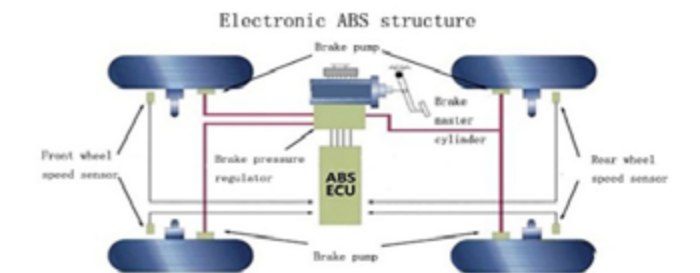


FIGURE 32 – SCHEMATIC DIAGRAM OF ANTI-LOCK BRAKING SYSTEM

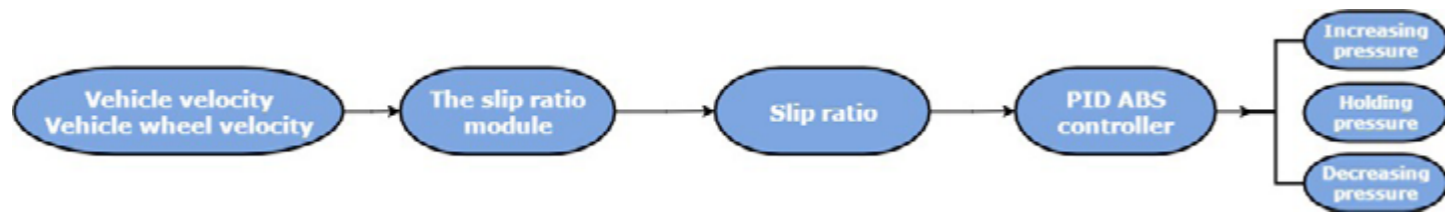


FIGURE 33 – FLOW CHART OF PROCEDURES IN INTELLIGENT SYSTEM OF VEHICLE BRAKE

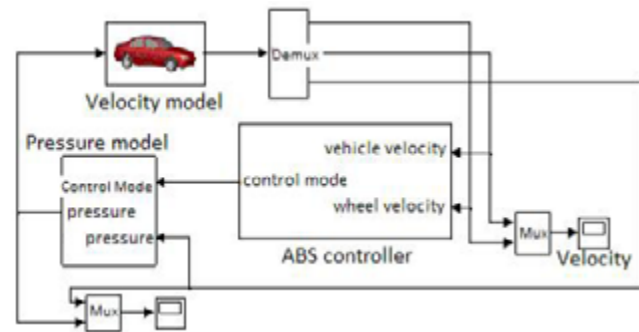


FIGURE 34 INTELLIGENT BRAKING SYSTEM

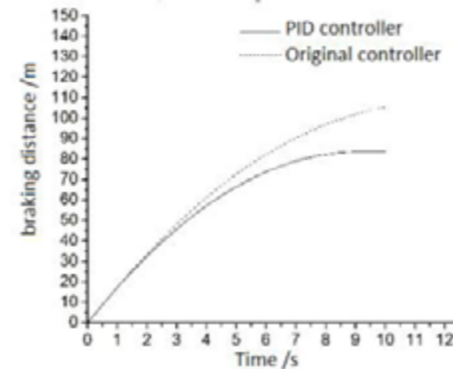


FIGURE 35 – BRAKING DISTANCE

the vehicle brake performance on ice and snow roads.

4.5 DISCRIMINATION OF HIGHWAY SNOW CONDITION WITH VIDEO MONITOR

Snow detection in image sequences with video monitor has become an attractive research issue, since it needs no extra on road equipment.

The previous study contains limited comparison and explanation of the chosen methods for classifying road conditions. The study done by Chunyu Zhang et al (2012) gave the video based snow detection area extraction method and extracted its image feature for snow cover from the selected area.

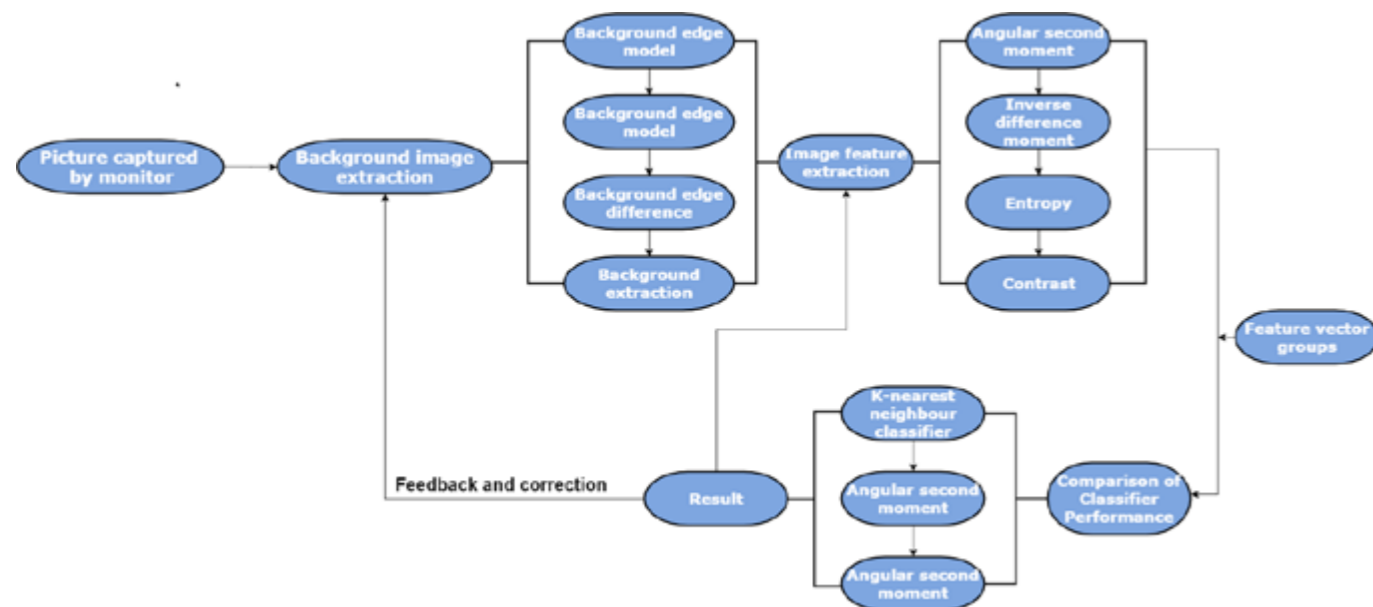


FIGURE 36 – FLOW CHART OF PROCEDURES IN DISCRIMINATING HIGHWAY SNOW CONDITIONS

5. REFERENCES

[1] Ning, G.C., Kang, C.Y., Chen D.H., 2016. Analysis of Characteristics of Traffic Accidents Under Adverse Weather Condition in China During 2005-2014. *J. Arid Meteorology*. 34(5), 753-762.

[2] Brodsky H, Hakkert A.S., 1988. Risk of a road accident in rainy weather. *J. Accident Analysis & Prevention*. 20(3), 161-176.

[3] El-Basyouny K, Kwon D.W., 2012. Assessing time and weather effects on collision frequency by severity in Edmonton using multivariate safety performance functions. *Transportation Research Board 91st Annual Meeting*.

[4] Zhang D.W., Ni G.C., 2016. Snowfall changes in China during 1956-2010. *J. Tsinghua Univ (Sci & Technol)*. 56(4), 381-386.

[5] Leng B., Liao M.J., Wang K.Y., Han W., 2015. Overview on Winter Road Maintenance. *J. Transportation Review*. 37(5), 76-83.

[6] Han Z.B., 2013. Present Status and Future Development Trend of snow removing for Highway. *J. Highways & Automotive Applications*. 6, 142-145.

[7] Hao W., Dang J.Q., Lian X.Y., 2008. Present Status and Thoughts of Snow Removing Technology for Highway. *J. Communications Standardization*. 12, 84-86.

[8] Wang M., Li X.L., Du D.C., Zheng G.Y., Zhang L.Q., 2014. Preparation and performance of organic-inorganic composite environmental protection deicers. *J. Modern Chemical Industry*. 34(12), 66-69.

[9] Guo G.Z., 2016. Research on the Snow Removing Capacity of Autonomous Track Snow Removing Device Combined with sweeping, Sucking and Casting Functions. *J. China Railway Science*. 37(6), 90-96.

[10] Yan Z.R., 2014. Design of intelligent control system for snow melt agent emulsion distributor. Master thesis: China University of Chang'an; 2014.

[11] Zhao H.M., Xia Y.Y., Li X.C., Tao Z., 2017. Performances evaluation of epoxy asphalt mixture containing snow-melting agent. *J. Construction and Building Materials*. 155, 762-769.

[12] Wang Z.J., Zhang T., Shao M.Y., Tao A., Peng Z., 2017. Investigation on snow-melting performance of asphalt mixtures incorporating with salt-storage aggregates. *J. Construction and Building Materials*. 142, 187-198.

[13] Xu H.N., Wang D.W., Tan Y.Q., Zhou J., Markus O., 2018. Investigating of design alternatives for hydro- nomic snow melting pavement systems in China. *J. Cleaner Production*. 170, 1413-1422.

[14] Han C.J., Xiong (Bill) Y., 2017. Feasibility of geothermal heat exchanger pile-based bridge deck snow melting system: A simulation based analysis. *J. Renewable Energy*. 101, 214-224.

[15] Wang X.Y., Fan H.T., Zhu Y.Z., Zhu M.Z., 2016. Heat transfer simulation and analysis of ice and snow melting system using geothermy by super-long flexible heat pipes. *The 8th International Conference on Applied Energy – ICAE*.

[16] Zhang L., Lei L.P., 2017. Intelligent System of Vehicle Brake on Ice and Snow road. 2017 9th International Conference on Intelligent Human-Machine Systems and Cybernetics.

[17] Zhang C.Y., Wang W., Su Y., Bai X., 2012. Discrimination of Highway Snow Condition with Video Monitor for Safe Driving Environment. 2012 5th International Congress on Image and Signal Processing.

[18] Liu Y.L., Ren G.Y., Yu H.M., 2012. Climatology of Snow in China. *J. Scientia Geographica Sinica*. 32(10), 1176-1185.

[19] Li C., Xie T., Chen H.W., Dong J.K., Jiang Y.Q., 2017. Experiment Investigation on Deicing Characteristics Using Infrared Ray as Heat Source. *J. Infrared Technology*. 39(4), 378-382.

[20] Yu W.B., Li S.Y., Feng W.J., Yi X., 2011. Snow and Ice Melting Techniques of Pavement: State of the Art and Development Tendency. *J. Glaciology and Geocryology*. 33(4), 933-940.

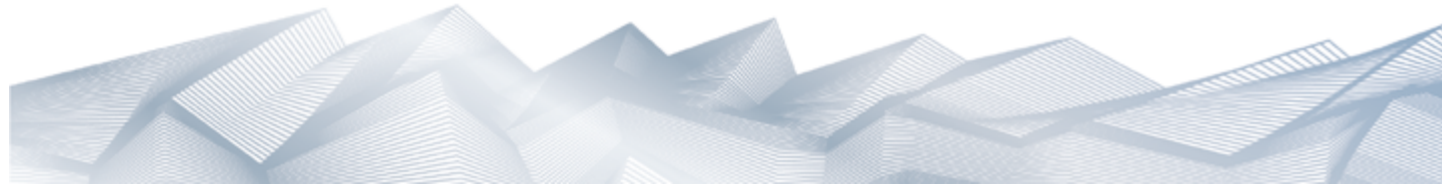
[21] Yuan G.J., Wu D., Li Y., Wei D., Chen J., 2016. Research on Pavement Performance of Blended Aggregate AC – 13 of Gneiss J. *North Communication*. 4, 70-74.

[22] Cao L.T., Liu S., Han Y.F., 2010. Analysis on Key Technology and Development Trend on De-Icing and Anti-Icing. *J. The World of Building Materials*. 31(5), 53-56.

[23] Jiang C.Z., Yang J., Liu J.J., Zheng J.C., 2012. Studies Review of Organization for Winter Road Maintenance Program. *J. HIGHWAY*. 4, 215-219.



CZECH REPUBLIC



1 DEMOGRAPHICS AND ROADS

1.1 GRAPHICAL PLACING OF THE CZECH REPUBLIC IN EUROPE



1.2 SHORT DEMOGRAPHIC OVERVIEW OF THE COUNTRY AT 31ST DECEMBER 2017

The Czech Republic is a medium-sized country (78,867 km²) situated in the centre of Europe, surrounded by Poland to the northeast, Germany to the west, Austria to the south and Slovakia to the east.

At 31st December 2017, the population was 10.613 350 million inhabitants corresponding to 134,6 2 per one square kilometre. Its capital and largest city of the country is Praha that has 1.290. 513 inhabitants. The Gross Domestic Product per capita was 89, according to EUROSAT (where is EU28=100).

The Czech Republic is a federal state being formed from three nations:

- Bohemia (6.486.639 inhabitants),
- Moravia (2.399.641 inhabitants) and
- Silesia (1.205. 886 inhabitants).

Since the year 2000, the republic has been divided into 14 administrative regions, and also 14 main Winter maintenance centres (WMC).

From an altitude view, 67% of roads are below 500 m, 32 % of roads are from altitude 500 to 1000m, and only 1% of roads are over 1000m. The Czech highest point is located at an altitude of 1200 m (Bozi Dar, and the lowest one in Hrensko 115 m).

CZECH REPUBLIC

1.3 THE CZECH ROAD NETWORK AND TRAFFIC TO 31ST DECEMBER 2017

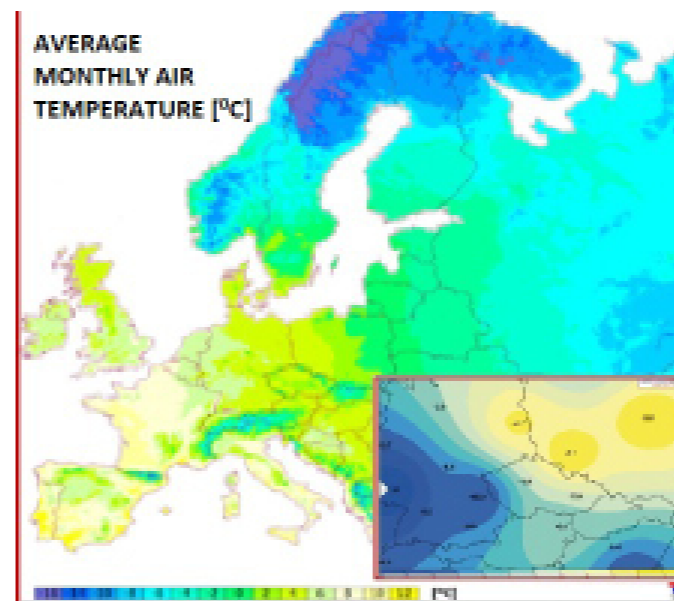
Total length of roads	55 756 km	Highways	1239,8 km
		Roads class I	5 824 km
		Roads class II	14 588 km
		Roads class III	34 103,4 km
Density of road & motorways	0,707 km/km ²		
Total number of Vehicles	6 280 718	Passenger cars/ light	5 538 222
		Trucks and lorries	690 500
		Buses	20 719
		Special cars	31 277
		Motorcycles	1 102 392
Latitude of the capital (Prague)	50.08		

In 2017, the total length of the public road network was 55 756 km, out of which 1239,8 km is motorways and rest 54,516 km are regional and local roads.

The national fleet has reached in year 2017 6 280 thousand vehicles, where 5 538 thousand are passenger cars, the rest are lorries, buses and other vehicles.

The Winter season in the Czech Republic, according to the Road Law was defined for a period between November 1st and March 31st of the following year.

2 CLIMATE



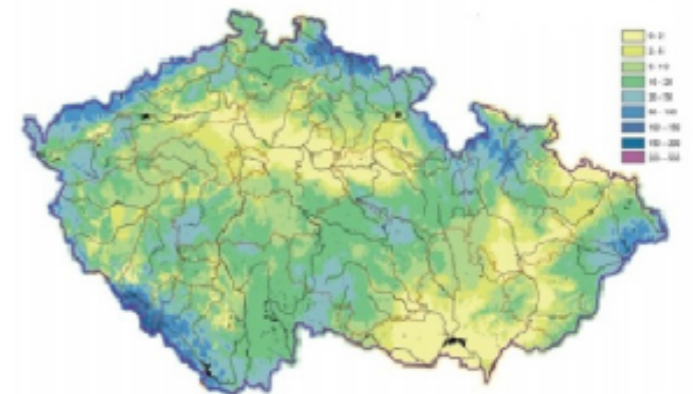
The Czech Republic is a landlocked country located in moderate geographical latitudes in the Northern hemisphere. The general climate of the Czech Republic is mild but variable locally and throughout the whole year. It differs markedly among the various regions, depending on the altitude and cardinal direction.

2.1 SHORT CHARACTERIZATION OF THE CZECH CLIMATOLOGY

The winter months are considered be December, January and February. The colder of these is regularly January. In January and February, precipitation at lower altitudes usually has the form of rainfall, while in the hills

Snow coverage lasts for several months only at higher altitudes. However, during March, April and May the snow coverage usually melts.

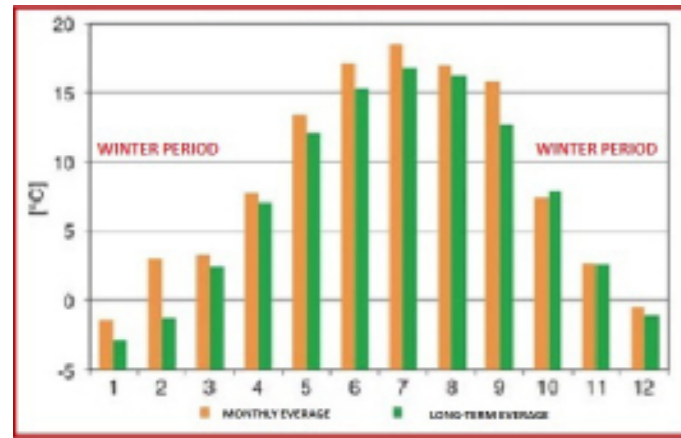
2.2 SCALE OF TEMPERATURE



The annual course of spatial air temperature in 2017 in comparison with the long-term average for the period 1961–1990 (taken as an average for the Czech Republic) was 8.7 °C in 2016. The difference between the year's temperature and the long-term average temperature for 1961–1990 was +1.4 °C.

As mentioned previously, the average air temperature is influenced by altitude, cardinal direction and also by the unpredictable position of the Jet Stream. The temperature distribution between the highest road at 1200 m (0.2°-0.40C) and at the lowest level 115 m (9,0-10,0 0C). Also, the annual precipitation depends markedly on altitude.

ANNUAL DISTRIBUTION OF TEMPERATURE PER MONTHS



The most rain or snow falls in the areas are in the higher roads of the west and northwest. Their average total precipitation is around 634 mm, the total for 2016, which was a normal year in terms of precipitation and only 6% below the long-term average.

3. WINTER ROAD MANAGEMENT

3.1 APPLIED STANDARDS AND RULES

Winter maintenance is regulated by the following documents:

- 1) **Act No. 13/1997 Coll.**, on roads, as amended.
- 2) **Reg. 104/1997** "Implementing order of the Act No. 13/1997", as amended.
- 3) **Tech. doc.** "Winter management and maintenance regime" from 2004.
- 4) **Tech.doc.** "Technological procedure for winter maintenance of motorways" from 2007.
- 5) **Tech.doc.** "Regime of road signing and marking and facilities, administration and maintenance".

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The road management and maintenance together with winter maintenance is ensured during the whole year by state organization of the Roads and Motorways Directorate. It has responsibility for 1240 km of motorways and 5824 km of class I. roads. The other roads of the lower classification (II., III. and IV.) are managed by regional administrations.

During the winter, the road administrators eliminate or at least reduce problems with road serviceability according to the schedule set in the winter maintenance plan and regulated by the Road Law. (chap. 3.1.3)

When snow cover exceeds 3 cm plows need to be used. Frost ice, snow and slush under 3 cm is removed with the help of deicing agents. In the winter maintenance we distinguish just plowing, chemical materials spreading, or both activities carried out simultaneously. Separately, we consider regular checks of roads serviceability.

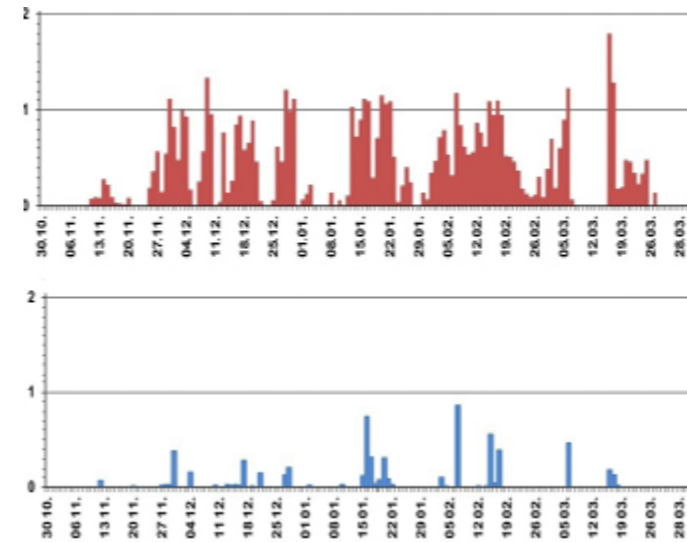
As already stated, the main WMSC (chapter 1.2.) have to ensure the winter maintenance for roughly 50km motorways or Road Class I. equivalent to 1,000 km² of pavements.

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

From the graphical comparison (2017/18) of the snow ploughing and salt and brine spreading results in Czech winter maintenance it can be seen that spreading operations dominate ploughing.

Further, data show the last five-year winter period was rather mild. It has led to a considerable decrease in winter maintenance costs for materials, km operations, ploughing and spreading, as you can see in the following table (next page).

Nevertheless, the winter maintenance costs are, above all, the costs for salt purchase and operation of the individual WMSC.



If the winter conditions cause an exceptional number of maintenance operations the financial consequences will impact summer maintenance.

CONSIDERABLE DECREASES OF THE WINTER MAINTENANCE SERVICES							
WINTER SEASONS	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
SPREADING [km]	303 988	241 530	419 283	188 679	236 021	222 747	276 639
SPREADING PLOUGHING [km]	304 240	139 501	383 993	35 266	150 956	125 721	169 227
PLOUGHING [km]	68 934	16 332	47 435	3 761	12 244	12 648	16 989
SALT CONSUMPTION [t]	44 547	22 509	50 832	12 565	25 165	21 822	29 534
BRINE CONSUMPTION [l]	16 394 944	8 686 743	15 395 115	4 062 523	7 839 856	6 954 917	9 022 087

Winter maintenance is a specific section, because costs strongly depend on weather, which cannot be predicted. It is therefore difficult to predict the total cost of winter maintenance. However, winter maintenance cannot be restricted, thanks to its importance, and because of the pressure of the economy and its immediate impact on the trafficability of motorways.

The dependence of winter maintenance costs on weather conditions does not mean that winter maintenance cannot be economically effective.

De-icing salt is purchased in a tender. When the preliminary conditions are fulfilled the cost decides. Costs are determined individually for every WMSC and quarter and they include all customs fees and transport. So the costs vary by WMSC and quarter of the year in which salt is purchased. In second and third quarter they are 10% lower than in the first and fourth quarter. Purchases of the salt in summer season is the most cost effective.

However, the limited capacities of warehouses and the possibility of unnecessary purchase of supplies,

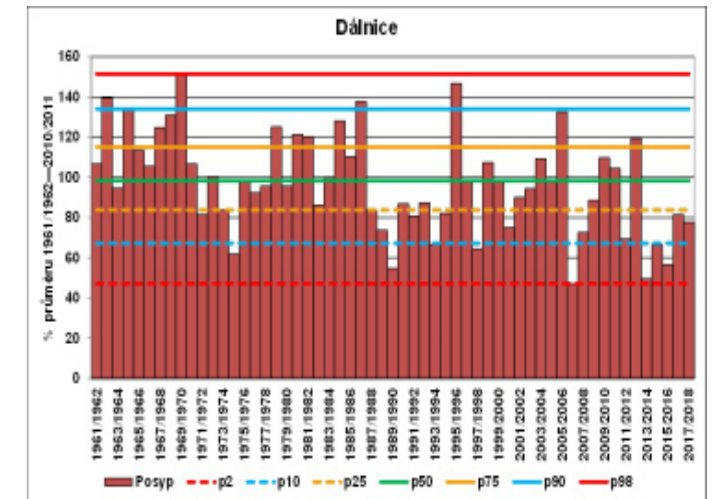
which may not be needed in a mild winter are factored against this strategy.

A basic level is procured in the summer with further procurement during the winter, based on operational need.

Supply contracts are drawn up so that the organisation only purchases what is necessary to suit operations and the financial situation.

The accuracy salt dosage and application have a large influence on consumption. It is important to use machinery that reliably applies the stated amount (10-20g/m²). It not only impacts on cost, but traffic safety and the environment.

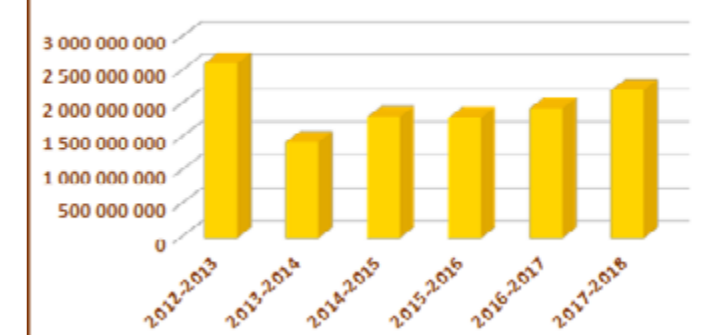
The costs of winter maintenance are almost independent on any planning. The funds are drawn from the



total plan and in a severe winter there is a shortage of funds for summer maintenance. If, however funds are allocated based on some level of maintenance, a relative waste of funds could occur.

In this case, in line with previous winters, the plan is to modify after the first quarter. In the long-term the

COSTS IN DOMESTIC CURRENCY FOR THE LAST FIVE WINTER SEASONS



optimal amount of funding must increase to allow for inflation. In the winter of 2017/18 it reached 88.6 million euros.

3.4 TRAFFIC SAFETY AND SHARING OF INFORMATION

The main trigger for winter maintenance operations is precipitation and its intensity. It can occur as rainfall, snowfall, frost formation of ice. The timing of the operations is key and often relies on the experience of the supervisor. Nevertheless, the optimum decision is based on various information and resources:

- Permanent monitoring by radar and satellites
- Weather conditions from own meteorological stations (RWIS)
- Information from road-users, police or winter maintenance operatives
- 24-hour media information (radio, internet, TV)
- Consultation with weather forecasting specialists at the meteorological station
- In addition to these the road operators can talk direct to the forecasting engineer.

In general intervention levels are set at what the maintenance personnel and public consider to be unsafe road surface conditions.

The most difficult situations are when changes to the road surface come quickly or are not immediately apparent, such as black ice and hoar frost. So, it is important to also use knowledge of the local climatic and geographical features and experience from previous seasons.

To ensure the appropriate level of winter maintenance service it is best to harmonise several administrative, organisational, social, distributions and repair operations.



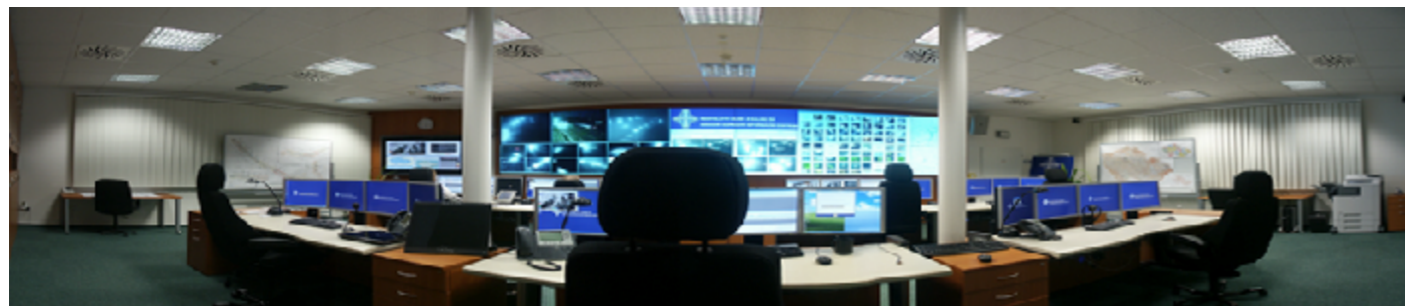
3.5. INFORMATION SHARING

All above information and final decisions are to be transferred to all road users. The drivers have to be kept informed, not only by radio. They are getting news about serious road conditions by:

- Overhead LED road signs
- Special GSM messages
- Smart phone application focused on:
 - road closure, accidents, etc.,
 - camera view in complicated sections,
 - overview of map icons,
 - chart of serviceability

4. ON – GOING RESEARCH AND STUDIES

- A continuing development of the 2DRoad weather camera, in cooperation with Swedish institutions. It is

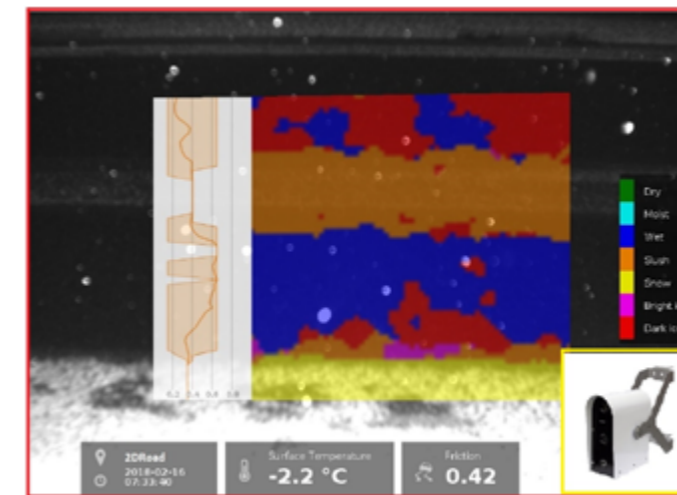


an innovative weather camera that can scan area of up to 6x6 meters with a resolution of 4096 points.

It determines the state of the road across its width using seven different categories, from wet, through to snow and slush, to various kinds of ice.

Thanks to thousands of sensing points it is also possible to detect where the traffic on the road is risky, whether it is on the roadside, the centre of the road or a recess in the rails.

Such a view of the road is much more efficient and more accurate, and it is particularly appreciated by maintenance engineers. The camera can also recognize so called "black ice" (see red colour below in the output from the camera.)



- An advanced road weather and maintenance information system "METIS" was developed in 2003. It is a national maintenance decision support system that integrates all 600 road weather stations in the country and other online and forecast weather information so-

urces, like special road surface forecast and treatment recommendation module.

The important part of the system is focused on winter maintenance reporting and evaluation, including central vehicle tracking system with approx. 1000 connected vehicles, which enables a thorough supervision of maintenance efficiency.

The system assists to achieve the same level of service throughout the country while optimizing the maintenance costs and keeping the traffic safety high in all winter conditions.

5. REFERENCES:

- Demographic data Czech statistic institution URL
- Climate data
 - Weather forecasts: <http://portal.chmi.cz/predpovedi/predpovedi-pocasi/ceska-republika/tydenni-predpoved>
 - Snow falls statistic: https://cs.wikipedia.org/wiki/Podneb%C3%AD_%C4%8Ceska
 - Temperature statistic: Czech meteorological institution

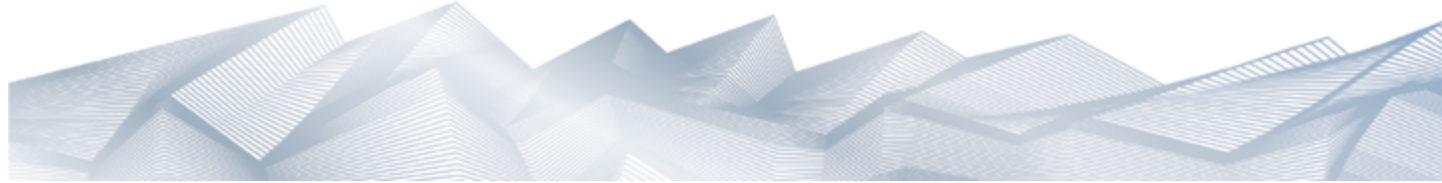
3. WINTER MANAGEMENT AND MAINTENANCE

- <http://www.mdcz.cz>,

4. ON-GOING RESEARCH AND STUDIES:

- 2DRoad weather camera xx <http://www.cross.cz/en/news>
- METIX winter maintenance program <http://www.cross.cz/en/news>

THE WHOLE MATERIAL WAS PREPARED BY:
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1 DEMOGRAPHICS & ROADS

1.1 INFORMATION ABOUT COUNTRY

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

Denmark has approximately 5.7 million inhabitants



- this roughly amounts to 0.5% of the total EU population. In addition to Denmark itself, the kingdom also includes the Faroe Islands and Greenland.

The highest point is 171 m above sea level. No one in Denmark is more than 50 km from the sea. The climate is temperate coastal climate; January and February are the coldest months with an average temperature of 0.0 °C and July the warmest with an average temperature of 17.4 °C.

Administratively, the country is divided into 98 municipalities.

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

1.2 ROAD NETWORK & TRAFFIC

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

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

In 2017 Denmark has app. 74,700 km of road, 1,229 km being motorways. With 1.68 km of public roadways per square kilometre, Denmark, then, has a road density that is among the highest in the world, with a general excess capacity.



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

Local Council roads are administrated by the local councils and constitute app. 70,650 km, about 95% of the public road network. National roads are administrated by the Danish Road Directorate and constitute app. 3,800 km; the remaining 5% of the public road network, still the public roads cover 46% of all traffic in km travelled vehicles. That means that 46% of all traffic in Denmark travels every day on 5% (3,800 km) of national roads.

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

The individual roads are classified according to their function.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Danish climate is determined by the country's position on the edge of the continent of Europe close to large sea areas and in the zone of prevailing westerlies. This position results in cool summers with a mean

temperature of around 16.4 °C and winters that are not particularly cold, with mean temperatures of around 1.9 °C. Denmark is thus placed in the temperate climate zone.

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

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

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

The average temperatures for winters are normally 0.5 °C. Number of complete days below 0.0 is around 20 days in a year. The variation of snow amount during a winter season is between 10-40 cm, and nation-wide snow weather occurs max. 20 times during a winter.

2.2 SALT INDEX

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

Formula of salt index:

$$V_i = \sum_{1. \text{ Oktober}}^{1. \text{ maj}} V_{\text{dag}}$$

$$V_{day} = a \cdot (10b + 0,1c + 7f + 18g) + 0,3a$$

a: Days with road temperature below +0.5 °C

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

c: the parameter c denotes the number of times the road temperature drops below

0 °C of at least +0.5 °C to -0.5 °C

f: If within a day measured precipitation below the freezing point in a total time of minimum: 30 minutes, f = 1 90 min, f = 3 270 min, f = 9 420 min, f = 12

g: When the road temperature gets below the freezing point examined whether there has been precipitation over the past 3 hours. If at least 3 logs have shown precipitation at the interval set g = 1

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS & RULES

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

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

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

DESIRED DURATION OF ROAD CONDITIONS:

	Call-out [Minutes]	Turnout duration Winter road class I (Hours)	Frequency Winter road class I (Hours)	Turnout duration Road winter class II (Hours)	Frequency Winter road class II (Hours)
Carriageways – salting	Max. 45	Max. 3-4		Max. 5-6	
Carriageways – snow clearing	Max. 90		2-5		4-8
Paths, sidewalks and other areas - salting/gritting	Max. 60 - 90	Max. 3-4		Max. 5-6	
Paths, sidewalks and other areas - snow clearing	Max. 90		4-8		6-10
Super Bike Paths - snow clearing	Max. 90		Max. 4		

Service objectives for Road Class	Type of road
State roads Freeways European Freeways	Priority roads Regional Roads Other priority roads
Other state roads	Other regional roads

3.2 ORGANISATION AND OPERATION OF WINTER MAINTENANCE

Clear roads without any substance of weather condition.

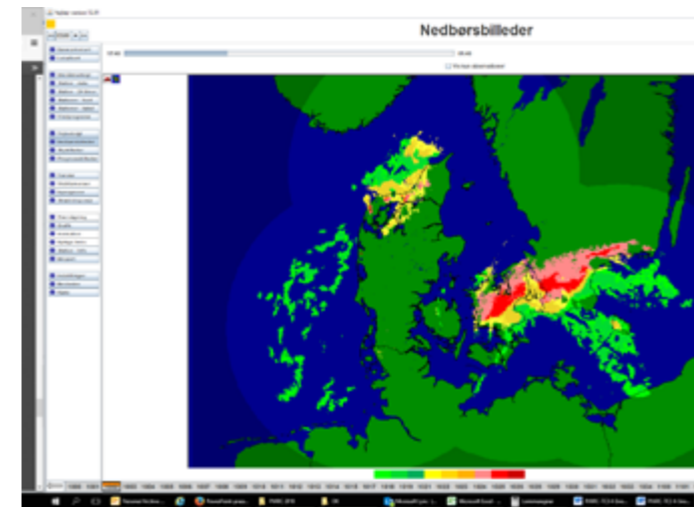
The Danish Road authorities planning of winter services of own roads. The country is divided in 3 service centres equipped with 1 winter surveillance centre.

The winter central is responsible to act for entire national roads. All convenient jobs (hauling by truck o.l.) are supplied in accordance with EU's service- directive, and are managed by private haulage contractor.

HOW TO MONITOR ROADS?

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

Winter service department cooperate particular with the Danish Meteorological Institute (DMI) and use their special forecasts for road and weather purposes, and radar and satellite imagery. Moreover, using the Road Weather Information System "VejVejr" (Road Weather), which provides comprehensive monitoring and forecasting facilities, so winter monitoring has the best possible basis for decision making in relation to the chance to call out for road salting.



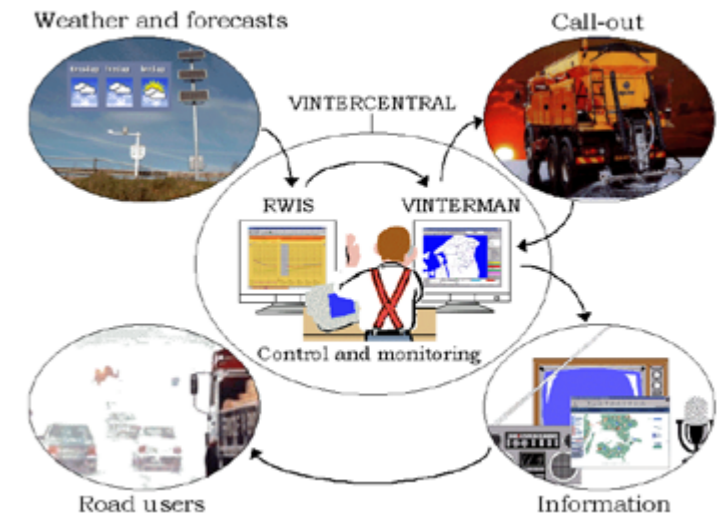
Information about road and weather situation by monitoring, webcams, police, citizen inquiries and winter monitoring is also used to form the total picture.

Winter supervisory is used when during Snow falls, where they are out driving on the road to examine the need for extra effort, for example in connection with the operation of formation.

INFORMATION DISSEMINATION

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

The Danish Road Directorate & Danish Meteorological Institute (DMI) have had an arrangement since 1983; the agreement is constructed to exchange information throughout Road Weather Information System and is mainly about road weather forecast and the objective is to maintain a satisfactory traffic ability and level of



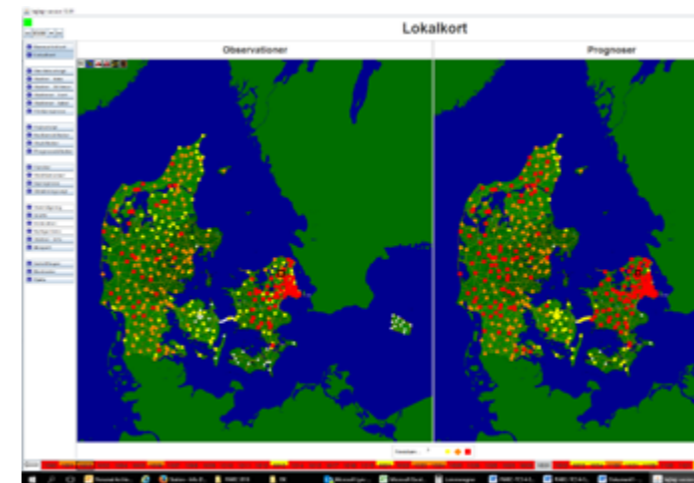
traffic safety on the roads during a winter season.

Written agreements exist between every member that is connected to Road Weather Information System.

"Vejvejr" is a system that is installed in a series of computers including one national winter surveillance centre and 85 municipalities and other authorities. These receive and present data from the recording stations and the DMI (Danish Meteorological Institute).

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

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



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

The Road Weather Information System is based on a network of approx. 470 recording stations. About 180 of them are placed on national roads and the rest on regional roads.

The winter crews' procedures to decide call outs for salting or snow removal are as based on:

- Online data about slippery road from monitoring stations located throughout the country
- Forecasts from each station - to develop the next 24 hours
- Residual salt measurements
- Freezing point temperature
- Regional weather
- Radar Pictures
- Patrol - monitor out on the roads
- Comments from motorists and police
- Experience - local conditions and vulnerable places.

There is 1 national winter surveillance central carrying out winter service around the country. The winter central have manned guards where winter preparedness is affiliated.

TRAFFIC INFORMATION CENTRE

Traffic Information Centre (TIC) monitors the traffic situation throughout the year and forward messages to various media. Reports deal typically with traffic jams and accidents which cause problems for the flow of traffic.

In winter do TIC inform about warnings of slippery roads, and is an integrated part of the winter monitoring.

METHODS

Winter service usually is provided from

1. Oct. - 30. Apr. throughout Denmark. Before that period, materials and equipment are checked and repaired and staffs are trained in comprehensive programmes.



Definite activation depends on the weather forecasts.

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

Provision of snow fences has less significance in Denmark, mainly because of few snowy days, which counts to app. 20 days in a year and because of expenses related to small benefits.

Route optimisation happens individually for each route. The planning is made for entire road network based on requirements and occurs manually for all superior and subordinate road networks.

Founded on weather forecasts, if the snowfall appears or it has already taken place. The duty engineer must carefully decide when and in which extension snow clearing should be carried out.

Snow clearing of carriageway should begin, when the snowfall has reached to 3-5 cm. snow and there is prospect for continuous snowfall. Normally salting is a supplement to snow clearing.

However, these procedures are different from urban or rural area.

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

EQUIPMENT

Denmark has one operation winter surveillance centre. The operation centre is supplied with Danish Road Weather Information System and operating with the winter management system VINTERMAN.

The Road Directorate owns as for today 233 spreaders, and 581 snowploughs for securing against slippery roads, mostly pre-wetted salt-spreaders together with a couple of combination spreaders and liquid spreaders. The development in Denmark still goes to use of brine. Driving through of a salt route handles typical 3-4 hours from call-out to finished task, and route covers typical an area at brief 360.000 m².

Each spreader covers small 45-km. roads incl. stand-by spreader. Moreover, there is a salt depot for every 350-km. All new vehicles are supplied with stationary GPS equipment.

There is only a driver in the truck common for salting as well for snow clearing.

To start guiding of mentioned materials the equipment such as de-icer spraying installations, road he-



ating's and uses of ice-delaying pavements has been used but none of them are used anymore because of the results and the economic perspectives.

MANPOWER, TRAINING AND PRIVATISATION

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

Training and education

The technical development of winter service demands education and in-service training of personnel.

For winter maintenance management and administrative staff exist, an in-service training arranged by Danish Road Directorate.

The classes included winter maintenance in practice and a depth examination of warning-system for slippery roads.

For drivers whom participant into the winter service, Road Directorate has in collaboration with the Transport Trade Education council has established a nationwide series of seminars for drivers in winter service. The courses are held at AMU (Adult Vocational Training) centres and/or suitable material sites. The courses are also approved for the compulsory training of drivers.

The courses are modular and contain topics such as basic winter service, winter road maintenance on roads and pathway, and snow removal. It is expected that participation to those classes will be demands for coming invitation to tender.

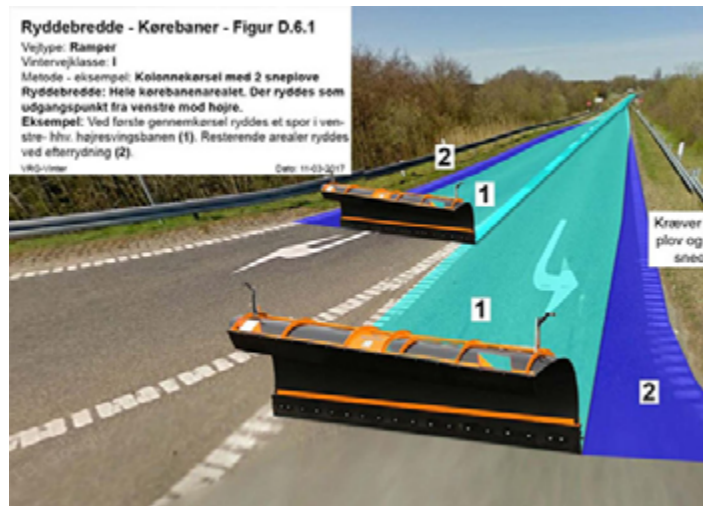
PRIVATISATION

Private companies are usually hired to operate as drives in occasions of salting or snow clearing.

The government is contributing with equipment (spreaders and snowploughs) while private companies are supplying vehicles.

OPERATIONAL ORGANISATION OF WINTER MAINTENANCE

In a typical winter in Denmark, there are about 107 call-outs for salting due to risk of icy conditions, on approximately 4.000 km of the national and regional roads. Salting because of snowfall, on the other hand, occurs only 10-20 times a year. In Denmark, preventi-



ve actions are taken to salt the roads, before they get slippery. The decision on whether a call-out is needed is made at a winter operation centres, while a local contractor carries out the actual activity. Two computer systems have been developed to support these tasks at the winter centre, the Road Weather Information System (RWIS) and VINTERMAN.

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

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

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

Every salt spreaders are now equipped with GPS data collection. Information regarding speed, dosage, spreading width etc. is registered. Thus, VINTERMAN is

able to provide statistics on the number of activities, consumption of salt, duration and time of callout along with the cost of salt and payments to contractors. This provides the opportunity to monitor and control the work quality, and eventually to re-organise action-plans if needed.

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

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

INTERNAL ASSESSMENT

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

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

The systems can be integrated in a large familiar system; however, the interfaces between these two fields are so well-defined that it's often more suitable with smaller systems than a separate system.

Main tasks for a winter administration system, the winter maintenance is often organised differently from one road authority to another, but regardless how, a winter administration system is always required. The primary structures of organisation for completion of winter duty are:

- Primary applications from own employees. In this case a winter administration system will secure options to document the contribution and estimate a resource allocation for the employees.
- The own monitoring stations with decision round contribution, but with contractors to do the perfor-

mance at the routes. In that situation the system will secure the data, so that the payment of the contractors proves in order.

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

Information regarding all call-outs can later be obtained along with comprehensive data. Road centres are using these data in sending invoicing basis to the contractors. The organisations are frequently political to be certain; however to all three situations an administration and recording system of data is required around winter maintenance. The winter administration system must handle subsequent jobs:

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

EXTERNAL ASSESSMENT

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

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

The Road Directorate make a national-wide user survey once a year and the users' opinion have an importance in the evaluation phase, in order to improve

the strategy to obtain a satisfaction among the users.

3.4 TRAFFIC SAFETY & INFORMATION

With a high degree and accurately it is possible to inform motorists of icy roads and weather conditions both nation-wide and local.

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

The information is distributed by radio, telex, etc. and by direct telephone contact when road users calls or through websites www.vintertrafik.dk & www.trafikinfo.dk.

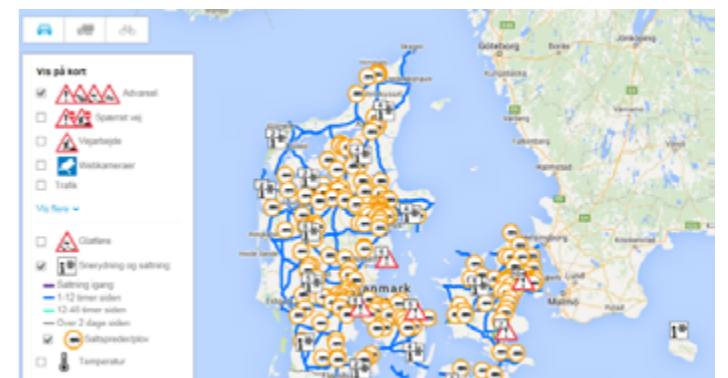
INTERNATIONAL EXCHANGE OF ROAD INFORMATION

Supplement: International exchange of road information

The Danish Traffic Information Centre sends traffic information to ARC, from where it is distributed to many European countries together with traffic information from other countries.

The Danish Traffic Information Centre exchange traffic information across the border with Sweden in Datex II, and it is also the plan to exchange traffic information across the border with northern Germany.

In addition The Danish Traffic Information Centre sends traffic information to a number of international service providers. Supported by the EASYWAY VIKING EU-project exchange of traffic information across the border is being set up with Sweden, and it is also the



plan to exchange traffic information across the border with northern Germany.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

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

Also as on-going project "De-icers Management System DIMS" that has as main objective to calculate a proper dosage, based on parameters that have influence on slippery surfaces occur on roadways. The models behind it, should take the traffic intensity and precipitation, road temperature etc. in consideration. A further goal is to apply with dynamic spreading. Dynamic spreading, require that the system DIMS would be able to continuously computes new dosages as the salt spreader covers its route.

ROad STate MONitoring System (ROSTMOS) is among projects that take place in cooperation with other Nordic countries and supported by the NordFoU organisation. NordFoU is a co-operation between the national Nordic road administrations to initialize, finance and run R&D projects. The project aims to develop a system for the registration/verification of road state that with high precision can monitor the condition of the road network in real-time.

The project will demonstrate how road state data can be collected and linked with other information such as weather conditions and operational measures in the form of snow clearing and gritting. It will also be shown how road state data can be used to improve the prognosis for the development in the driving conditions.

Test of salt spreaders in the Research centre Bygholm:

This project aims to examine whether a narrow the setting of spread width is important for slippery roads effectiveness, and whether there are differences in the use of combi- and pre-wetted salt-spreaders.

In order to identify the object, it is described in several objectives:

1. The salt transport on the road surface in relation to traffic speed, road conditions and time.
2. The importance of salt spreader speed
3. The importance of salt quality (fine-grained versus coarse-grained)
4. A determination of similarities / differences at use of the combi- and pre-wetted salt spreaders. The project team worked on the hypothesis that the salt spread in adjusted spreading width, will as a consequence of traffic impacts and road side fall slowly move to areas outside the adjusted spreading width. All the experiments show that the salt moves toward roadside and beyond the discount, but not all of the salt that makes it. Some of the salt by-fades completely from the road surface, which cannot be seen from the diagrams

SPREADER MONITORING AND CONTROL:

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

The winter management system VINTERMAN in Denmark is under continuous development. In connection with this project they are now working with a system linked to GPS-guided salting tied to dynamic spreading where forecasts for weather and road conditions interacts to section based forecasts of road surface. The intention is that the driver just has to drive the lorry while the GPS and the program control the spreader.

The project includes examination with GPS controlled brine spreading with nozzles versus the spread of salt with dish.

PATH DEVELOPMENT GROUP:

Cycle tracks and similar, are currently subjected to attention in all Nordic countries. The goal is to, focus on the path spreader spreading quality and observations about road conditions and residual salt after salting.

ICE-CAROUSEL:

The purpose of Ice-carousel is both to determine friction energy created by the rolling resistance between tyres and the road surface and to determine traffic accelerating power and time of thawing of ice.

Traffic has an accelerating effect on the thawing of ice. The outcome may be utilizing to reduce salt consumption, or, at best cases, avoiding certain callouts for salting.

EPAS (External influences spray patterns - particular focus on salt quality, vehicle speed and drive system) is also a NordFoU project

The main goals in the project are to achieve knowledge about:

1. Correlation between driving speed and spray pattern by spreading prewetted salt with disc and spreading brine with nozzles and the effect off crosswind.

2. Correlation between salt quality and spreading pattern of pre-wetted salt with disc.

3. Correlation between the drive system and the spray pattern, pre-wetted salt with disc.

This project uses the knowledge gained through other projects regarding winter maintenance on roads, but combines it in a way that is usable for the operations level of the winter maintenance organisation.

5. REFERENCES

www.vd.dk
www.vintertrafik.dk
www.trafikken.dk
<http://www.easyway-its.eu/>



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

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

Area	45 339 km ²
Population	1 317 797
Density of population	29 per km ²
Capital: Tallinn	443 894 inhabitants
Latitude (capital)	59° 44' N
Cars per 1,000 inhabitants	370
Density of national roads	366 km per 1,000 km ²

GENERAL FACTS ABOUT ESTONIA

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

Most harbours are located on the northern shore of the sea and, therefore, goods and people are used to being transported through Estonia. Nowadays international route Via Baltica (from Estonia through Baltic States) is developed.

WINTER 2016/2017 IN ESTONIA

Town	Monthly average Temperature (30-years average)					Snowfall (cm) (30-years max)		Precipitation (30-years average) (cm)				
	Nov	Dec	Jan	Feb	Mar	Daily maximum snowfall	Maximum snow depth	Nov	Dec	Jan	Feb	Mar
Tallinn	1.3	-1.9	-3.3	-4.3	-1.0	25	54	7.0	5.7	5.6	3.6	3.7
Tartu	0.3	-3.3	-4.6	-5.3	-1.0	16	42	5.3	4.9	4.8	3.5	3.8
Jõhvi	0.0	-3.6	-5.1	-6.0	-2.0	15	53	6.5	5.0	4.5	3.3	3.9

1.2 ROAD NETWORK

Total road	network km	National roads km				Other roads km
		Total, including:	Main roads	Basic roads	Secondary roads	
58,936	16,594	1,609	2,405	12,478	102	42,342

The Republic of Estonia is administratively divided into 15 counties.

2 CLIMATE

2.1 STATISTICS ON TEMPERATURES AND PRECIPITATION

Snowfalls and slippery conditions usually begin in October and winter conditions last for 6 months until April. But we have had snow even in the end of May. The climate varies from the wet maritime on the coasts to the dry continental in the eastern and southern areas. We must be ready to meet quite low temperature like -25 °C. Road surface temperature often alters from minus to plus degrees and therefore the skid resistance control is utmost important.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

LEGAL OBLIGATION TO PERFORM WINTER MAINTENANCE

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

1. Requirements for the State of the Road.
2. Requirements for Winter Maintenance Technologies.

It is stated by the Traffic Law that winter tires are required to be used by vehicles up to 3.5 tonnes during

the period from December 1 until March 1.

Driving with studded tires is allowed from October 1 to April 30.

CLASSIFICATION OF THE ROADS - LEVELS OF SERVICE

ADT	Required level of service			
	Main road	Basic road	Secondary road	Local road
Motorway	4	-	-	-
over 6000	3	3	3	-
3001-6000	3	3	3	2
1001-3000	3	2	2	2

Indicators	Requirements for the state of road by service levels			
	1	2	3	4
State of road surface				
Allowed road condition	Packed snow or icy road surface is allowed with anti-skid treatment in unsafe spots.	Packed snow or icy road surface is allowed with entire anti-skid treatment	Sidewalk and all wheel tracks free of snow and ice de-icing	Sidewalk and road pavement is free of snow and ice entire de-icing
Required minimal friction coefficient	0,20 and at risk areas 0,25	0,25 on whole driveway	In wheel tracks 0,30 and in other driveway 0,28	0,30 on whole driveway
Snow critical thickness				
Allowed depth of loose snow	< 10 cm	< 8 cm	< 4 cm	< 3 cm
Allowed depth of slush, mix of salt and snow	< 5 cm	< 4 cm	< 2 cm	< 2 cm
Width between snow mounds	> 6 m or at least road width	> 8 m or at least road width	Whole driveway and shoulders	Whole driveway and shoulders
Evenness				
Allowed depth of ruts or unevenness in packed snow	< 4 cm	< 3 cm	Packed snow layer ~2 cm between wheel tracks	Bare pavement. When T < -12 °C snow layer < 1 cm between wheel tracks

REQUIREMENTS FOR THE STATE OF THE ROAD



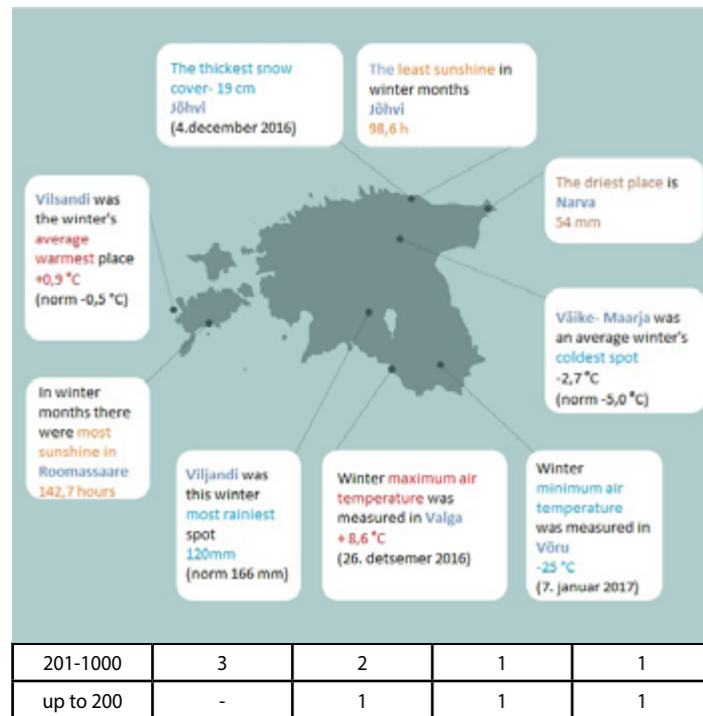
LEVEL 1



LEVEL 2



LEVEL 3



MAXIMUM SERVICE CYCLE TIME (H)

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

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

ORGANIZATION OF WINTER MAINTENANCE

The three principal spheres of work of a maintenance undertaker – routine service, periodic service and retain repairs are all included in a single contract that lasts for 5 years. The evaluation of and payment for routine service is fully performance-based. That means there is no counting of amount of work that has to be done; the attainment of the required service level is what counts.

In Estonia, we have 5-years maintenance contracts. As of 31.12.2016 we have 18 countywide performance-based contracts (400-1300 km). In public procure-

ments usually, 5-8 bidders compete. Road maintenance market is progressively developing in Estonia, depending on the location of road construction companies- the most developed is Tallinn area. Tartu follows the next. There is less entrepreneurship on islands and in the Southern Estonia.

The main winter service works are:

- snow and slush prevention from the roads and side of roads with the front and side ploughs of service trucks, graders and tractors;
- cleaning intersections, turn-offs, acceleration and deceleration lanes, public vehicle stops, waiting platforms, road and pedestrian crossings, parking lots and motorbus turn-over sites of snow and slush;
- cleaning bridges, overpasses and tunnels of snow;
- cleaning road signs of snow;
- ice prevention by sprinkling chlorides, abrasive materials or their mixtures or chloride aqueous solutions with gritters;
- removing ruts and irregularities;
- mechanical coursing with the scarifier blades and tooth blades of service trucks and graders;
- mechanical snow and ice prevention at level crossings;
- maintenance of speed camera booths and speed displays;
- placing markers.

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

CHANGES IN THE CONTRACTS. ESTABLISHING THE WINTER SERVICE LEVEL 3+



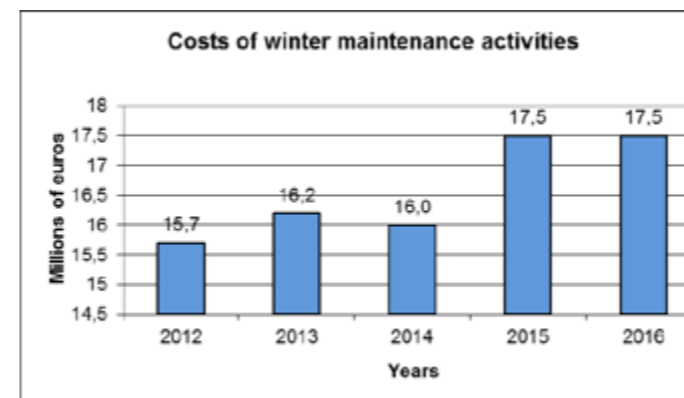
On 01.10.2016, the biggest state roads were given the winter service level 3+. The winter service level 3+ means that the maintenance cycle is 2 hours to ensure the required coefficient of friction of the road; other maintenance times and requirements are the same as with winter service level 3. The winter service level 3+ applies on all weekdays from 5am–11pm, with the required level on other times being 3.

The main difference between level 3+ and 3 are the shorter maintenance cycles: during daytime, 2 hours instead of 4, and during night-time, 4 hours instead of 8.

CONSUMPTION OF DE-ICING MATERIALS

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

The amount of salt used depends on winter conditions, especially on how many times temperature varies between plus and minus degrees. In the last years in winter in average 30-36 thousand tonnes of NaCl was



used.

COSTS OF WINTER MAINTENANCE ACTIVITIES

SPECIAL REQUIREMENTS FOR START UP, MAINTENANCE AND USING OF ICE ROADS ARE FIXED

Ice roads are established for vehicles to move over a frozen sea between the mainland and the islands or over a lake connecting different places in the mainland. When signs of the ice road starting to form appear, all vessel traffic will be stopped.

Ice roads are established and maintained by compa-

nies having such expertise. According to the contracts made with the companies, the establishing and maintenance of the ice roads is the responsibility of the companies which have to conduct experiments, establish traffic control, organise surveillance, communicate the conditions of the road, etc. The Road Administration will monitor the fulfilment of the obligations of the contract.

The following rules apply when using ice roads:

- ice roads are open for traffic only during daytime; the traffic will be closed if visibility is under 300 m;
- the recommended driving speed is 25 km/h or 40-70 km/h (with speeds of 25-40 km/h, the vehicle may cause resonance that can do damage to the ice);
- on the ice road, it is permitted to drive only in the designated areas, with minimum intervals of 2 minutes;
- the distance between vehicles have to be maintained at minimum of 250 m;
- overtaking and two way traffic on the same lane is prohibited;
- driving outside the marked ice road is prohibited;
- the seat belts need to be unfastened and the doors need to be easily openable;
- uneven areas need to be crossed as slowly as possible;
- stopping the vehicle, speeding, driving in blizzard, fog or night-time is prohibited.

MAIN CHARACTERISTICS OF ESTONIAN ROAD WEATHER STATIONS AND ROAD WEATHER FORECASTS

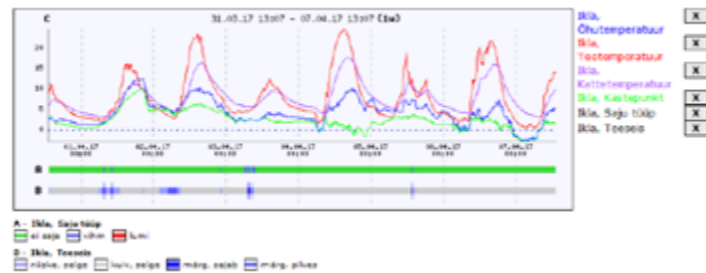
In Estonia four types of road weather stations are used: 31 ROSA, 5 RWS200 and 7 optical stations made



by Vaisala (Finland) and 25 GMS stations made by Saab (Sweden). Finnish stations measure the same data as GMS stations plus valuable additional information about road surface condition, salt usage etc. ROSA/RWS200 stations measure the following parameters among others:

- air, dew point, surface and pavement temperature; air humidity;
- wind speed and direction;;
- type and amount of precipitation. also visibility (not in all stations)
- road surface status – dry, wet, snowy, slippery, icy etc.;
- the amount and concentration of salt.

Road weather stations do not provide any weather forecasts by themselves, they only give information about the past and present weather conditions on the road. Estonian Road Administration is buying/developing road weather prognosis data in good cooperation with Estonian Environment Agency and Finnish companies/agencies producing the data in question.

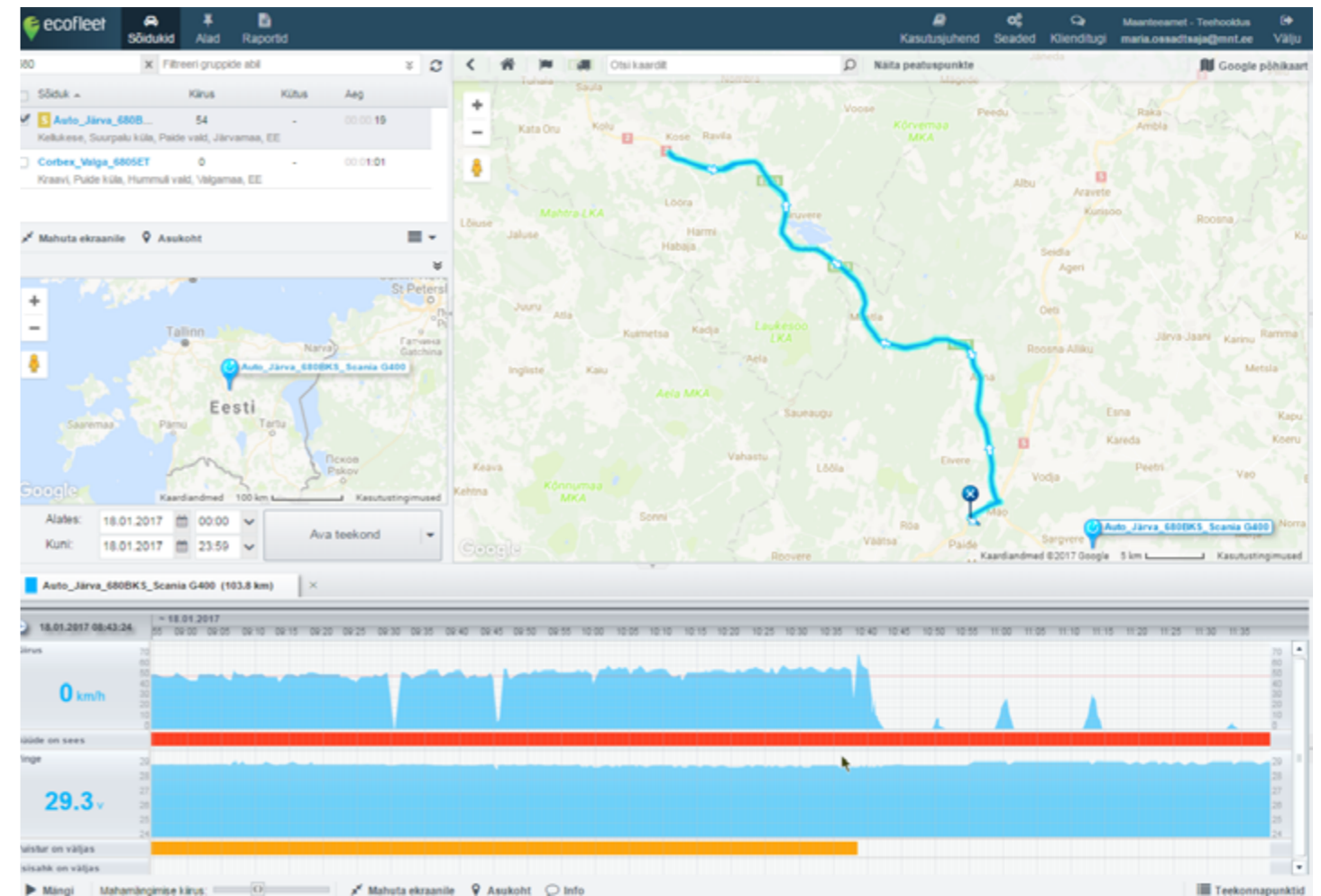


Another important part of Estonian RWIS are road cameras. There was 112 road cameras in Estonia at the beginning of year 2017 and this network is growing constantly; each year around 10-15 new cameras get installed on state roads to give road masters visual information on road and weather conditions which is updated every 10 minutes.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

The Guide for Inspection of Roads stipulates the road

A SAMPLE OF A QUERY FROM A NEW INSPECTION LOGBOOK: (IN ESTONIAN)



GPS APPLICATION OF SERVICE VEHICLES: (IN ESTONIAN)

inspection order for supervision.

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

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

checked.

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

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

The development of the new surveillance diary started in the year 2014. From the beginning of 2016, new maintenance and surveillance diaries were enforced and the personnel of the maintenance works were specified and shown in the diaries. The next step in the development of the maintenance work diaries occurred at

the end of 2016 when a section for making periodical overviews was added. Currently, there is a user-friendly information system in place for the surveying of road conditions which is of help to both the surveying specialists as well as to the drivers in assessing the inspections and work of the maintenance staff.

The surveillance staff of the Road Administration can via a specific app follow in real time the movement of maintenance vehicles.

In addition to the movement of vehicles, the work of snowploughs and gritters can also be observed.

3.4 TRAFFIC SAFETY AND INFORMATION INFORMATION PROVISION TO THE ROAD USER

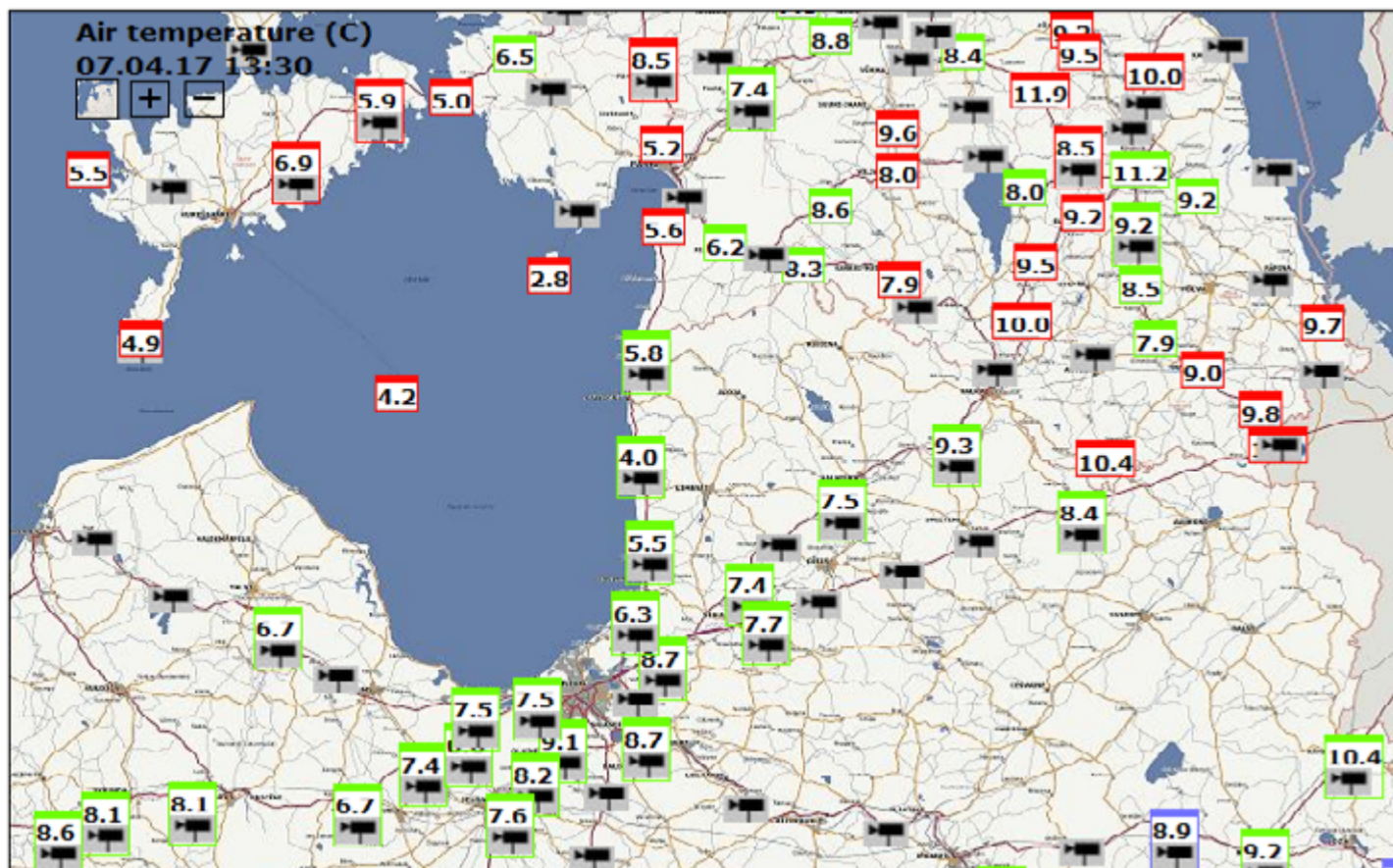
Road Information Centre was established in 1997 to improve the traffic information for road users.

Estonian Road Administration was buying the service of collecting and spreading of road information from a private company. A 3-year contract was signed after an open tender held in the end of 2003. In the contract

there were certain rules that the private company had to follow in collecting information from road weather stations, meteorological centre and road users.

In the September of 2011, Road Information Centre was added to the Estonian Road Administration, and it started servicing road users from the 1st of January, 2012.

The service was introduced to the Road Administration during the crisis of the snow storm "Monika" in 2010, when it was also decided to strengthen the crisis communication capabilities of the Road Administration. With the addition of Road Information Centre to the Road Administration, the modernisation and subsequent rapid development of the latter was made possible. In addition to the new work space in the Road Administration facilities, the Centre started a new traffic information system called Tark Tee ("Smart Road") in the summer of 2012. In the February of 2013, the Road Information Centre started providing phone service for the traffic registry. In 2014, the road information service incorporated the use of a GIS-based Road Information



A SAMPLE OF A QUERY FROM WEB SITE

Centre's information system called MIKIS that provided new and faster options for receiving and managing information and notifying partners.

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

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

BALTICROADS.NET – A CROSS BORDER ROAD INFORMATION PROJECT

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

Automated Road Weather Information System (RWIS) is used to continuously record the current and predicted status of driving conditions on the road network.

The four countries have joined resources to develop a common Internet interface to share and transfer the existing RWIS data collected around the Baltic Sea Region more effectively to the transport sector and other road users. The overall goal of the Internet interface is to provide better access to the accurate road weather information for the transport industry and the driving public thus resulting in better service and improved traffic safety. The co-operation between the national road administrations improves the utilization of the information from the existing road weather information stations in road maintenance operations.

The Baltic RWIS Internet interface provides current data (less than 30 minutes old) on the local road we-

ather displaying data such as: road and air temperature; type of precipitation; road condition; wind speed and direction; as well as dew point and humidity.

USE OF WEATHER RELATED ROAD SENSORS AND VARIABLE ROAD SIGNS

There is four variable message signs in Estonia, two of them are situated on Estonian-Latvian border, one on our main road Tallinn-Narva and one on Tallinn, our capital, border.

Suggestions about speed and warnings about slipperiness or other bad driving conditions are given to motorists via those signs plus some additional information - about general Estonian traffic rules for example - via border signs. Suggestions and warnings shown to motorists are mainly based on weather data gathered by nearby road weather stations.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

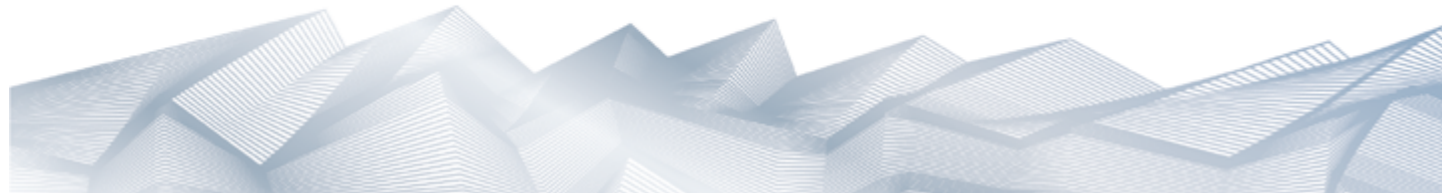
There are 2 different subjects related to winter maintenance that are researched at present.

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

Second is about RWIS (Road Weather Information System) good quality road weather prognosis service. During winter 2016-2017 ERA (Estonian Road Administration) bought road weather prognosis data from Finland and made it available to all road maintenance companies for free. Our goal for next 4-5 winters is to develop this service locally in good cooperation with National Environment Agency.

5 REFERENCES

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1 DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY



FIGURE 1 FINLAND'S LOCATION

Finland is a country in northern Europe with an area of 338,432 km². It is situated between Sweden, Russia and Norway and borders on the Baltic Sea too. The country has 5.5 million inhabitants, 16,25 per square kilometer, most of whom (71%) live in towns or urban areas. The average percentage in EU is 73%. About one million people live in the metropolitan area of Helsinki.

1.2. ROAD NETWORK AND TRAFFIC

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

The road network comprises 78,000 km of public roads, of which 50,745 km has asphalt pavement. 890 km of these are motorways. In addition, there are 30,000 km of streets and planning roads and 350,000 km of private roads.

Kilometrage on state roads is 38 000 million km and the share of buses and trucks is 3,300 million km per year. Public roads carry about 79% of all traffic.

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

Area	Total snowy regions	338,432 km ²
Population	Total snowy regions	5.5 million
Length of road	Public state roads	78,000 km
	Streets and planning roads	26,000 km
	Private roads	350,000 km
Latitude (capital Helsinki)		60°19'N

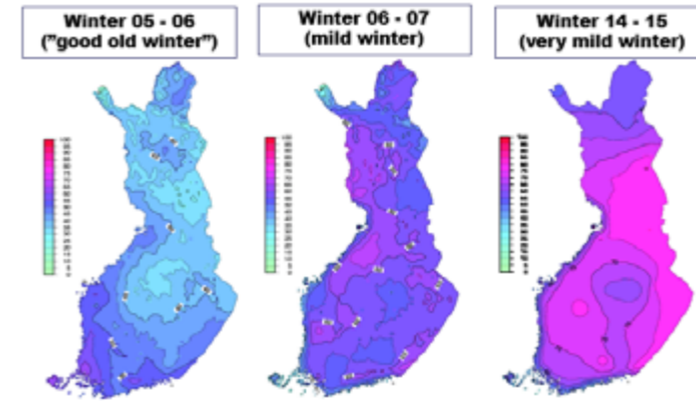


FIGURE 2 EFFECTS OF CLIMATE CHANGE ON FREEZE-THAW CYCLES. (TEMPERATURE UNDER 0°C TIMES/WINTER)

2 CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS

Finland is situated between the 60th and 70th northern parallels in the Eurasian continent's coastal zone.

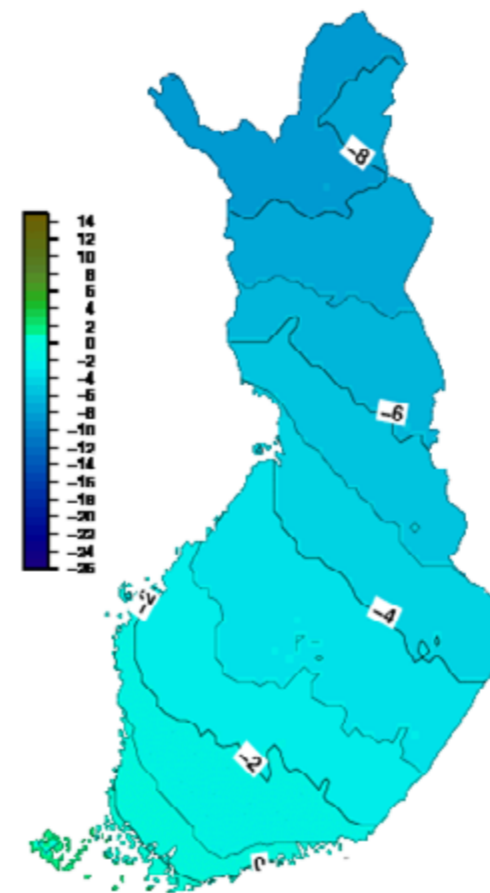


FIGURE 3 MEAN ANNUAL WINTER TEMPERATURE (°C) DURING 1981-2010

The mean temperature in Finland is several degrees higher than that of other areas in these latitudes, e.g., Siberia and south Greenland. The temperature is raised by the Baltic Sea, inland waters and, above all, by airflows from the Atlantic, warmed by the Gulf Stream.

Conditions differ in the various different parts of the country. In the coastal areas, where the climate is closer to a marine climate, weather and driving conditions vary greatly and slippery conditions develop easily. In the country's eastern and northern parts, the weather resembles a continental climate and is clearly colder. However, winter maintenance is getting more challenging in eastern and northern Finland also because of climate change (Figure 2).

2.2. STATISTICS ON TEMPERATURE AND PRECIPITATION

In Southern Finland the average winter temperature is about -2 °C and in the North approximately -7 °C (Figure 3). However, the average temperature in recent

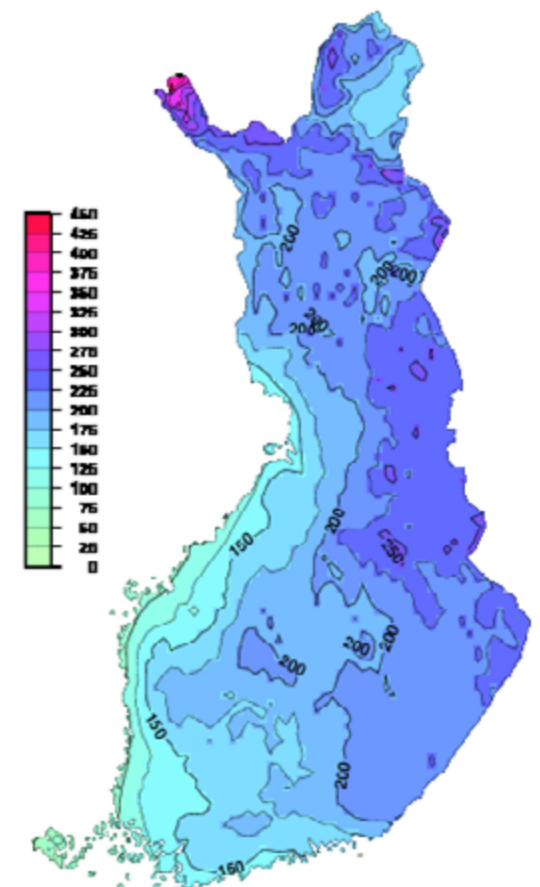


FIGURE 4 MEAN ANNUAL SNOWFALL (MM) DURING 1981-2010

years has been about 0 °C in Southern Finland and about -5 °C in the North. The annual rainfall is less than 600 mm in the North and 600-700 mm in the South.

Permanent snow falls usually in October or November in the North and in December in the South. The long-term average snowfall converted to millimeters of water varies from 75 to 250 mm in different parts of Finland (Figure 4). This amount of snow accumulates throughout the winter season, mainly as snowfalls under 10 mm.

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

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

2.3. WINTER INDEXES

Finland does not currently use any index that would describe the severity of winter purely from the perspective of weather conditions.

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

3 WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

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

TABLE 1 CORRELATION BETWEEN FRICTION VALUES AND DRIVING CONDITIONS. THE FRICTION VALUE IS MEASURED BY C-TRIP

Friction value	0.00-0.14	0.15-0.19	0.20-0.24	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 dry, not slippery

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

ROAD CLASSIFICATION

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

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

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

QUALITY STANDARDS

A friction value is an important quality standard in Finland because packed snow and ice are also allowed on the main roads. The traffic volume on many road sections of the main roads is so low that a reasonable amount of salt is not able to keep them bare. The friction value is measured by friction meters (either traditional braking meters like EI-trip or new acceleration sensor meters).

TABLE 2 QUALITY STANDARDS OF ANTI-ICING

Winter maintenance class	Ise, Is	I	Ib	II	III	K1 K2
Normal Friction requirement	0.30	0.28	0.25			
	road surface below -6 °C 0.25	road surface below -4 °C 0.25	spot sanding 0.25 line treatment 0.22	Roughened surface, problem locations are spot sanded	Roughened surface, problem locations are spot sanded	According to traffic needs
			Line sanding of icy compacted snow	Line sanding of icy compacted snow		
Cycle time	Ise: 0 h, Is: 2 h	2 h	salt 3 h, sand 4 h	6 h line sanding	8 h line sanding	2 h

TABLE 3 QUALITY STANDARDS FOR SNOW REMOVAL

Winter maintenance class	Ise, Is	I	Ib	II	III	K1	K2
Maximum snow depth	4 cm	4 cm	4 cm	8 cm	10 cm	3 cm	4 cm
Cycle time	2.5 h (slush 2 h)	3 h (slush 2.5 h)	3 h	4 h	6 h	3 h	4 h
						Ploughed clean before 06	Ploughed clean before 07

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

Only half as much slush is allowed as snow.

TABLE 4 QUALITY STANDARDS FOR SURFACE EVENNESS

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

TAILOR-MADE MAINTENANCE

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

RULES REGARDING MATERIALS AND EQUIPMENT

Winter maintenance is ordered from contractors based on the principle of quality responsibility. It is mostly

the contractor's own decision as to which kind of maintenance actions and equipment are used. However, tractor usage is not allowed on main roads. The equipment has to meet also certain standard requirements like minimum Euro III for trucks and stage II for tractors. The equipment has also to be safe, noticeable enough and suitable for the use.

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

THE CUSTOMER SATISFACTION BONUS

The Finnish Transport Agency has actively tried to find ways to improve the service provided for road users. The target has been to find ways of improving the service without significantly increasing the costs. As one of the ways of encouraging contractors to serve

road users better, the Finnish Transport Agency has developed a customer satisfaction bonus to be paid to contractors if satisfaction is high enough.

In spring 2004, a separate research and development project was done to develop the customer satisfaction bonus, as well as already piloting the bonus scheme at the same time in relation to five contracts that began in 2004.

The bonus, which is based on customer satisfaction, has been used since 2004 in little different forms. Bonus on customer satisfaction is available annually. The extent of the bonus depends on 6 different assessment factors, of which 4 relate to customer satisfaction, one deals with the success of winter maintenance and one relates to the success of summer maintenance on the basis of an assessment carried out by the client. The assessment carried out by the client is based on the reporting of the contractor in relation to measures taken. Customer satisfaction bonus is paid annually and the extent of the bonus varies between 0 and 2 percent of the annual costs of the contract.

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

3.2. ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

ORGANIZATION

In 2001 the Finnish National Road Administration was divided into the Finnish Road Administration (Finra), which orders services from producers, and the Finnish Road Enterprise, which takes care of construction and maintenance among other contractors and also provides consultation services. In the beginning of 2008 Finnish Road Enterprise became known as Destia. The Finnish Road Administration, Railway Administration and Maritime Administration were united together and the Finnish Transport Agency was established in the beginning of 2010. The regional Centres for Economic Development, Transport and the Environment (ELY-centres) manage the regional implementation and development tasks of the state administration.

The Finnish Transport Agency specifies national policy, quality standards and guidelines of procurement

process. The regional ELY-centres are clients doing the competitive biddings in practice and paying to contractors.

In Finland, client orders winter maintenance along with summer maintenance as area maintenance contracts from contractors. The contractors for each regions are chosen on price. Some standards for quality and company turnover has to be met also. A new contract model based on target price is also piloted since 2014.

There are four ELY-centres, which are responsible for the ordering of the maintenance to different parts of Finland under guidance of the Finnish Transport Agency. The total amount of ELY-centres responsible for traffic is nine. There are 79 regional contracts and a long-term life-cycle contract on some road sections of E18. Every regional contract includes 450-2300 km of road network and lasts 5 years.

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

OPERATIONAL MANAGEMENT

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

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

The most important measures involved in the maintenance of roads in a condition set out in the quality

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

ROAD INFORMATION PROVISION

In order to ensure the timeliness of winter maintenance, various kinds of information on the current and impending weather conditions are necessary. To this end, client (the Finnish Transport Agency and ELY-centres) has at its disposal road weather stations and weather camera systems. In addition, client subscribes to various kinds of weather reports as well as satellite and

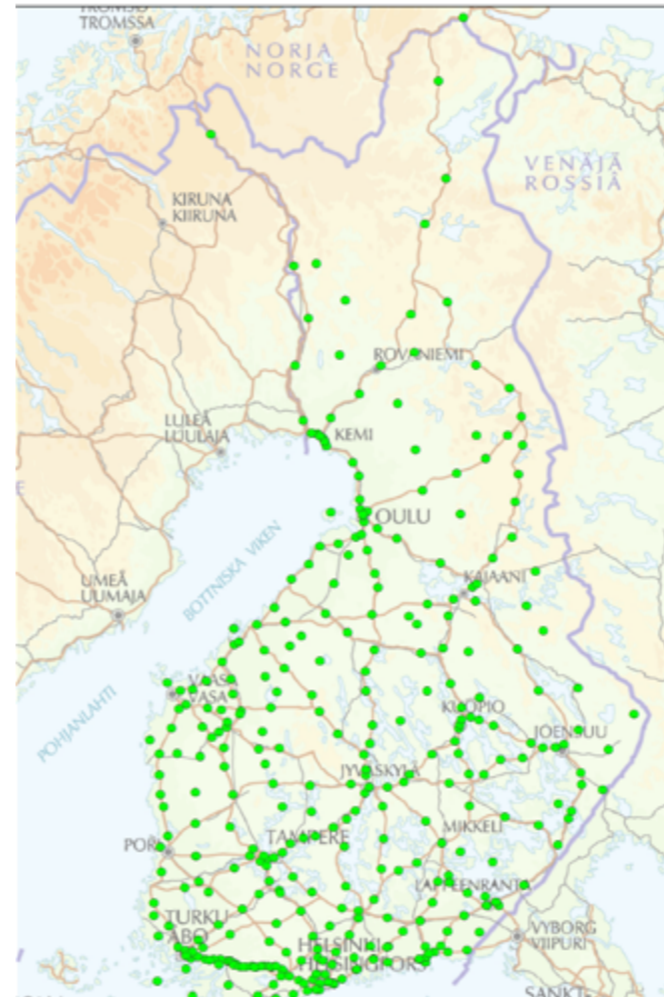


FIGURE 5 LOCATIONS OF THE ROAD WEATHER STATIONS.

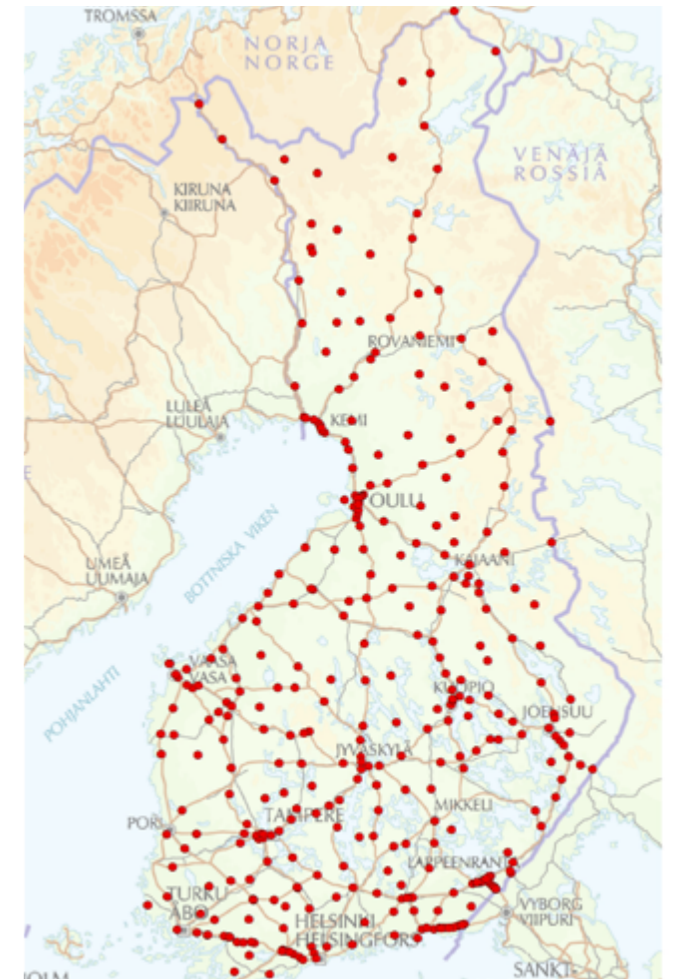


FIGURE 6 LOCATIONS OF THE WEATHER CAMERAS.

radar images from external organizations. The supplier of weather information is also selected through competitive tendering. The weather information produced and subscribed by client is also available to the regional contractors. Contractors can acquire additional weather information services to those provided by the client at their own expense.

The road weather station network consists of over 375 road weather stations. The stations gather information on factors affecting the weather and driving conditions, such as the temperature of ambient air and the road surface, wind velocity and the moisture level of the road surface. The road surface information is assessed using a small sensor placed on the road surface. In addition there are optical remote surface state sensors, which give also the surface friction value (0.0-1.0). These sensors are combined to the 150 normal road weather stations. In the winter, road weather information

is updated at least three times an hour. The information is updated more regularly when the temperature approaches zero, as this is when the weather is at its worst from the perspective of drivers and road maintenance staff. The locations of the road weather stations along the road network are shown in Figure 5.

The weather camera network of the Finnish Transport Agency and ELY-centres comprises over 500 weather cameras. The network provides equal coverage of the whole of the Finnish public road network. In the autumn and the winter, all cameras are operational. The weather camera image is updated at an interval of approximately 15-90 minutes; more regularly in bad weather, and less regularly in good weather. The locations of the weather cameras along the road network are shown in Figure 6.

3.3. ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

COSTS

The modest average daily traffic and long road network, which is maintained year-round to ensure usability, unavoidably leads to a relatively low level of cost-effectiveness. The annual winter maintenance costs have, however, been in same level as a result of competitive bidding. Winter maintenance costs of state roads (78,000 km) are about 99 million euros. This indicates a cost of approximately 1,270 euro/km. In addition to this, some costs come also from road weather system maintenance and information systems.

The Finnish Transport Agency finds the winter maintenance of lower-level roads (usually with a maintenance class of III) an especially demanding challenge and the users of these roads are unsatisfied with the maintenance. The length of lower-level roads is considerably higher than that of main roads, but percentage of kilometers driven on these roads is very low. The average daily traffic is often only a few hundred vehicles a day, whereas ADT on main roads usually is some thousands and tens of thousands near biggest cities. This is why focus on the maintenance of main roads provides higher efficiency in improving safety in traffic, for example. Most fatal head-on accidents on winter time take place on main roads. Due to the large number of lower-level roads, even a small increase in the level of quality creates significant additional costs. The

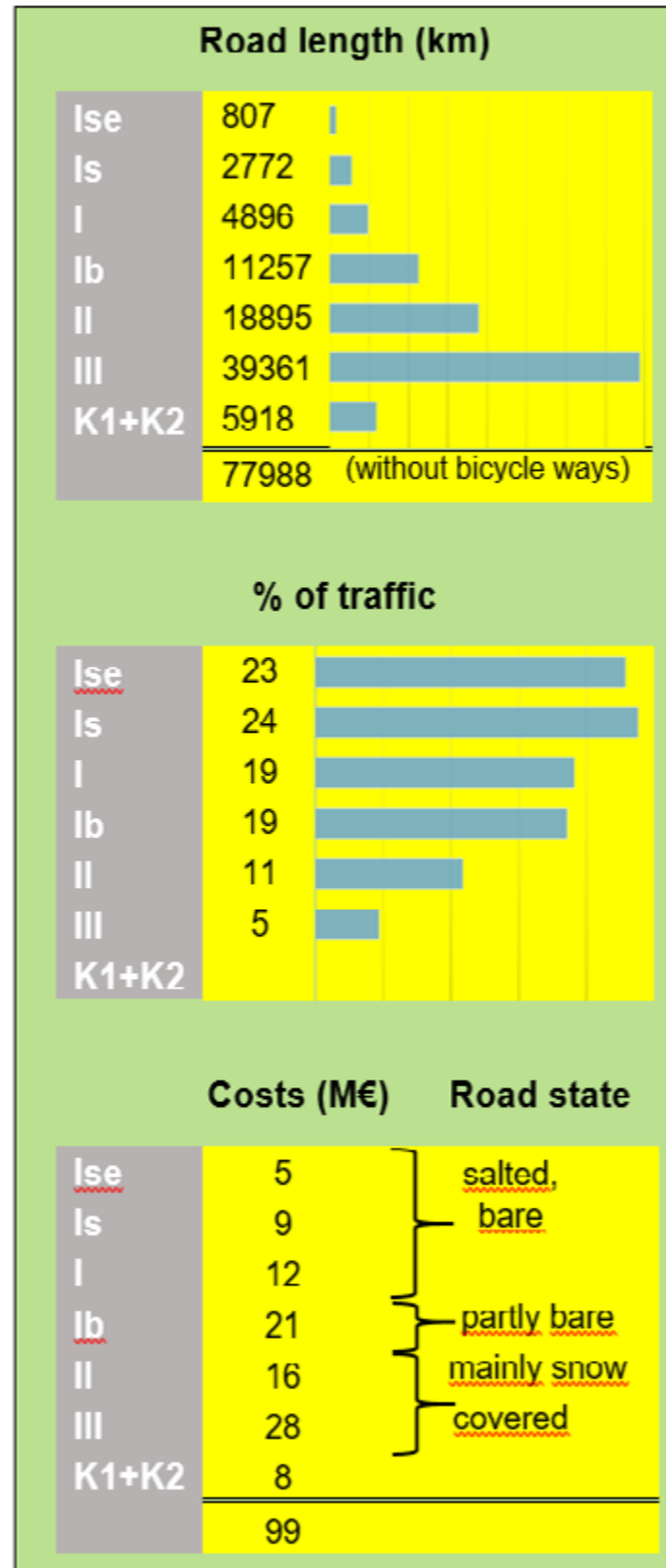


FIGURE 7 ROAD LENGTHS, PERCENTAGE OF TRAFFIC AND COSTS OF WINTER MAINTENANCE IN DIFFERENT MAINTENANCE CLASSES 2012.

division of roads, traffic and winter maintenance costs in relation to different maintenance classes is shown in Figure 7.

SALT CONSUMPTION

The most significant environmental issue resulting from winter maintenance is the damage suffered by ground water due to the salt used in anti-icing. The use of salt has traditionally been popular in the coastal regions of Southern and Western Finland, where weather conditions often change suddenly and traffic volume is high. However need of salt usage has increased inland also because of climate change. In some areas of Northern Finland, there is no need to use salt at all, as the amount of traffic is low and the weather conditions are colder and more stable. Amount of salt use in winter maintenance has been quite stable per kilometer already for 20 years.

The reduction of the harmful effects of salt is aspired to in many ways. According to the winter maintenance policy of the Finnish Transport Agency, very little salt is used on groundwater areas for anti-icing, or potassium formate is used and probably sodium formate in future also.

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

In order to restrict the use of salt, the Finnish Transport Agency also defines on an annual basis the amount of salt to be used in each contract area on the basis of salt amounts used in previous years and winter maintenance classes. In addition, separate, stricter restrictions are set for the use of salt on the groundwater areas. If the contractor uses more salt than has been agreed a year, fines will be enforced. Previously salt bonuses were also used to encourage contractors to minimize salting. The accepted amount of salt is, however, increased in winters that are considerably warmer than average.

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

ASSESSMENT OF THE WORK

The contractor is responsible for ensuring and demonstrating the achievement of the quality of their work, as agreed in the quality plan. Quality reporting comprises reporting of the procedures that have been carried out and any deviations that have occurred. The reporting maintenance actions takes place on real-time on client's information system. Maintenance actions are also shown to road users in real-time through FTA's internet pages. The contractor is expected to fill in a separate deviation report whenever the quality requirements are momentarily not met in relation to an individual section of the road network.

The client monitors the efficiency of the quality assurance measures taken by the contractor, and carries out random checks to ensure that the work is being carried as agreed. Consultants are used to assist these random checks, especially during night time and at weekends. If a failure to meet the quality requirements is identified, the contract will receive a warning or a fine.

Winter maintenance in contracts is based on total price. The contractor will receive payment for the work done on a monthly basis.

3.4. TRAFFIC SAFETY AND INFORMATION

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

The Traffic Information Center provides information on traffic conditions primarily through the mass media – the radio, television and the Internet. The images from nearly 460 weather cameras and over 100 traffic cameras of the Finnish Transport Agency as well as information gathered by about 400 road weather sites are available on the website of the Finnish Transport Agency. Road users can also report any disturbances that they witness on the roads to the line for road users maintained by the Traffic Information Center. In addition, road users are guided with the help of variable road signs and traffic symbols to select their route in such a way as to make travel time as short as possible and the level of service as high as possible throughout the journey.

Variable speed limits exist on some important main roads and motorways comprising over 400 kilometers in total. The speed limits are displayed according to the road surface condition, weather monitored and traffic volume in real time. Occasional disturbances for traffic such as road accidents or road maintenance work may be reasons for a lowered speed limit displayed as well. Furthermore, variable message and traffic signs may be used as complementary tools, for example, to inform the drivers of road weather conditions or important traffic incidents. Variable speed limit signs have also been installed at some special sites where accident risk is high, in order to lower the speed limit for a short period of time.

In addition to the road weather stations and the weather cameras, the Traffic Information Center gathers the information it needs for communicating and guiding traffic through an automatic traffic measuring system (LAM). The system comprises 450 traffic-measuring devices with sensors placed on the road as well as the related systems for transferring, storing and printing out the information. The system provides information on the amount of traffic on a stretch of road, the average speeds and the overall time spent on a journey.

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

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

duced by meteorological services and weather radar and satellite pictures are available for both winter maintenance operators and the Traffic Information Center.

Winter time speed limits are used in approximately 9000 kilometers on average for five months a year. Lowered wintertime speed limits save 12 lives a year. The use of winter tires is mandatory from 1st December to 28th February. Accident risk during winter period is the same than summer period.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

DEVELOPING FRICTION METERS

In Finland, the road authorities, quality control consultants and the private winter maintenance contractors measure the road friction. The Finnish Transport Agency specifies the instruments and methods to be used in state roads friction measurements. In Finland, during last 25 years, road friction measurement has based on the method, where the small electrical in-car accessory determines the deceleration during braking and therefore estimate the friction.

These traditional friction meters have one remarkable shortage: the meter installation needs professional expertise and becomes more difficult when electrical systems in the new vehicles are getting more complicated. That's why new friction meters utilizing acceleration sensors are today so interesting. For these new meters, it's enough to install them firmly near to the dashboard. If the installation is firm enough, the deceleration measured by the acceleration sensor is same as the deceleration of the vehicle during braking. And the friction value displayed is relative to the deceleration.

The object of Finnish friction studies has been to assess if the new friction meters with the acceleration sensors are so reliable and accurate, that these meters can be utilized in winter maintenance quality control in Finland. Furthermore, the object has been to determine quality requirements for friction meters.

Friction meter comparison study included several friction meters intended to use in winter maintenance quality control, as well as some other types of friction meters.

As a result, the quality requirements for friction meters were introduced and many new meters based on

acceleration sensors were accepted for friction measurements.

Finland has put a lot of effort on digitalization in government period 2015-19. For example digital procurement, fleet information, continuous photo-shooting and real-time information systems have been developed. Many experiments have been done with optical mobile friction measurement devices. Finland has also participated RostMos-project (Nordic Road state Monitoring system) since 2016. One of the projects aims to compare different friction measurement devices and their accuracy in different road conditions.

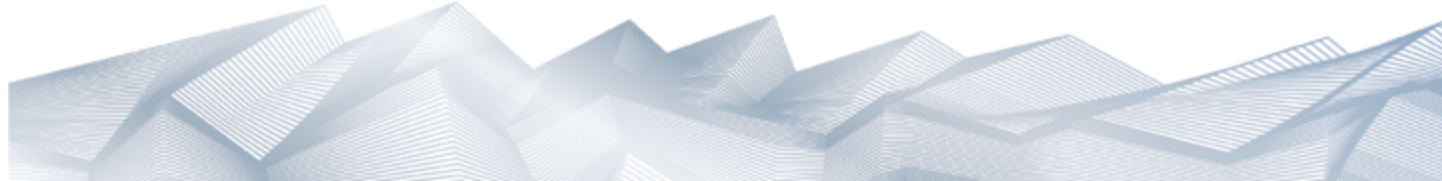
New contract models have been piloted actively during last years in Finland. Program Managed Performance Based Maintenance Contract (PBMC) model started in Contact of Espoo year 2014. The contract model is more open than traditional area maintenance contract. The aim is to develop more simple and feasible version of this contract model and introduce it 2019 in those areas where the contacts will end year 2019.

New information and reporting system of maintenance HARJA was taken into production use October

2016. The HARJA system combines information from several of the client's databases as well as certain data from contractors' information systems. The total number of systems has now decreased, and monitoring is now easier to coordinate. The system is essentially based on contracts financial follow-up and reporting maintenance actions done. The material reports include, among others, the volumes of sand and salt used in the winter. The HARJA system can be used to monitor winter maintenance actions through a real-time map interface or to browse previously completed actions. Contractors and the client can upload weather reports and quality data into the HARJA system using a mobile interface directly from the roads. Road user feedback can now also be viewed on a map.

5. REFERENCES

Statistics Finland: http://www.stat.fi/index_en
 Finnish Transport Agency: <http://www.fta.fi>
 ELY-centres: <http://www.ely-keskus.fi/en>
 Travel and traffic information:
<http://www.liikennevirasto.fi/alk/english/>



1 DEMOGRAPHICS AND ROAD

1.1 INFORMATION ABOUT THE COUNTRY

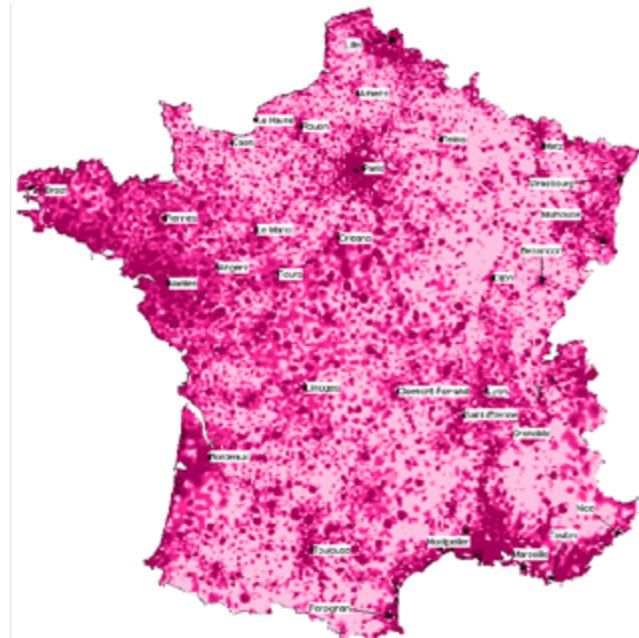
Surface area	551,695 km ²
Population	66.9 million
Density	117,6 per km ²
Capital	Paris
Latitude (capital)	48,8 N

1.2 ROAD NETWORK AND TRAFFIC

The French road network represents about 1 million kilometers. Depending on the type of road, it is managed by the State, local authorities or concessionary companies:

State departments, divided into 11 DIRs (directions interdépartementales des routes - road directorates operating across several French départements)	National roads and non-concessionary motorways (12,900 km)
Département councils	Département roads 380,000 km
Towns	Communal roads (600,000 km)
Concessionary motorway companies	Toll motorways (9,000 km)

Private car transport accounts for the bulk of passenger transport (83%); similarly, goods are mainly transported by road (85%)



France is a medium-sized country on the Atlantic seaboard, with a population of 66.9 million distributed somewhat unevenly.

Its geography and climate are diverse, making France a preferred tourist destination. Aside from the major economic activity generated by tourism, France's industrial and agricultural sectors remain very active. Its administrative organization and history have endowed France with a dense road network.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC ZONES AND MAIN WINTER EVENTS TO BE CONTROLLED

France has 5 main areas:

- **Mediterranean climate**
Temperatures are mild in winter (6 to 11°C on average in January), but sometimes fall suddenly due to the effect of windchill. There are between 10 and 60 days of frost per year in the plain and often fewer by the sea. Snowfall is rare and the population is not used to it. It rains between: 500 and 900 millimeters per year for 50 to 90 days.
- **Oceanic climate in western France**
Rainfall is frequent, but of low intensity (between 120 and 180 days per year), humidity is high and temperatures mild.
- **Modified oceanic climate**
There is less precipitation, winters are colder and there are more days of frost.
- **Continental climate** From north to east. Dry, harsh winters with snowfall.
- **Mountain climate:** (Vosges, Jura, Alps, Pyrenees). Because of the altitude, temperatures are lower and rain and snow more frequent.



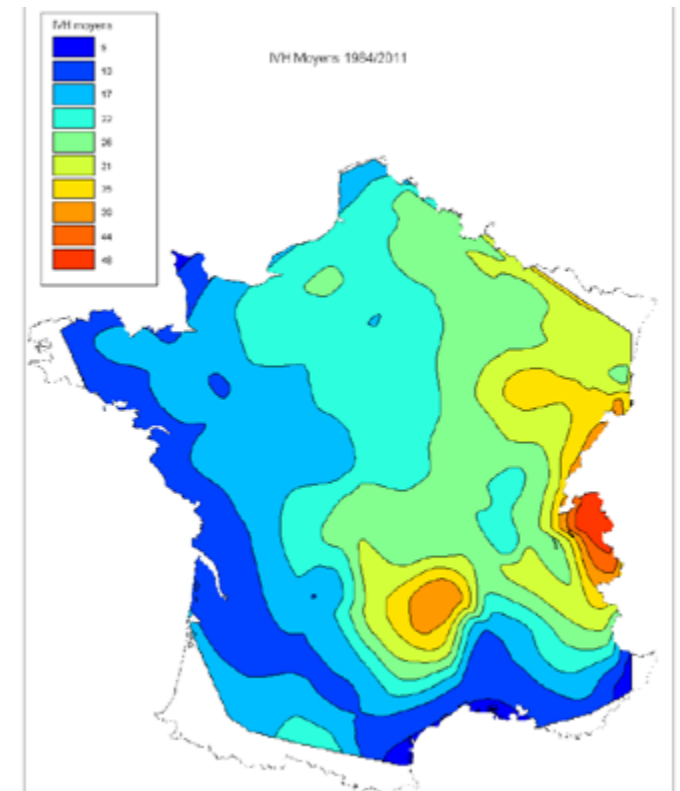
The combination of these parameters gives the IVH and an image of the meteorological risk associated with road operation in winter.

The IVH100 is used to compare winters with each other and to monitor changes on a given site. A so-called average winter has an IVH100 of 100.

Climate	T°C		Rainfall	
	January	Days of frost	Annual amount (mm)	Number of days
Mediterranean	6 to 11°C	10 to 60	500 to 900	50 to 90
Oceanic	5 to 7 °C	10 to 60	600 to 1200	120 to 180
Modified oceanic	2 to 5 °C	30 to 70	600 to 1000	100 to 160
Continental	-1 to 1°C	60 to 100	600 to 1400	110 to 170
Mountain	-1 - 4°C	60 to 120	800 to 1600	100 to 180

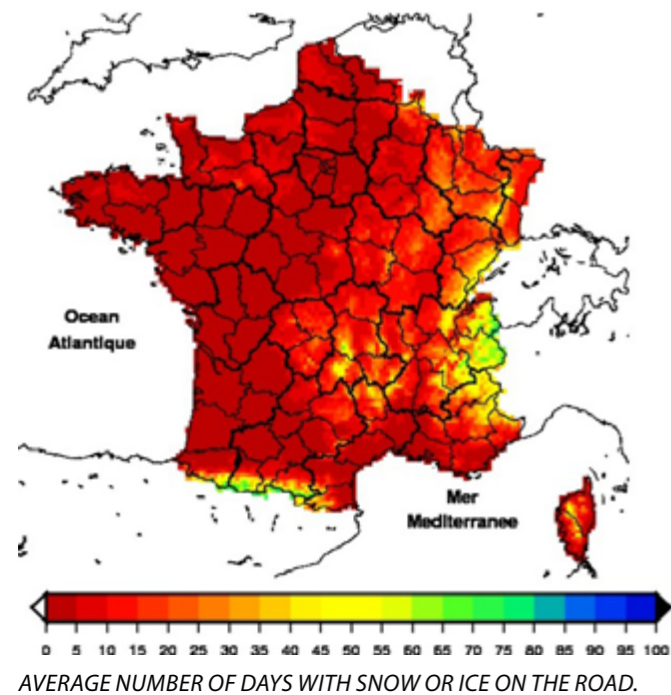
2.2 WINTER INDEX USED IN THE COUNTRY

The winter road maintenance index (Index de Viabilité Hivernale - IVH) is an indicator of winter road network difficulties. It is built entirely around meteorological parameters obtained from meteorological station data.



MANAGERS ALSO MAKE USE OF OCCURRENCES OF SNOW AND ICE:

Nb jours moyen en condition hivernale (neige et/ou verglas)



3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND REGULATIONS REGULATIONS

In France there is no legal obligation to carry out winter maintenance (WM). Managers do, however, have the duty of policing the safety and security of users and guaranteeing normal maintenance of the road for use as intended. Documents produced and distributed by the Ministry of the Environment, Energy and the Sea (Ministère de l'Environnement, de l'Energie et de la Mer - MEEM) set out general rules. The other contracting authorities (motorway companies and département councils) draw on the rules defined for national roads for their service levels, or develop their own specifications. These rules are formalized in the winter maintenance organizational documents (Winter road maintenance file and the Winter maintenance operating plan) (SETRA 2009 Guide Méthodologique Approche Globale).

Bad weather and snow plans are drawn up to deal with meteorological conditions (snowfall, freezing rain, etc.) that are likely to exceed the threshold conditions that can severely degrade traffic conditions on the road network. Their aims are to ensure the safety of users in

all circumstances, to implement traffic management measures requiring coordinated action by departments in order to prevent the network from becoming jammed, insofar as this is possible, by ensuring that car traffic remains fluid even under degraded conditions, and to implement inter-departmental operational coordination arrangements with a view to providing assistance and even emergency help to affected users if necessary:

These plans define:

- the decision-making process to be set up according to the type of event
- the operational organization of departments to implement the decisions taken
- the various coordinated traffic management measures that can be applied according to the context encountered
- the organization of communication to users.

These plans may be local (département-wide) or zonal (covering a Defense and Security zone). The coordinating authorities for these plans are the département, and Defense and Security zone prefects respectively. They are supported by a COD (Centre Opérationnel Départemental - département operational center) and a zonal control center.

The objectives of a bad weather plan are to ensure:

- traffic flow even in degraded weather conditions, preventing users from getting stuck
- human safety by implementing inter-departmental operational coordination arrangements with a view to providing assistance or even emergency help to users.

The main measures defined in these plans concern:

- information to users
- traffic management
- assistance or emergency help to users

Defense and Security zone prefects and all those identified in the zonal bad weather patterns can use the AGORRA (assistance for operational management of road risks and hazards) web application for operational implementation of traffic management measures and monitoring them.

STANDARDS FOR STAFF

European Directive 2003-88 of 4 November 2003 concerning certain aspects of the organization of wor-

king time, transcribed into French national law, structures the organization of work in both public and private sectors. The legislation proposes several forms of exemption to work organization rules to respond to specific situations. Performing winter service (working at nights and at weekends) comes into this context. The selection and implementation of an exemption to work organization rules requires discussion between staff representatives and the employer, and monitoring of health and safety conditions. As the consequences in terms of numbers and financial cost (on-call work, allowances, overtime, etc.) are linked to the organization adopted, the legislator has devolved this decision to local level. The principles are respected in highly heterogeneous fashion in small municipalities and companies.

Equipment standards

Standards for winter maintenance facilities and equipment have been produced.

NF P 98-180, USE OF SODIUM CHLORIDE AS A ROAD DE-ICING AGENT, SPECIFICATIONS

XP P 98-181, THIS EXPERIMENTAL STANDARD AIMS TO CONTROL ALL DE-ICING AGENTS THAT CAN BE USED ON ROADS, WHETHER MINERAL OR ORGANIC, BY-PRODUCTS OR EVEN INDUSTRIAL CO-PRODUCTS IN LIQUID OR SOLID FORM.

THE LATTER TWO STANDARDS ARE IN THE PROCESS OF BEING REPEALED AND REPLACED BY EUROPEAN STANDARDS.

NF P 98-792, WINTER ROAD MAINTENANCE EQUIPMENT, CAB CONTROL POSITION, CHARACTERISTICS AND SPECIFICATIONS

NF P 98-793, WINTER ROAD MAINTENANCE EQUIPMENT, TERMINOLOGY

NF P98-795, "WINTER ROAD MAINTENANCE AND ROADSIDE MAINTENANCE EQUIPMENT - SIGNAGE, MARKING AND LIGHTING OF WINTER SERVICE RESPONSE UNITS - CHARACTERISTICS AND SPECIFICATIONS"

NF P98-797, "ROAD MAINTENANCE MATERIALS AND PRODUCTS - ROAD DE-ICING AGENT SPREADER - STATIONARY TEST METHOD FOR FLOW MEASUREMENT"

NF EN 15 432-1, "WINTER ROAD MAINTENANCE AND ROADSIDE MAINTENANCE EQUIPMENT - FRONT-END EQUIPMENT - PART 1: FIXED FRONT BASE PLATES"

NF EN 15 432-2, "WINTER ROAD MAINTENANCE AND ROADSIDE MAINTENANCE EQUIPMENT - VEHICLE INTERFACE FOR FRONT-MOUNTED EQUIPMENT - PART 2: INTERCHANGEABILITY OF LIFTING SYSTEMS"

NF EN 13021+A1 AND IN1: MACHINES FOR WINTER SERVICE, SAFETY REQUIREMENTS

NF EN 15597-1, "WINTER MAINTENANCE EQUIPMENT - SPREADERS - DOSING REQUIREMENTS"

NF EN 15583-1, "WINTER MAINTENANCE EQUIPMENT - SNOW PLOWS - PRODUCT DESCRIPTION AND REQUIREMENTS"

NF EN 15583-2, "WINTER MAINTENANCE EQUIPMENT - SNOW PLOWS - PART 2: TEST CRITERIA AND REQUIREMENTS"

NF P 95-303, ANTI-AVALANCHE EQUIPMENT, SNOW BRIDGES, SNOW RAKES, SPECIFICATIONS AND DESIGN

NF P 95-304, ANTI-AVALANCHE EQUIPMENT, AVALANCHE NETS, SPECIFICATIONS AND DESIGN

NF P 95-305, ANTI-AVALANCHE EQUIPMENT, AVALANCHE NETS, SNOW BARRIERS, SPECIFICATIONS AND DESIGN

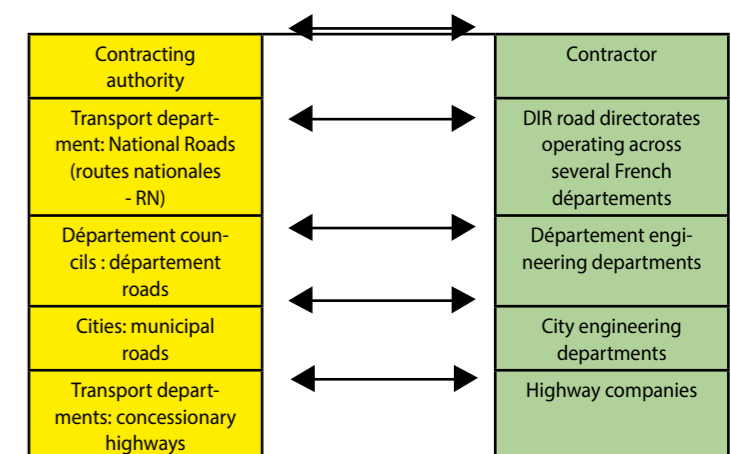
NF P 95-310, ANTI-AVALANCHE EQUIPMENT, ARTIFICIAL TRIGGERING: TECHNICAL PRINCIPLES

NF P 95-311 ANTI-AVALANCHE EQUIPMENT, ARTIFICIAL TRIGGERING: EXPLOSIVE CABLE CONVEYORS (CATEX)

NF P 95-313, PROTECTION AGAINST AVALANCHES, GAS ACTIVATION

3.2 ORGANIZATION AND INTERVENTIONS GENERAL REMARKS

In France the organization for road maintenance is as follows:



Whatever the contracting authority, the organization set up for winter road maintenance is set up along the same lines, which in most cases results in the production of a DOVH. This document is a kind of contract between the contracting authority and the contractor. It is used to inform the different partners about the objectives, the limits and the measures taken. It details the organization and the actions to be taken in each situation. The aim is also to ensure coherence between

Condition de conduite hivernale	Figuration	Intitulé / code couleur	Perception du danger	Probabilité d'un blocage
C1		Normale (vert)	Sans objet	Sans objet
C2		Délicate (orange)	Faible (présence de verglas peu perceptible, neige localisée)	Faible, possible en pente ou rampe supérieure à 3%
C3		Difficile (rouge)	Aisée pour la neige Faible pour le verglas	Forte
C4		Impossible (noir)	Évidente	Blocage effectif

managers. The DOVH sets out the measures concerning road information.

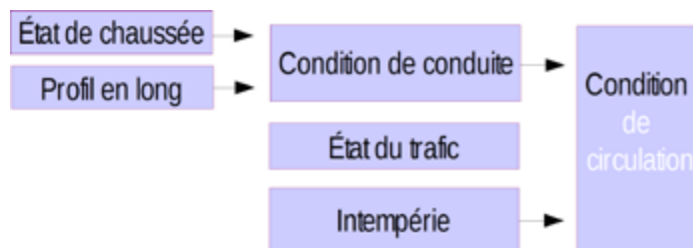
Normal winter is generally defined from 15 November to 15 March and even from 1 November to 31 March for areas with severe winters.

Winter road maintenance services operate on average 14 days a year, from 0 to 150 days depending on the years and zones. There are twice as many interventions by night than by day.

The involvement of public sector staff is relatively great for DIRs, cities and département councils.

DIRs comply with state requirements for the way they are organized. With concessionary highways, they generally have the highest level of service.

Winter road maintenance in urban areas is becoming more and more important. Organization is significantly improving and more and more consideration is given to intermodality in the strategies.



IT IS ONLY ONE OF THE POSSIBLE COMPONENTS OF A TRAFFIC CONDITION.

DRIVING CONDITIONS: THE BASIS OF A COMMON LANGUAGE

The winter driving condition Ci which users may encounter solely due to the state of the roadway in rela-

tion to the presence of snow or ice provides the basis for a common language.

The driving condition Ci is defined as a function of the roadway states EC, themselves expressed as a function of the type of weather phenomenon.

Roadway States (EC)	Terminology of standard 99-320	Operational terminology
EC1	Dry, Transitory moist, Moist, Wet, Streaming wet	None
EC2a	White frozen, Frosted, Icy, Ice Localized or thin formation	Localized, thin formation of ice (by freezing of existing moisture or condensation) or ice patches
EC2b		
EC3	Frosted, Generally icy due to the freezing of supercooled droplets or freezing of pre-existing water	Generalized formation of ice due to the freezing of existing moisture
EC4	Generally icy following precipitations on the road at below-zero temperatures or supercooled precipitations	Generalized formation of ice following freezing rain

ROAD CONDITIONS, EXAMPLE OF ICE

Road conditions (illustrative data, to be specified and adapted)			Winter driving conditions	Color code
Ice	Snow, no slope or incline	Snow, with slope or incline > 3%		
EC1	EC1	EC1	C1	Green
EC2	EC2a	EC2a	C2	Orange
	EC2b			
EC3	EC3	EC2b	C3	Red
		EC3		
EC4	EC4	EC4	C4	Black

LINK BETWEEN ROAD CONDITIONS AND WINTER DRIVING CONDITIONS.

DEFINITION OF LEVELS OF SERVICE

The quality objectives defined are called levels of service (LS) This choice is defined by the various road owners and is expressed according to the type of meteorological phenomenon.



CHANGES IN DRIVING CONDITIONS AS A RESULT OF ICE

These service levels LS are based on the driving conditions Ci according to the following principle: in winter, a road has a reference condition compatible with the traffic on it and its geographical location. During a weather event, driving conditions will fall below the reference condition. At the end of the weather event, the service must restore the reference conditions within a given amount of time. This response time is a quality indicator. For ice, the clock starts at the time the alert is issued; for snow, it starts at the end of the snowfall.

Levels	Li	Lii	
		Modality 1	Modality 2
Periods of validity			
Reference condition			
ice conditions	without precipitation	Minimum condition	
	with precipitation	Minimum condition	
Snow conditions		Restoration time	
		Minimum condition	
		Restoration time	

STANDARD FRAMEWORK FOR DEFINING LEVELS OF SERVICE

Average restoration times are:

- short: 1 to 2 hours
- average: 3 to 5 hours
- long: over 6 hours
- indefinite time

The minimum driving condition corresponds to the intensity of the most frequent bad weather conditions - snow or ice - on which the manager can take action. It therefore involves defining threshold weather situations beyond which it is considered that normal service can no longer be maintained (transition to crisis).

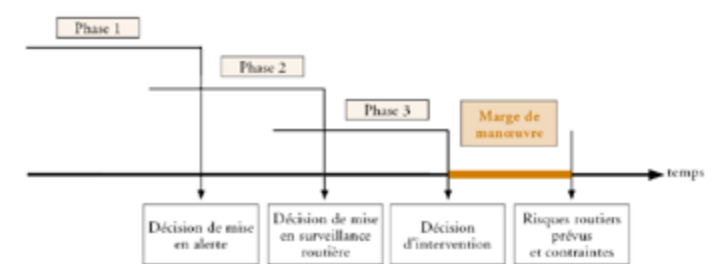
Parameters	Criteria and associated values
1 - Intensity of snowfall	Average hourly snowfall (non-melting snow), calculated over a three-hour period, at least equal to N cm/h
2 - Duration of snowfall	Continuous or intermittent snowfall (non-melting snow) at < 6-hour intervals, for a total duration of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

CHARACTERIZATION OF A THRESHOLD WEATHER SITUATION

ORGANIZATION OF WINTER MAINTENANCE

While the quality objectives or level of service LS are unique to each manager, the decision-making process is identical.

Three types of pre-response activity can be identified:



identified:

- Taking weather forecasts into account
- Collecting information on road networks

- Selecting the type of response. These activities correspond to three decision levels, spread out over time with increasingly shorter deadlines:

- The decision to issue an alert
- The decision to monitor road
- The decision to respond.

Three phases can be identified:

- Qualified weather watch and the decision to issue an alert
- Close meteorological monitoring and the decision to monitor roads
- Detailed analysis of road hazards and the decision to respond.

Meteorological data, information obtained from SADSHs and observations from patrols are used to make decisions regarding whether response actions are needed.

Equipment and organization levels can vary widely depending on the network managers. Sometimes, pa-

trol officers can themselves decide to respond if they are alone at the operation center. Patrols can sometimes be made directly using response units, which then take action if necessary.

For each winter phenomenon, rules and procedures are defined, defining the people involved and the measures to be implemented.

The winter road maintenance plan (Plan d'exploitation de la viabilité hivernale - PEVH), which is the local version of the DOVH for operational centers, describes these procedures. All the procedures are described in detail, usually giving the following information:

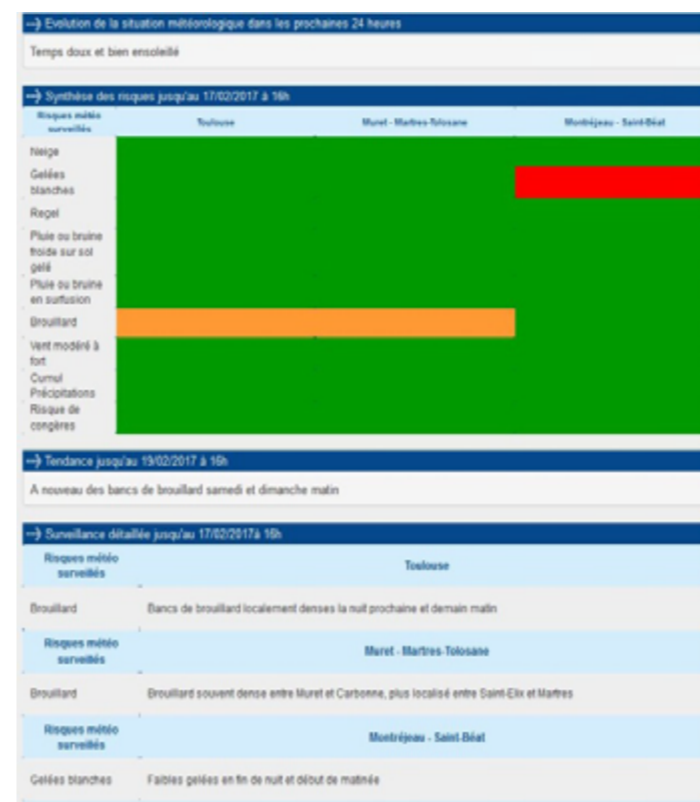
- Various maps
 - roads and levels of service
 - patrol routes and control points
 - location of SADSHs
 - response centers and materials storehouses
- map with road conditions.
- Guides for:
 - the distribution and use of weather reports;
 - decision-making assistance
 - organization in exceptional situations.
- Other documents
 - patrol checklist
 - equipment and materials checklist
 - checklist describing actions (for decision-making and response purposes)
 - name and contact information of managers
 - instructions for pre- and post-winter actions.

Winter maintenance documents (DOVH and PEVH) regularly updated as part of a continuous improvement process. They are reviewed after each winter season (winter assessment and associated information) and re-validated for the following season in collaboration with trade unions.

RESOURCES USED

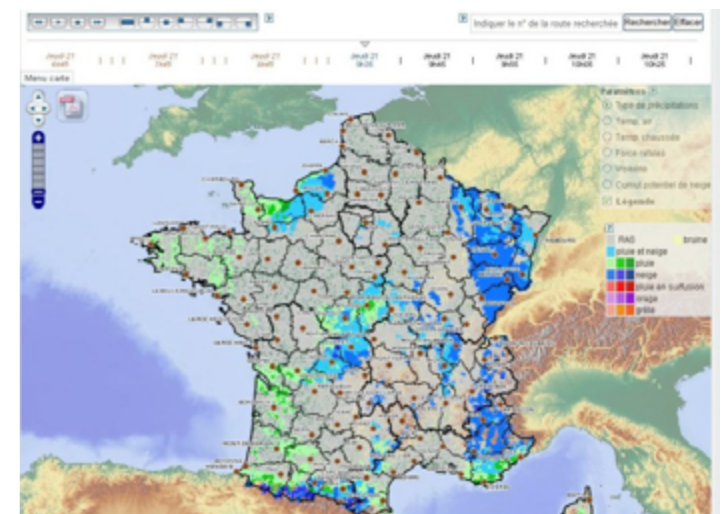
Meteorological information

Each local administration must purchase its local weather forecasts from a forecast service provider. There is no national contract and the information is not centralized. There are several weather forecasters including the „historic“ provider Météo-France which is a state service. Basic weather information is also provided to the CRICR (organization responsible for road information and including peacekeeping forces (police, gendarme-



rie) and equipment). For the purposes of road safety, the CRICR may pass on the information to département services.

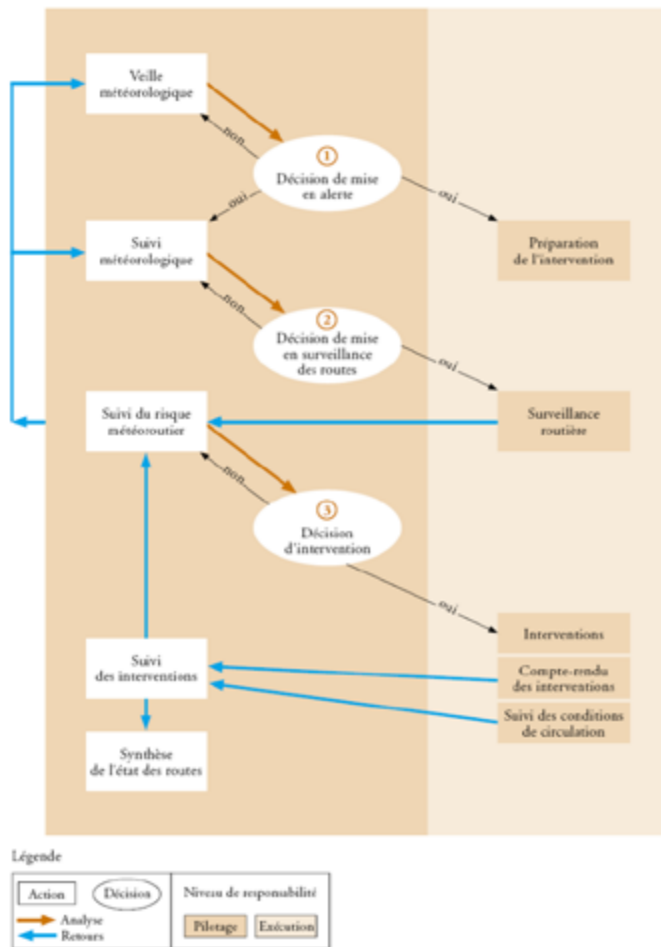
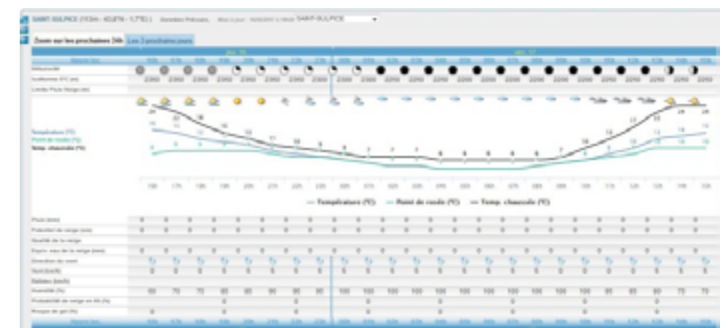
The different weather forecasting services usually provide the following weather information:



- Observations:
 - radar
 - satellite
 - on the ground from Météo-France stations
 - on the ground from the operator's road weather forecasting stations
 - the immediate forecast (extrapolation of radar images and precipitation discrimination)
 - the short-term forecast: D/D+1
 - the mid-term forecast: D+2/D+4
 - the long-term forecast up to D+9
- The parameters forecast are sensitive weather, air temperature, dew-point temperature, humidity, road temperature, precipitation (occurrence, type and intensity), thunderstorms, wind, cloud cover, fog, rain/snow threshold, snow height and snow quality.

These forecasts are provided in various forms (the examples below are from Météo-France):

- WM bulletin: bulletin drawn up by a forecaster and detailing the D+1 forecast for phenomena impacting roads in the operator's network. This bulletin also alerts as to the exceeding of thresholds defined by the operator (threshold meteorological situations for example).





WINTER MAINTENANCE DECISION SUPPORT SYSTEMS.

This bulletin is written up twice a day but can be sent as an alert if thresholds are exceeded between two updates;



VEHICLE USED FOR THERMOHYDRIC SURVEYS



- Highlighted weather maps: forecasts from D to D + 4 are given for several municipalities representative of the operator's road network;
- Interactive map with road sections colored according to the value of the parameter represented (here, precipitation with snow in blue and rain in green); Atmogram: a table giving the forecast of several weather parameters up to J+4 and even J+9 in increments of 1h or 3h for a given forecasting point;
- Weather flash: Alert bulletin (written, email or vocal) on the forecast occurrence of weather phenomena that are hazardous for roads (e.g. snowfall, air temperature below -10 C, etc.) at times ranging from the next hour to D+1.

In addition, road operators can also contact a forecasting engineer directly by telephone to obtain information on the weather situation.

For road temperatures, Météo-France has developed a model providing Troadway forecasts in 1 km grid points over the whole of France.

These Troadway forecasts can be improved on the forecast points corresponding to weather stations, by resetting the model in real time with the observations from Troadway and T in the ground of these stations.

Minimum weather information is also provided to zonal prefectures. For the purposes of road safety, the area prefectures may pass on the information to département services.

WINTER MAINTENANCE DECISION SUPPORT SYSTEM (SADSH)

There are about 800 winter maintenance decision support systems (Système d'Aide à la Décision en Service Hivernal - SADSH), most of them on motorways or major roads.



TYPE OF WINTER SERVICE VEHICLE STANDARD IN INTERCITY ENVIRONMENTS

There is no centralized information from these stations on a national scale. The information is sometimes centralized over an area and/or a region (for the same manager).

It is also possible to include meteorological station data in real time to take them into account in forecasts and weather information.

These information systems can be coupled with weather forecasts to produce road weather forecasts.

Choosing the location of an SADSH:

SADSHs are generally positioned in the most representative places, following the production of a thermohydric profile or based on the knowledge of the agents.

PATROLS

Patrols are routinely sent out to the networks, for the purpose of recording information (road conditions, surface temperatures, etc.) enabling decision-making for precautionary and/or curative treatment.

RESPONSE VEHICLES

The French standard for equipment used to fight ice and snow is: a carrier, equipped with a spreader and a front blade. However, because of their size and weight this equipment exceeds the general traffic rules imposed by the French Highway Code. French regulations have therefore adapted to this by creating a special sta-

tus for this equipment:

- winter service vehicle (ESH). As defined in detail in the French highway code, the carrier may be a freight transport vehicle of more than 3.5t or an agricultural tractor. A decree lists the authorized tools and gives the maximum weights and dimensions allowed to come into this category. This recognition also allows certain waivers from the general rules of movement necessary for ESH mission best practice, such as being allowed to cross the central white line.
- Category N vehicles responsible for road maintenance are authorized to operate in the public domain with a frontal tool coupled to the front of the vehicle provided that the tool carrier interface is a base plate conforming to European standard EN 15432-1 and that the tool does not exceed the values defined in the decree.

There may still be significant differences in equipment depending on regions and types of networks.

SPECIAL RULES FOR TRUCKS

In France, almost all trucks are semitrailers and when a steep road (over 4% for example) is slippery, they cannot use it. On heavily trafficked roads, heavy goods vehicles (HGVs) often cause problems such as accidents and traffic congestion. The dissemination of information has greatly improved with the use of dynamic message signs (DMS) and radio (BP). Trucks are sometimes asked to stop and wait as part of the measures taken during bad weather plans.

On smaller networks, there is no dynamic signaling. On some roads, „white convoys“ are organized. Approximately 10 trucks follow a response vehicle supervised by a police vehicle. Light vehicles (LV) can travel on the other lanes. But this system is difficult to operate when truck traffic is very dense and requires good coordination between the services providing WM and the police.

TRAFFIC

Article R414-17 of the French Highway Code states that:

On roads, when at least one lane of traffic is covered with snow or ice over all or part of its surface:

1. Overtaking or changing lane is prohibited for drivers of vehicles whose total authorized weight exceeds 3.5 tons or for drivers of a group of vehicles whose length exceeds 7 meters;

2. Overtaking winter service equipment in action on the carriageway is prohibited for any vehicle.

PLOUGHING TOOLS

The use of multi-purpose scraper blades is becoming widespread throughout the road network.

MATERIALS

Sodium chloride remains the most used road de-icing agent (> 99%), in chemical form and as a moistened salt. For exceptional situations, such as very cold temperatures and freezing rain, some use solid NaCl and CaCl₂ brine.

The proportion of brine and solid salt can be adjusted on the spreaders. The trend is to vary the proportion of brine according to the weather phenomenon. The most common practices range from 15% to 30% brine, and up to 100% brine.

This brine (water saturated with salt) is usually manufactured with water and NaCl at the response center. Very rarely used calcium and magnesium brines are generally delivered.

Salt consumption varies between 0.4 and 2 million tons per year, the average being 1 million tons. For pre-curative treatment, 15 g/m² are used on average. For curative treatment, between 25 and 30 g/m² are used on average.

Various documents on the optimal use of salt have been published at national level. They contain general information and advice, but no universal recipe. The amount of salt depends on the kind of road weather phenomenon. For example, the amount of salt to be spread will differ depending on the kind and amount of ice, etc.

AUTOMATIC BRINE SPRAYING

This technique has been used in France for some twenty years, but relatively rarely because of its cost. These sprinkler systems are generally present on some motorway sections due to heavy traffic or on small sections of 100 to 300 m.

SNOW FENCES

Snow fences are used preventively. A standard gives information about the choice and location (AFNOR 1992). Vegetation is also used. The decision to set up a snow fence is made and funded locally.

Staff and training

Between 30,000 and 35,000 agents may be mobilized in all departments performing winter maintenance. Standard jobs are identified for specific tasks.

- Response manager: responsible for the response equipment and, depending on the organization in place, may decide when to carry out response actions and informs the CRICR;
- Response authority or weather guard: centralizes all of the information available: meteorological, SADHS, patrols, truck drivers. Depending on the organization in place, he decides when to carry out response actions and informs the response managers;
- Patrol agent: verifies road surfaces and driving conditions, takes note of road weather parameters and observes any formation of ice;
- Response team or response unit driver: carries out response actions with the response units (spreaders and snowplows).

This organization is used for most managers. However, for small structures, functions may be accumulated due to the small number of staff: For example: The patrol agent may decide to respond.

TRAINING AND EDUCATION

There is no engineer training or training school dedicated to winter maintenance. For the larger structures, training is organized internally: motorway concession holders have a training center and provide specialized training in winter maintenance.

Meteorologists are also asked to provide specific training on the use of weather forecasting for WM via the tools available to them.

For national roads, the training is organized in professional training centers (Centre de valorisation des ressources humaines - CVRH) and provided by the winter maintenance scientific and technical network (approximately 10 people). There are other public and private structures providing training. There is special training for newcomers and beginners' courses in more general training.

Operational issues

There is no general policy for winter service, but in general there are different activation states that depend on normal and abnormal situations

Background	Types of action		Remarks
Normal situation	Performing winter service by fixed service levels	With own resources only	Resources (staff and equipment) permanently available to the road operator. The decision to mobilize these is decided upon according to the present and foreseeable weather situation.
		With own and complementary resources	Resources which the road operator may use in addition to its own resources, systematically or based on the extent of adverse weather, using pre-established procedures and governed by contracts or agreements.
	Special traffic management measures		Provisions specific to these measures are defined in the TMPs and/or in adverse weather plans. These measures may be preemptively taken in normal situations and/or taken in abnormal situations
Abnormal situation	Winter service performed with mobilization of support services (3)		Resources that will be mobilized in addition to the organization's own and complementary resources in the event that the threshold meteorological situation is exceeded, following the provisions made in the Winter Maintenance Organization File (lists of resources, mobilizable companies, etc.), aiming for compliance with the levels of service, but without any guarantee regarding the often uncertain mobilization of support services.
	Temporary downward adjustment of service levels on part of the road network(3)		The aim here, if the threshold meteorological situation is exceeded, is to focus response actions (see the three types defined above) on a fraction of the network (a lane, number of lanes, etc.) designated by the owners of the road. The terms for the implementation of this type of measure must be defined in the DOVH and/or in the adverse weather plans.

ICE

On networks with a high level of service „pre-curative” treatment strategies are implemented, meaning that they are used just before the appearance of the phenomenon. These involve spreading road de-icing agents to prevent the formation of ice or to limit its adherence to the road if the phenomenon is intense .

Snow

Pre-curative treatment can also be carried out before snowy weather. The aim is to limit adhesion between

the snow layer and the road surface covering in order to facilitate subsequent mechanical operations.

Ploughing is the most effective way to remove snow. Salt spreading, as well as traffic, are used to make the snow change into a more easily „ploughable” snow.

Removal techniques may differ from one manager to another, especially on multi-lane carriageways: the right-hand (or left-hand) lane may be cleared as a priority, the left-hand lane may not be cleared, etc.

Abrasives are sometimes used in mountainous areas. Mechanical sweeping is little used in France.

ABNORMAL SITUATIONS

There are also bad weather plans to deal with crisis situations. Each plan defines:

- The coordinating authority, as well as the control center on which to base its action;
- The decision-making and coordination structure of the authorities involved;
- The operational organization of departments to implement the decisions taken;
- The organization of communication to users;
- The various coordinated operating measures that can be applied according to the context encountered.

Their objective is to ensure maximum safety for users, particularly during severe weather, by:

- providing information for users;
- road traffic management to ensure optimal traffic flow even under degraded service conditions;
- assistance and rescue operations for blocked users.

WHITE ROADS

Some cities are beginning to adopt white-district strategies, i.e. ploughing for snow-related events and no chemical treatment. Low service level roads may undergo no winter maintenance treatment or even be closed. Abrasives are rarely used, except in some towns and in winter sports resorts (which are nevertheless using more and more road de-icing agents).

POROUS ASPHALT

Porous tarmac is generally treated differently. An informational document explains the particular difficulties encountered with these surface coverings, and proposes methods for monitoring and treating them.

The average dosages are greater (between 50 and

100%) and there may be up to twice as many interventions. In the event of snow, motorway companies plan a ploughing operation every 20 minutes.

Thin asphalt concrete is also sometimes problematic. The only known solution is to plan more interventions and higher dosages.

CIVIL ENGINEERING STRUCTURES

There are no regulations recommending special arrangements for the winter operation of bridges. There is, however, a set of measures contained in various documents or standards, intended mainly for the designers of civil engineering structures.

The use of non-corrosive de-icing agents to systematically treat all bridges is no longer justified today.

Recently built structures, or older ones that have recently undergone maintenance and upgrading, benefit from modern constructive methods or protection techniques. For these, it is not necessary to use special non-corrosive de-icing agents.

The use of special non-corrosive de-icing agents is therefore reserved for metal bridges that have not undergone any particular maintenance over the past two decades or are showing signs of local corrosion.

AVALANCHES

There is a special organization for forecasting avalanches. Avalanche fences can be installed.

High-altitude weather stations (known as NIVOSE) record meteorological data and the characteristics of the snow cover. In ski resorts, qualified staff take snow samples every week to examine changes to its various layers.

A model called SAFRAN-CROCUS-MEPR which takes into account meteorological forecasts and the physical parameters of the various layers of the snow cover calculates the avalanche risk for a given point. The information is then broadcast to users using various means (TV, radio, etc.). When possible, avalanches can be provoked when there is a hazard.

3.3 EVALUATION OF RESULTS ASSESSMENT OF EFFICIENCY

A few years ago, the French Roads Directorate performed an assessment using the following parameters: salt consumption, cost per kilometer, number of man-hours

for winter maintenance. User satisfaction surveys were conducted.

Inspections are sometimes performed to determine how directives are applied by the departments.

Analyses that are now fairly old were performed regarding the application of circulars and the quality of the DOVHs. The DIT (as the Roads Directorate is now called) has initiated thinking on the implementation of indicators, in particular user satisfaction indicators.

3.4 ROAD SAFETY AND INFORMATION INFORMATION FOR USERS

User information concerns:

- Information prior to the winter campaign
- Real-time information

Before winter, information is disseminated by road managers through various media such as radio and newspapers or in public places, town halls, etc. Maps showing the levels of service are distributed.

As part of the preparation for winter, the prefectures (département and zonal) also organize discussions with road professionals (local freight carriers and /or freight carrier federations).

Real-time information consists of delivering relevant and coherent information in real time to the greatest number of users concerned, thereby enabling them to adapt their behavior and to better accept the inconveniences.

The information is prepared based on a few main ideas:

- to be intelligible, information must reflect the general situation, from the meteorological data to the actions decided upon

Condition de conduite hivernale	Figuration	Intitulé / code couleur	Traduction pour la communication et l'information des usagers		
			Perception du danger	Probabilité d'un blocage	Conseils à diffuser aux usagers
C1		Normal (vert)	Sans objet	Sans objet	Soyez prudents. « Une route ne peut jamais être considérée sans danger »
C2		Difficile (orange)	Faible présence de verglas peu perceptible ; neige localisée	Faible, possible en pente ou rampe supérieure à 3%	Réduisez votre vitesse et soyez très vigilants. Augmentez l'interdistances entre véhicules. Prenez l'avis conseillé.
C3		Difficile (rouge)	Aisée pour la neige Faible pour le verglas	Fort	Montez des équipements hivernaux adaptés aux conditions, selon définies votre déplacement !!
C4		Impossible (noir)	Évidente	Disagère effectif	Ne circulez pas

DRIVING CONDITIONS AND USER INFORMATION

- to be effective, information must be differentiated according to whether users are distant, approaching or in the area where traffic is disrupted
- to be credible, the information must not be discordant: the message drawn up at zonal level must be used by all the sources of information, possibly with clarification at the level of the département.

There are many channels for disseminating information in real time:

- radios
- real-time equipment
- websites
- new technologies (GPS, mobile phones, etc.)

As far as radio information is concerned, agreements between road managers and local radios and/or between the coordinating authority and local radios define how this information is to be disseminated.

On the concessionary motorway network, the single radio frequency 107.7 broadcasts traffic information.

Real-time equipment (dynamic message signs) also allows operators to inform users about the traffic conditions they will encounter on their journey.

Road departments also have websites that display driving conditions in real time.

The "bison futé" website broadcasts a map of the entire national road network (concessionary and non-concessionary) to all users and carriers 24 hours a day:

- driving conditions
- traffic status
- events

New technologies allow fast and reliable information to be disseminated (spreaders equipped with GPS, mobile phones, etc.), as well as targeted information for users based on their location and destination. Bison futé makes all the information it collects available to any operator.

4 ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY AND RESEARCH

Research projects in the field of winter maintenance have experts in methodological and organizational approaches working closely together. Some of these projects aim to define more exactly the road conditions (ECi) used to define levels of service.

Further work is being done in the study of how de-icing agents transfer to natural environments through the assessment of road runoff water treatment systems and investigation of opportunities to improve treatments of road de-icing agents.

Research projects currently underway include:
Alert prediction system

On-going research on the development of an on-board warning/forecast system for vehicles integrating connected vehicle data in real time: an experimental campaign is under way between Météo-France and an automotive supplier comprising 200 connected vehicles spread throughout France to:

- ° define methods for taking into account data from vehicles (temperature, wipers for precipitation, ESP/ABS for surface condition, headlights for visibility, etc.) to enhance meteorological observations
- ° send meteorological information about the route (alerts forecasts) to vehicles

Environmental impacts of road de-icing agents:

- * Monitoring of road runoff containment ponds: assessment of the quantities of pollutants (de-icing agents, heavy metals) entering and leaving these ponds, study of the physico-chemical processes involved;
- * Development of water pollution control solutions based on phytoremediation: laboratory tests, development of a methodology, preparation of in situ tests in progress (planting halophilic plants in the ponds);
- * Development of a methodology for the mapping of pressures due to road de-icing agents.

Impacts of de-icing agents on the aging of materials:



ODEMIE DEVICE

* Development of the Prototype for Observation of Corrosive Reactions - Study by Cyclic Immersions (PORC-EPIC);

* Development of tests to monitor corrosion kinetics.

- Improved numerical tools for predicting surface temperature (ice frequency susceptibility maps, statistical approach based on multiple linear regression),
- Thermolog, a software program for determining road susceptibility to icing, based on the thermohydric signature of a route, which helps managers to install signs and road weather stations,
- Tools for determining weather visibility by using a road camera and an infrared camera to access a visibility distance in meters,
- Improved on-board vision systems for driving assistance with methods for restoring images in the presence of rain and estimating visibility by image processing
- Prototype for measuring residual salinity on surfaces, and software for assessing the amounts applied
- Photo processing software to assess the amount of salt spread by a winter service machine. This helps to quantify the longitudinal and transverse homogeneity of a spreading operation
- Device for determining the thermo-physical characteristics of the road infrastructure materials (thermal radiative)
- Adjustments to the software for predicting the temperature and surface condition of the carriageway adapted to the routes, with a module dedicated to de-icing agents, in association with Météo France
- Development of tests to verify spreaders (ODEMIE devices)
- Experiments on the guidance of winter maintenance units (WM) (GSM/GIS);
- Development of test protocols to evaluate the „use value“ of de-icing agents.
- Roadways with frost-free surfaces

The research action „Roads with frost-free surface“ concerns the study of heating roadways based on the use of porous asphalt, in a binding layer, allowing a heat transfer fluid (water) to circulate in order to prevent snow from sticking or ice from forming. In particular, the pos-

sibility of incorporating such roadways into year-round self-sufficient energy loops, enabling solar energy to be captured and stored (in the ground) during hot or sunny periods, and released according to winter maintenance requirements. For certain critical points, the challenge is to increase the levels of service, reduce the material and financial resources devoted to winter maintenance, and to reduce the amount of salt applied to road surfaces and the effects of this: vehicle corrosion and pressure on the environment. A demonstrator set up by Cerema has been operational since 2015 in Egletons, Corrèze. Complementary work on storage by phase change materials is also under way, making particular use of spectroscopic skills and the use of climatic chambers. It should be noted that this issue of heating roadways is part of a more general one concerning roads and energy. Innovation-related activities also address the issue of freeze/thaw cycles, leading to severe degradation of the road network. Work begun a year ago attempts to evaluate the addition of a non-toxic chemical compound to snow removal salt in order to reduce the swelling of water as a solid phase in the upper layers of the roadway. A partnership between a Dutch industrialist, Cerema and DIRMC was set up in 2016.

4.2 NEW MANAGEMENT AND ORGANIZATIONAL APPROACHES

The methodology for defining levels of service was updated in 2009 and a new circular regarding its application for the national road network will be released shortly,

Snow plans and traffic management plans are operational.

Sustainable development and Environmental impact

There is no substance with zero environmental impact. Even so-called „green“, „ecological“, or „environmentally friendly“ products have negative impacts on the environment, mainly due to the way they are manufactured. Even when particular attention is paid to manufacturing processes in order to lessen their environmental consequences, no process is totally neutral. This is because all products need raw materials and energy to be manufactured. All products must be packed and transported. And even if it is recycled several times, any product or packaging will eventually become waste. The challenge is therefore to identify which

product has less impact than another used for the same purpose. The ecological quality of a product is characterized by all the environmental impacts caused by the product throughout its life cycle.

The concept of environmental impact refers to all qualitative, quantitative and functional changes in the environment (negative or positive) generated by a project, by a process, by organisms and by products, from design stage to their end-of-life. The assessment of an environmental impact is quantified through the measurement of potential flow indicators and potential impact indicators.

For air, five indicators are used:

- contribution to the greenhouse effect;
- acidification of air
- tropospheric ozone formation
- depletion of the ozone layer
- particles and respiratory effects caused by inorganic substances.

For water, four are used:

- eutrophication of fresh water
- aquatic ecotoxicity
- eutrophication of marine water
- water consumption (flow indicator).

For soil resources and human health, the following four indicators are used:

- primary energy consumption (flow indicator)
- depletion of non-renewable resources
- human toxicity
- land use.

4.3 TRANSNATIONAL COOPERATION TO IMPROVE SERVICE LEVELS BETWEEN NEIGHBORING COUNTRIES

Strong cooperation exists at European level and the work of COST 353 has helped lay the foundations for thinking on European service levels. Standardization work is being carried out at European level.

There is cooperation with the Quebec Ministry of Transportation on road de-icing agents and the environment. A joint report is currently being prepared and will serve as a guide for further thinking on this subject.

5 REFERENCES

A website to collect knowledge in the field of winter maintenance is operational and accessible to all.

<http://www.viabilite-hivernale.developpement-durable.gouv.fr/>

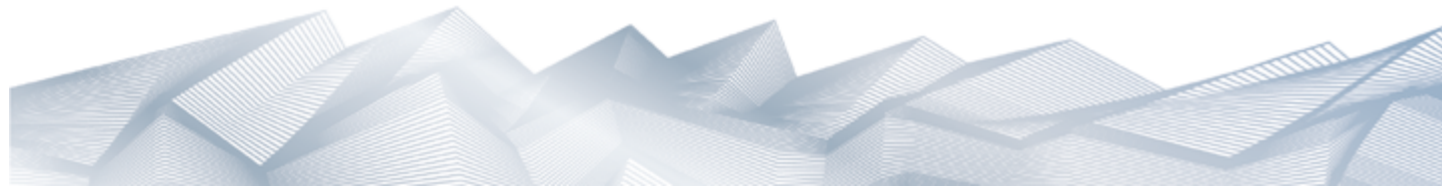
Glossary

DOVH : Dossier d'organisation de la viabilité hivernale (Winter road maintenance organization file), a document about the organization of WM.

PEVH: Plan d'exploitation de la viabilité hivernale (Winter road maintenance plan), the local version of the DOVH

DIR: Direction interdépartementale des routes (Inter-département road directorate), an operational delegation coming under MEDDE CRICR: Centre régional d'information sur la circulation routière (Regional information center on road traffic). Organization run by the Ministry, the police and the army, which centralizes road information and informs users.

MEDDE (French Ministry of Ecology, Sustainable Development and Energy)



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Germany in the centre of Europe borders on the Netherlands, Belgium, Luxembourg, France, Switzerland, Austria, Czech Republic, Poland and Denmark and has sea accesses to the North and Baltic Sea.

The Federal Republic of Germany, consists of 16 Federal States, the 3 „City-States“ (Berlin, Hamburg, Bremen) included, whose territories are of different size between 71.000 km² (Bavaria) and 2.700 km² (Saarland). Each German State has its own constitution and public authorities. Road Authorities exist in each State.



MAIN ROAD NETWORK IN GERMANY (MOTORWAYS RED)

1.2 ROAD NETWORK AND TRAFFIC

During the past decades Germany was faced with an enormous increase of traffic on the highways. Today passenger traffic (passenger-km) on the road amounts to more than 90 %, commercial traffic (tons of merchandise-km) to about 7067 % of the total traffic while the remainder traffic distributes itself to other travelling and transportation modes, i.e. on rail, water ways or air. Motorways in Germany (so called „Au-

Area		356,700 km ²	
Latitude		47°16' to 55°03'N	
Population		82.80 million	
Length of road 2002-12-31	Federal trunk roads	Federal motorways (Autobahnen; 4- and 6-lane divided highways)	12,80013.000 km
		Federal highways	40,60038.300 km
	Other federal-aid roads	State highways	86,600 900 km
		County roads	91,500 900 km
		Community / urban roads	413457,000 km
Total		68544,1500 km	
Capital		Berlin	
Latitude		52°30'N	
Inhabitants		3.52 million	

tobahnen“); all together 12.80013,000 km, carry more than 40 % of the total traffic of the entire classified rural, interurban road net (consisting of Federal Motorways, Federal-, and State-Highways and County roads), although they represent only about 6 % of the total length of this road net.

The enormous increase of traffic volumes in recent years will continue even more rapidly in future time as a consequence of the ongoing political and economic developments, especially the European process of unification. The extension of the European Union to the east is expected to bringhas brought another great amounts of traffic to the „transit-country“ Germany within the nextin the last years due to intensified economic cooperation's.

The extension of the road network in the last years and also in the near future does not correspond to the increase of the traffic so that traffic volume on the roads and congestions raise up.

Maintaining traffic safety, optimum driving conditions and availability of sufficient capacity of highways all around the year, even during winter season is of crucial importance, especially for the economic development. As a consequence in future road operations and especially winter maintenance will become much more important.

The State Road Administrations are in charge of planning, construction and maintenance including winter maintenance for Federal motorways and highways and for State highways. The Federal Ministry, respectively Department of Transportation has the right of legal and technical supervision for the federal trunk roads.

Road Class		Property and financial obligation for planning, construction and maintenance	Administration of planning, construction and maintenance
Federal trunk 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

Due to a legal renewalment in 2017 in future the Motorways will be planned, constructed and maintained

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	1273
13	Bad Reichenhall (455m)	-4,0	-6,5	-4,5	-1,0	128	125	110	120	438	1665
14	Garmisch-Partenkirchen (719 m)	-5,7	-6,5	-5,1	-2,3	92	85	77	96	340	1364

no more by the Federal States, but by a central Federal Motorway Company, beginning in the year 2020.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

Germany has a moderate climate, often weather changes are characteristic. From the low lands in the northwest to 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 south eastern 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 1500 mm and in the south, close to the alpine region up to 2000 mm.

The daily and yearly temperature variations are not extreme, except in south eastern Germany and in the alpine region. The average temperatures in January vary from + 1,5°C and - 0,5°C in the lowlands, in the alpine region the average temperature may get below - 6°C, depending on the altitude (see Table above).

Typically for the German climate is the often change of temperature around 0°C with freezing and thawing periods following each other. This brings many problems for winter maintenance.

There is snowfall to a larger extent only in mountainous regions and the surrounding areas. Bavaria, the most southern State including the north edge of the Alps therefore is the most „snowy“ region in Germany with winter maintenance from November to April, whereas in other parts of Germany there is a shorter winter period. In the Northern Parts of Germany spreading is more dominant than snowfall. But here also appear sometimes very heavy snowfalls in short time.

But even in Bavaria there are great differences concerning the amount of snowfall in different parts of the State as follows (table)

Large parts of central and northern Germany receive the same amount of snow as the lower areas and river valleys in southern Germany. Other typical features of the climate are the great variation in the severity of consecutive winters, in relation to temperature and amount of snowfall. Main problems for the winter maintenance

management are the often temperature changing around 0°C or short heavy snowfalls.

State of Bavaria	Annual cumulative snowfall (measure at motorway maintenance stations)	
	average of the last winter periods	Maximum: Winter 2005/06
Front of alpine region	440 cm	1030 cm
Lower mountain regions	210 cm	645 cm
Lower areas, river valleys	50 cm	125 cm

2.2 WINTER INDEX

The Federal Highway Research Institute actually makes researches 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.

This index is also important to calculate the storage amount of salt needed for strong winter periods for each region.

The Investigations show that most relevant for salt consumption is the amount and frequency of snowfall in the snowy regions. In regions with less snow there is a relevant factor the number of temperature changings around 0°C

3 WINTER ROAD MANAGEMENT

3.1 STANDARD AND RULES

The legal obligation to do winter maintenance results from a general duty out of the German Civil Code. It is reduced also defined in the federal laws (Bundesfernstraßengesetz) and, the state laws (Straßen- und Straßenreinigungsgesetze der Länder) and in the statutes of the cities.

Regulations about the requirements, organisation and realization of winter maintenance are given in the Guidelines for Winter Maintenance Performance (MerkblattRichtlinien für den Winterdienst auf Straßen, 2010).

For snow clearing vehicles the following service cycle time-periods for motorways and highways are stipulated: The levels of Service for the different types of roads (“Anforderungsniveau Winterdienst”) are shown in the following table. The circulation times for the main roads are regulated as follows:

- Motorways and highways, 24 hours served 24 hours a day
- Circulation time for spreading 2 hours
- Circulation time for snow removal 3 hours which in connection with the (daily 24 hours) motorway-network have a significant traffic function
- motorway interchanges 2 hours (daily 24 hours)
- federal and state 3 hours
- highways (daily 6 am to 10pm)

For pure salt spreading activities distinctly shorter time-periods are standard. The Level of Requirement for Winter Maintenance is given in Table below.

On sections with steep grades and/or special traffic shorter circulation times are recommended but not special regulated.

There is an actual research project ongoing to evaluate the effects of heavy snowfalls on traffic and the needed maximum circulation times on different road types.

LEVEL OF REQUIREMENT FOR WINTER MAINTENANCE

road with traffic function	period of traffic stand by	weather or road condition		
		snowfall, icy roads, hoarfrost	heavy continuous snowfall	Severe drifting, avalanches, freezing rain
1 Federal motorways and additional stretches of highways, which in connection with the motorway-network have a significant traffic function	24 hours (daily)	trafficability on through lanes, interchanges, ramps in junctions and interchanges; passability on parking facilities, shoulders	trafficability on at least one through lane per direction of traffic, the most important ramps in junctions and interchanges as well as access roads to service areas, if required with snow chains; passability on parking areas without service cannot be any longer guaranteed.	trafficability cannot be any longer guaranteed
2 important rural roads, roads with strong rush hour traffic, roads with public transport	from 06.00 a.m. to 10.00 p.m. (daily)	trafficability	trafficability, if required with snow chains; on multilane highways at least one through lane per direction of traffic, if required with snow chains	
3 Further rural roads	appropriate to local traffic demands	trafficability	trafficability, if required with snow chains	
4 sidewalks, bicycle route, multipurpose lane	appropriate to local traffic demands	trafficability, usability for pedestrians	trafficability cannot be any longer guaranteed	
5 parking facilities in connection with important and other roads (row 2 and 3)	appropriate to local traffic demands	passability	passability cannot be any longer guaranteed	

“trafficability” means that obstructions as a result of remaining snow or – according to duration of winter maintenance operation - locally uniform snow covering must be expected, similarly possible local occurrence of slippery roads as a result of hoarfrost or icy roads even after spreading.

“usability for pedestrians” demands that one lane is kept clear of snow and ice to allow two pedestrians to pass each other carefully (approx. 1,0 to 1,2 m).

“passability” on parking facilities and shoulders means that access roads and lanes on parking facilities and shoulders can be used with an adjusted driving behavior appropriate to existing obstructions and that proper parking is possible.

“appropriate to local traffic demands” means that winter maintenance is carried out at times demanded by specific traffic. In the individual case this may mean that no winter maintenance is carried out.

3.2 ORGANISATION AND OPERATION OF WINTER MAINTENANCE

Organization and planning of winter maintenance activities have to be done early and comprehensively because the exact beginning and extent of the coming winter is nearly unforeseeable. Winter maintenance has to work effectively and efficiently from the very beginning of winter. Only careful planning guarantees a most economical realization of winter maintenance. Therefore 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 because there winter maintenance can be carried out

only successively and not everywhere at the same time. Useful criterions are:

- road category (motorways, federal highways etc.); in 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 etc.)
- special accident prone spots (steep grades, dangerous curves and crossings, stretches with frequent slipperiness in winter such as bridges, roads through forests, extremely shady roads).

PLANS FOR SNOW CLEARING AND SALTING

These plans assign crew and vehicles for winter maintenance activities to certain routes and in certain sequences.

For different weather conditions or different tasks there exist different plans.

SCHEDULE FOR STANDBY OF PERSONAL, WORKING SHIFT PLANS

These plans regulate on a day-to-day or week-to-week basis, which personal has to be appointed to standby for short term readiness outside of regular working time, in order to meet the Level of Requirement for Winter Maintenance. The 24 hour service on motorways requires shift plans.

SNOW AND ICE CONTROL STRATEGY

The strategy persuade in Germany on rural and main urban roads in connection with winter maintenance activities is to achieve again „black“ i.e. snow-and-ice-free pavements as soon as possible, with the aim of maintaining traffic flow as long as possible and to improve road safety: so-called „bare pavement policy“.

In cases when icy roads can be expected in the near future depending on the weather forecast this policy leads to preventive salt spreading which has become standard been more used in the last years.

On secondary and lower rank roads in urban areas and in municipalities, 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 streets and depending on weather conditions there is a gradation in the winter maintenance policy: application of de-icing agents on

major roads and so called „zero-spreadinggritting“ e.g. only snow clearing, on the lower, the residential streets.

Gritting with abrasive matters on roads which was used in former times has become very less common in the last years. A study on behalf of the German Umweltbundesamt (Federal Environmental Agency) has shown by screening of life-cycle analysis (LCA) that de-icing materials in total have less negative ecological effects than abrasives. And other studies concerning traffic safety showed that de-icing materials lead to a much lower accident risk on main roads and steep grades in urban areas. On residential streets with very low and slow traffic there is no safety problem without any spreading.

For optimization of winter maintenance management actual information and forecasts about weather and road conditions are necessary. Detailed road weather observation and surveillance by the nationwide Road Weather Information System – RWIS (‘‘Straßenzustands- und Wetterinformationssystem – SWIS’’) is standard today in Germany. RWIS combines synoptic extensive weather forecasts of the German Weather Service (Deutscher Wetterdienst – DWD) with data based on local meteorological stations and ice detection installations throughout the road net. The results are separate forecasts for areas with different local climates. The DWD provides several times a day very detailed middle term (3 days) and short term (24 hours) road weather forecasts to the road maintenance stations. In addition weather warnings are issued for sudden critical occurrences, which are not yet included in the general road weather forecasts. Information is distributed by computer network and reach directly the RWIS-computers in the maintenance stations. Improvements are on the way to extend the service by installing meteorological surveillance stations and pavement sensors for ice detection at all critical points of the road net. At present roadside meteorological stations exist mainly on motorways, but also on other rural roads, more than approximately 1,000 installations in Germany.

Additional the surveillance centres get information and data of their roadside meteorological stations with atmospheric and surface sensors.

Following data are measured and provided:

- air temperature
- road surface temperature
- relative humidity

- dew point (calculated out of air temperature and relative humidity)
- precipitation (type, intensity)
- road surface condition

GUIDELINES FOR SPREADING DOSAGES

In former times there existed only overall recommendations for the salt dosage depending on the different road and weather conditions.

In the last years there were developed different recommendations on the basis of practical experiences, several research projects and special calculations. They were established in New Guidelines (see the following table). They regulate spreading amounts of pre-wetted salt and full wet spreading. Preventive spreading is recommended every time when possible, that means

when weather forecast is clear (freezing moisture, hoarfrost and black ice). In these cases full wet spreading is recommended.

optional:

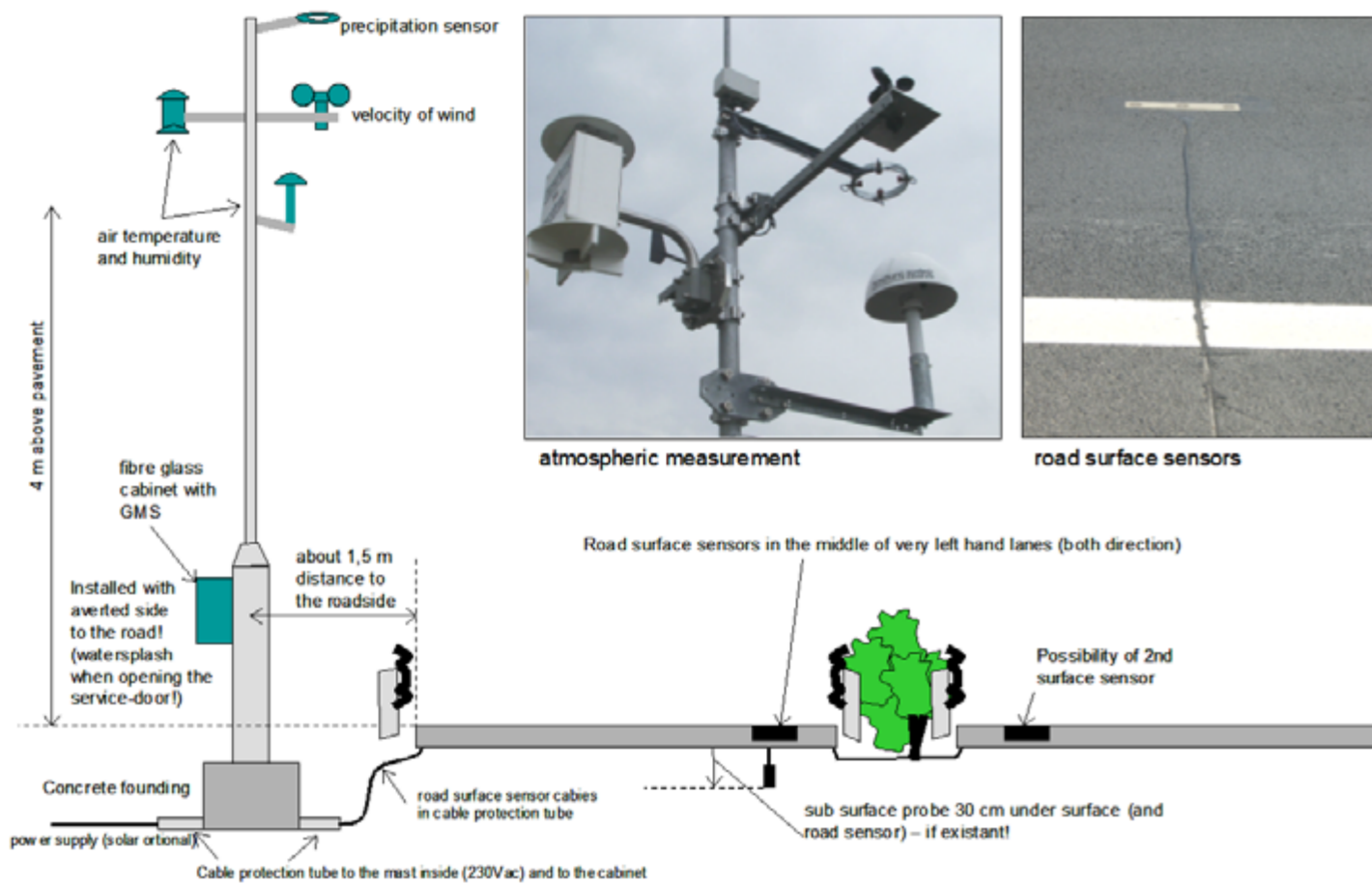
- road structure (sub surface) temperature in various depths
- wind (direction, speed)
- freezing temperature
- residual salt

3.3 ASSESSMENT OF SNOW AND ICE CONTROL MEASUREMENTS SALT CONSUMPTION AND WINTER MAINTENANCE COSTS

According to variable climatic conditions in consecutive winter periods salt consumption and expendi-

Expected Surface Condition	Recommended Winter Maintenance Action	Recommended Spreading Density ***
Hoarfrost	Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	10 – 15 ml/m ² 5 – 15 g/m ²
Light Black Ice (freezing moisture)	Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	10 – 25 ml/m ² 5 – 30 g/m ²
Black Ice (freezing wetness)	Preventive Spreading** - Pre-Wetted Salt or Liquid Spreading*	15 – 40 g/m ² (20 – 50 ml/m ²)
Freezing Rain (black ice)	If possible Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	40 – 60 ml/m ² 30 – 40 g/m ²
Snow Fall (packed snow)	1. Where possible Preventive Spreading with Liquid Spreading* or Pre-Wetted Salt 2. During Snow Fall Snow Removal and Spreading of Pre-Wetted Salt with low spreading density 3. After Snow Fall aggressive Removal of Snow and Spreading with Pre-Wetted Salt	15 – 30 ml/m ² (10 – 20 g/m ²) 10 – 15 g/m ² 20 – 40 g/m ²
	* Liquid Spreading only at temperatures above -6°C, at lower temperatures only Pre-Wetted Salt ** if preventive salting was not possible, existing slipperiness must be eliminated with Pre-Wetted Salt with double spreading density	*** low values for temperatures tight below 0°C, higher values for lower temperatures

TABLE: GERMAN GUIDELINES FOR SPREADING POLICY



atmospheric measurement



road surface sensors

tures for winter maintenance show large differences as follows. All data is given for motorways and federal highways.

It is evident that the last winter periods were mainly stronger than these before salt consumption and the winter maintenance costs are rising over the years, but with strong variances. Especially between 2009 and 2013 the values were very high. There were long periods with heavy snowfalls, often expanding over the whole country. This led to high salt consumptions and winter maintenance costs.

There In these winter periods there were problems with the salt delivery for many weeks. As result of the experiences in the winter periods 2009/10 and 2010/11 there were elaborated new guidelines for salt storage and salt management. Following this the storage capacity for salt was nearly doubled up to 2012, from 1,2 Mio. Tons up to 2,4 Mio. Tons now.

As average over the last 5 years there were spreaded 3248 t per km motorway and 1116 t per km highway each winter period. On motorways were spent 809500

€ per km each winter period, on highways 25900 € per km.

These values are more than double of the 50 % higher than the averages before the year 2000. of the last 20 years before.

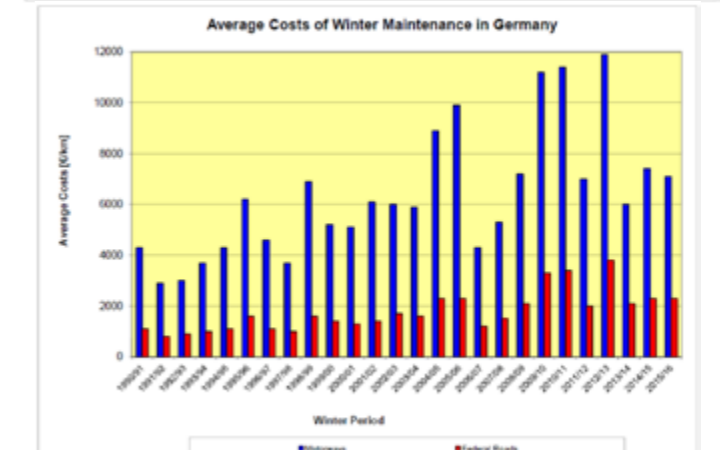
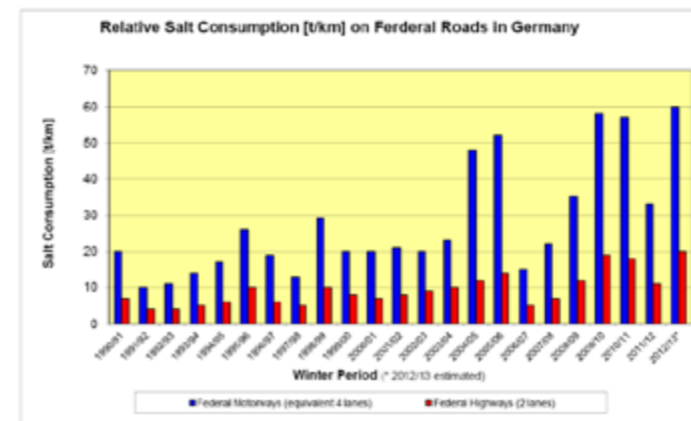
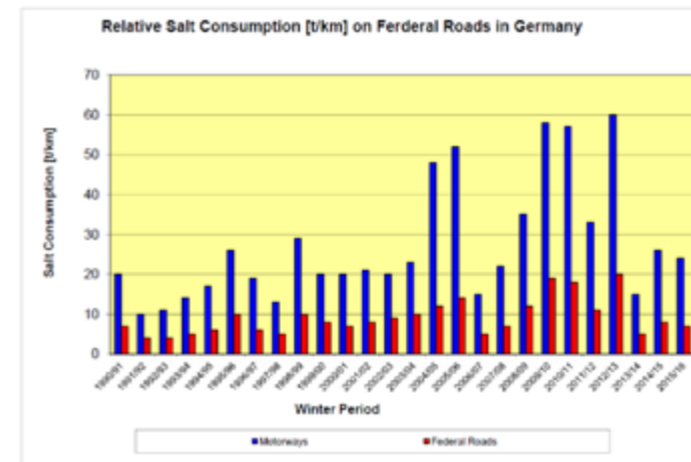
There is no special budget for winter maintenance, only a yearly budget for road maintenance. Yearly variable expenditures for winter maintenance have to be covered by the budget for road maintenance. This means, that after extreme winters even other road maintenance tasks have to be postponed to a certain extent; after extreme strong winters even additional funds from the construction budget are necessary.

3.4 ACTUAL RESEARCH AND DEVELOPMENT

In the last decade a lot of research was done to optimise winter maintenance and to decrease the expenditures and environmental impacts.

Pre-wetted salt ("FS 30" with 30 percent brine) is today standard technique in Germany.

But in the last years more and more full liquid spraying



of salt brine is used in Germany. Based on intensive research and practical experiences it is clear that liquid spraying is the best practice for preventive spreading at temperatures round 0°C.

The new winter maintenance removal and spreading strategy in Germany is shown in the following table.

Expected Road Condition	Recommended Winter Maintenance Strategy
Hour Frost	Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Freezing Moistness	Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Freezing Wetness	Preventive Spreading - Pre-Wetted Salt or Liquid Spreading*
Freezing Rain	If possible Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Snow Fall	1. If possible Preventive Spreading with Pre-Wetted Salt 2. During Snowfall Snow Removing and Spreading with low salt density 3. After Snowfall intensive Snow Removing and Spreading with Pre-Wetted Salt
*Liquid Spreading only to temperatures down to -6°C	

For each range of temperature there are recommended spreading densities in the new guidelines published in 2012.

With Following the new Winter Maintenance Policy (see Chapter 3.2) this strategy liquid spading will be used very often in Germany in future.

The winter maintenance operators will change their fleet from only pre-wetting machines to a combination of liquid and pre-wetting spreaders. Liquid spreading can be done by machines which are specialized for this or with combined spreaders which can do both, liquid and pre-wetted spreading.

It depends on the special situation what machines are the best. Normally on motorways special liquid-spraying machines are used, on rural roads and in cities more combined-spreaders.

Also on bicycle paths there is used more and more full liquid spreading in Germany. There are several pilot projects with good experiences. This is very important because bicycle use is rising in Germany, also in winter time. On icy or snow-covered bicycle lanes the accident risk is much higher than on salt-spreaded lanes.



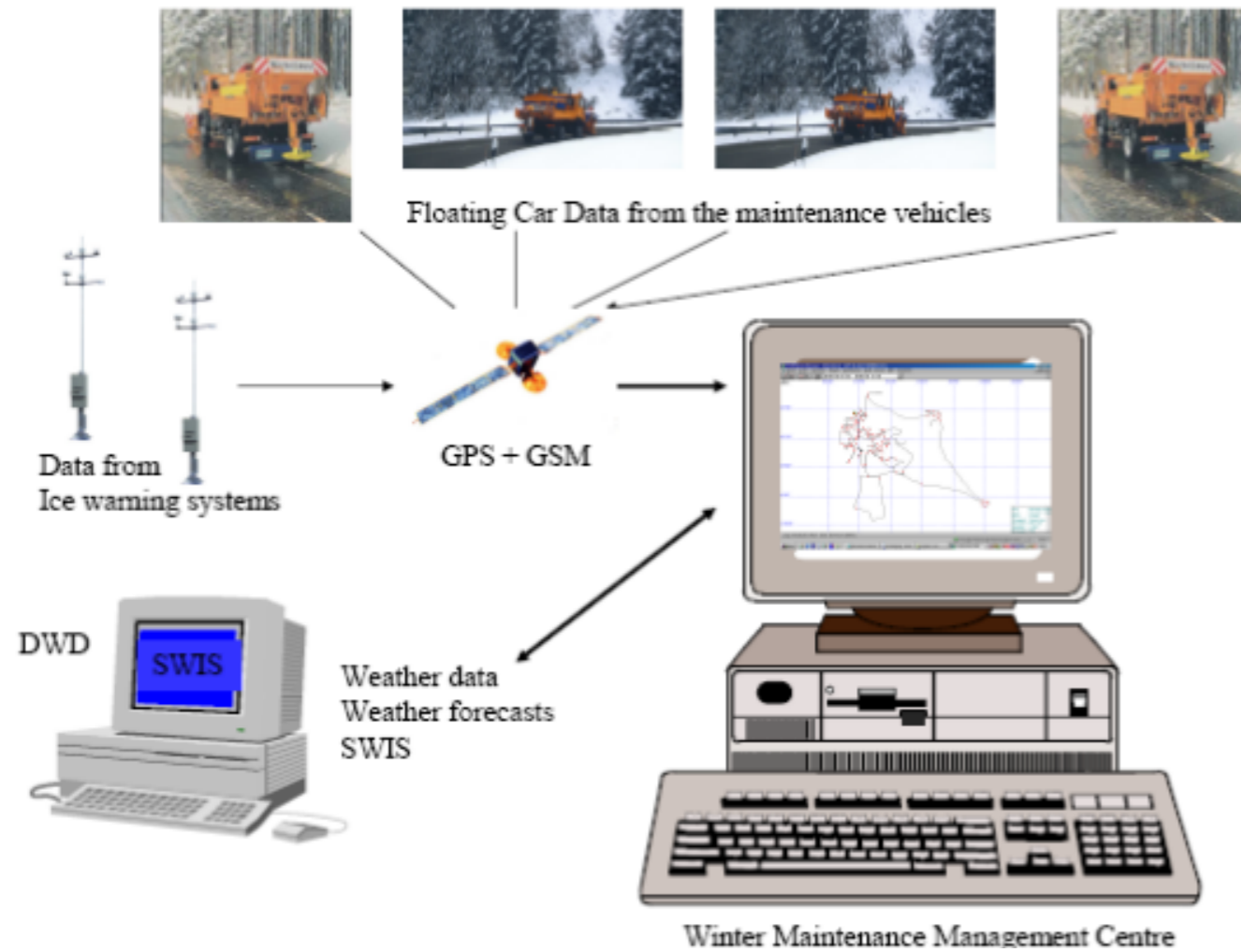
COMBI-SPREADER WHICH CAN SPREAD BOTH: PRE-WETTED SALT OR BRINE ONLY

3.5 TRAFFIC SAFETY AND INFORMATION

Information concerning weather forecast and road conditions is available on several systems such as radio broadcast, television, internet and telephone. Additio-

nally, drivers will be informed by radio broadcast, if chains are necessary or if truck drivers, especially drivers of trucks with dangerous loads, have to stop at the next parking place or rest area.

In mountainous regions traffic signs give informa-



tion, wether mountain passes are closed and whether winter tyres or chains are obligatory.

On several motorway sections variable road signs of traffic control systems are also used for traffic safety, for example during snowfall or during slippery conditions.

Winter Maintenance Management Systems are buildded more and more in the German States. When using all actual information from RWIS, from ice warning systems and from the maintenance vehicles (floating car data) an improved winter maintenance is possible.



1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

Hungary is a country in Central Europe which covers an area of 93,030 square kilometres in the Carpathian Basin, bordered by Slovakia, Romania, Serbia, Croatia, Slovenia, Austria and Ukraine. With about 10 million inhabitants, Hungary is a medium-sized member state of the European Union. The official language is Hungarian, the capital is Budapest. As far as its administrative division is concerned, Hungary is a unitary state nation divided into 19 counties. In addition, the capital Budapest is an independent entity, which is also its largest city and metropolis.



LOCATION OF HUNGARY; [HTTPS://AVILAGTITKAI.COM/](https://avilagtitkai.com/)

Most of the country has an elevation of fewer than 200 m. Although Hungary has several moderately high ranges of mountains, those reaching heights of 300 m or more cover less than 2% of the country. Its highest point is Kékes (1,014 m) in the Mátra Mountains northeast of Budapest. The lowest spot is 77.6 m above sea level, located in the south of Hungary, near Szeged (Gyálarét).

2. CLIMATE

Hungary has a mainly continental, very changeable climate. Despite of the country's small area, there can be significant differences in terms of weather conditions within the country, which is characterized by cold winters and warm to hot summers. The average annual temperature is 10 to 11 °C, in summer 27 to 35 °C, and in winter 0 to -15 °C, with extremes ranging from about 42 °C in summer to -35 °C in winter. Daily temperature variations change significantly throughout the year, with the slightest variations in December, which is the month characterised by the shortest days and the cloudiest skies. In the summer period, when days are longer and less cloudy, temperature variations might be even twice as big (11 to 13 °C) as during the winter.

Average yearly rainfall is about 500 to 750 mm. Distribution and frequency of rainfall are unpredictable. The western part of the country usually receives more rain than the eastern part, where severe droughts may occur in summertime. Weather conditions in the Great Plain can be especially harsh, with hot summers, cold winters, and scant rainfall. The period of May-July is characterised by the most rainfall, the months of January, February and March are the least rainy ones. The annual number of windy days (i.e. the number of days when the speed of the strongest wind stroke is above 10m/s) amounts to 122, with an average of 35 stormy days (i.e. with wind stroke speed above 15 m/s).

Winters are variable and unpredictable. Westerly winds bring mild oceanic air with highs between 5-10°C, almost no frost and scattered rain or snow showers. Depressions moving in from the Mediterranean Sea can bring snowstorms with 20-40 cm falling in a single day, followed by cold air from Russia.

Atlantic depressions and south wind can bring unusually warm weather with highs reaching 15°C even in January. The Siberian high brings every other year a sunny but very cold period lasting for a week or two with lows in the -15-20°C range. Anticyclones with centres above Western Europe produce cold inversion fog with no change in day and nighttime temperatures, they stay around or a bit under 0°C. The fog can last for weeks. Mediterranean depressions moving above the inversion fog layer can bring a day or two of freezing rain.

3. ROAD NETWORK AND TRAFFIC

Hungary has a public road network of 32,000 kilometres. The major part of the network is managed and maintained by the Hungarian Public Road Non-profit PLC. In case of two Hungarian private motorways – Motorway M5 and Motorway M6 – sections of approx. 480 km are operated, managed and maintained by concessionaire companies: M6 Duna Autópálya Koncessziós Zrt., M6 Tolna Autópálya Koncessziós Zrt., M6 Mecsek Autópálya Koncessziós Zrt. and AKA Zrt.

The Hungarian Public Road Non-profit PLC was established on 1st of October of 2005 by merging several individual road operator directorates of the counties.

Based on its 6069 employees and economic indicators, the company stays within the first ten state-owned enterprises in Hungary. Road operations are carried out in 19 counties, at 93 maintenance centres, under the supervision of the headquarters in Budapest.

The activities of the Hungarian Public Road Non-profit PLC consist of the operation, as well as the routine and preventive maintenance of the state owned public road network, including expressways and motorways. In addition to that, the company is responsible for the traffic management measures on the operated network, including dynamic traffic management and traffic lights, issuance of route permits for oversized vehicles, the control of trucks at weight control stations, the provision of trainings for professionals within the entire road sector and the operation of the Road User Information Services, the National Road Databank and the Road Museum in the municipality of Kiskőrös. The roads managed by the company fall into the following categories:

Road category	Length (km)
Motorway	1.167,7
Expressway	262,4
Primary highway	2.162,9
Secondary highway	4.797,4
Highway network	8.390,9
Slip road	17.903,4
Access road	4.514,6
Train station access road	468,9
Intersection leg	5,6
access roads to rest areas on express ways	49,4
Intersections and secondary roads	22.942,0
National public road network	31.332,9



MOTORWAY NETWORK OF HUNGARY; M6 TOLNA AUTÓPÁLYA KONCESSZIÓS ZRT

Since the end of 2017, the Hungarian Public Road Non-profit PLC is also responsible for the management of bicycle routes outside residential areas, with a total length of 1100 km.

4. WINTER ROAD MANAGEMENT

a. The Company's general winter maintenance regulations

The winter maintenance period starts on 10 November each year and ends on the 15th of March of the following year. The headquarters-based Directorate for Road Management is responsible for the coordination of road management duties among the counties. The county directors are in charge of the county-level coordination of the winter maintenance duties, winter coordination tasks are carried out directly by the directors or with the assistance of the county coordinators and county dispa-



SNOW SERVICE VEHICLES AT THE ANNUAL MACHINERY INSPECTION; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



SNOW SERVICE VEHICLES AT THE ANNUAL MACHINERY INSPECTION; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

ch services. The winter preparation process includes the preparation of county-level winter maintenance plans to be sent to the headquarters office by the 1st November at the latest. The preparation process for the winter maintenance period also involves a regulation establishing that any training on workplace safety and traffic code provided for the staff involved in winter maintenance duties shall be terminated by the 10th of November.

In addition to that, the preparedness of the machinery shall be verified by the 10th of November in case of own machines and by the 1st of December at the latest in case of rented machines. The intense preparation process starts already at the end of August and ends with the machinery inspection carried out in November, whereby professionals – county directors and headquarters-based experts – verify the adequate technical condition, complete corrosion protection and seamless operation of the winter service equipment used by the mainten-

ce centres. Besides the above, sufficient quantity of materials needed in winter period shall be provided by the 1st of November.

b. Anti-skid surfacing materials

For the safe performance of tasks, it is necessary to have sufficient supply of strategically important materials, such as salt, calcium chloride solution and granulation. For that purpose, framework contracts with salt suppliers are concluded for at least one year in the framework of public procurement procedures.

An average winter period usually involves the use of 100,000 – 180, 000 tonnes of road salt imported from abroad, mainly from the neighbouring countries where the biggest salt mines are located, such as Ukraine and Romania.

On low-traffic volume roads, it is also possible to apply sand or crushed gravel mixed with road salt. The com-



SALT STORE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



SALT STORE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



SALT STORE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



SALT STORE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

pany uses CaCl₂ solution for the pre-wetting of the road salt, which is also accessible within the country in large quantities as an industrial by-product.

Having regard the potential occurrence of extreme weather conditions, it is essentially important to accumulate sufficient reserves for the whole winter maintenance period in the salt stores.

Road salt is transported in bulk form and samples shall be drawn from each vehicle (typically 25 tonnes per vehicle) for quality control purposes.

As a pilot project, a new salt storage silo is going to be tested on the side of the expressway No M30. This storage method requires finer grained salt as usually and consequently goes along with an improved melting effect.

c. Skid control and “black” pavements

Road traffic must go on also in critical weather conditions; therefore ensuring “black pavements” for road

users is the primary goal of the winter service.

The maintenance centres shall apply skid control in case of skid detection and also as a preventive practice, in accordance with the provisions established by law, as follows:

Service class	Time elapsed between the skid detection and the start of the spreading	Duration of the spreading
I.	0.5-1 hour	2-4 hours
II.	1-2 hours	4-6 hours
III.	2-3 hours	4-8 hours
IV-V.	4-5 hours	6-24 hours

For the preventive and reactive control - taking into consideration the environmental and economic aspects - road salt shall be applied in the following quantities with the use of gritting control.

At critical locations, mainly in proximity to bridges aAt critical locations, mainly in proximity to bridges and



SALT STORAGE SILO; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



SNOWPLOWH IN WINTER SERVICE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

Work processes	Roads subject to regular winter patrols and expressways			Roads subject to sectional winter patrols and de-icing		
	Road condition	Type of spreading, quantity	Temperature	Road condition	Type of spreading, quantity	Temperature
Preventive	dry road, according to the forecasts, sleet, rainfalls, snowfalls, road freezing are expected	pre-wetted spreading 5-10 g/m ² of road salt mixed with 2,5 cm ³ /m ² CaCl ₂ solution	drops below +2°C, above +2°C no preventive control is needed With consideration of the weather forecasts and the data measured by the road and weather information system	in accordance with the winter plan, following the road track		
Pre-spreading	incoming snowfall	14-20 g/m ² of solid materials (without pre-wetting)	road salt shall be applied above -7°C, below this temperature pre-wetting is needed	incoming snowfall	14-20 g/m ² of solid materials (without pre-wetting)	road salt shall be applied above -7°C, below this temperature
Snowploughing/ Spreading	snowy	20-40 g/m ² of road salt (without pre-wetting) with combined equipment	until -26°C	snowy	20-40 g/m ² of road salt (without pre-wetting) with combined equipment	pre-wetting is needed until -26°C
Anti-skid measures/ reactive	ice control, condensation control	20-40 g/m ² of road salt, pre-wetting is needed in case of condensation		ice control, condensation control	20-40 g/m ² of road salt, pre-wetting is needed in case of condensation	
	compacted snow up to 4 cm	20-40 g/m ² of road salt, since granules are fixed by the compacted snow there is no need for wetting		compacted snow, up to 4 cm	20-40 g/m ² of road salt, since granules are fixed by the compacted snow there is no need for wetting	
	icy snow up to 4 mm, sleet	30-40 g/m ² of road salt pre-wetting is needed	icy snow up to 4 mm, sleet	30-40 g/m ² road salt pre-wetting is needed		



SNOWPLOUGH IN WINTER SERVICE; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

overpasses, traffic safety can be significantly improved with the use of installed, local anti-skid equipment. The operational principle is as follows: when there is a risk of freezing or rainfall, a melting solution is sprayed out on the road pavement. The method helps to shorten the time between the emergence of the risk source and the appearance of the anti-skid machine and the time point when the spread material becomes effective.

A good example for that is the automated anti-skid system installed as part of the grade-separated junction (underpass of the road No 10) located in Pilisvörösvár (northwesterly from Budapest), which uses the weather parameters in order to establish if there is a risk of freeze-up or slipping. In the event of danger, the system starts spreading the CaCl₂ solution. The project

also involved the placement of sensors (meteorological stations), containers, pumps and injectors installed under the road surface and pavement for the spraying of the anti-skid material.

d. Winter service support system

Winter service is supported by a dispatch system which enables the real time monitoring of the number of machines available for service and being in service at the moment in question. The system also shows the changing trends of the salt reserves.

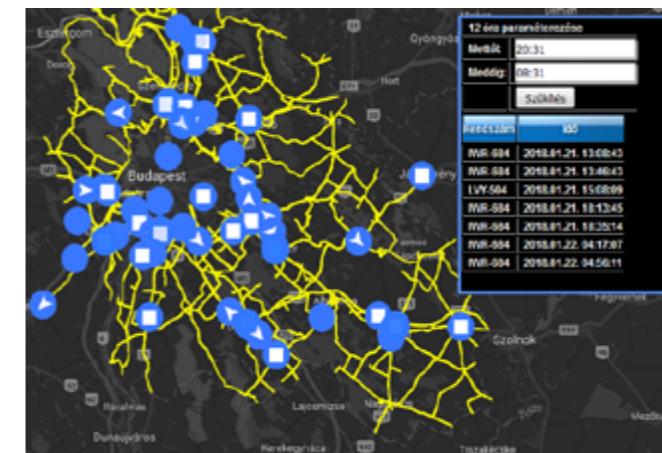
For that purpose, 800 winter work vehicles are equipped with GPS-based monitoring device.

e. Environmental protection

The Hungarian Public Road Non-profit PLC pays special attention to monitor the environmental impacts of their services. The impact of the road salt applied during the winter service on groundwater is monitored with the help of monitoring wells installed on the side of roads. Monitoring wells covered by water law permit are sampled at least once per year. Sampling and exams are carried out in accredited sampling laboratories, whereby – amongst others – general water chemical parameters are examined (e.g. total amount of dissolved materials, water hardness CaO (mg/l); PH; sodium, nitrate, chlorate, sulphate etc.). The obtained results are correlated to the contamination limits established by law.

f. Road weather data

The Hungarian Public Road Non-profit PLC has an own road meteorological system, with 213 road meteo-



WINTER SERVICE SUPPORT SYSTEM; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



GROUNDWATER MONITORING WELLS; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

rological stations for non-expressways and 159 stations for expressways, updating and sending data in every 10 minutes.

In accordance with the agreement concluded between the National Weather Service and the Hungarian Public Road Co., the National Weather Service operates a special webpage with up-to-date weather data to be used by the road authority.

These data provide information for each organization unit on the up-to-date weather and road conditions in the area in question.

g. Road user information services ("UTINFORM") – The source of up-to-date road-related information

The "Útinform" unit of the Hungarian Public Road Non-profit PLC collects essential information on the circumstances, events and incidents affecting the traffic flow and safety on the national public road network.

Based on the collected information, the road users are informed through various channels on every issue that affects the traffic flow and safety on the national public roads, including accidents, road closures and weather-related obstacles.



WEATHER SENSOR, TELECOMMUNICATION COMPONENT AND ROAD PAVEMENT SENSOR BELONGING TO THE ÚTMET ROAD AND WEATHER INFORMATION SYSTEM'S STATION; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

As "Útinform" is not only a unit of the Hungarian Public Road Company, but it is also the Main Responsible Body for Transport of the Ministry of National Development, messages are sent to the ministry in case of incidents subject to reporting obligation.

h. National Road Databank

The databank includes up-to-date information on the condition of the national public road network. The program developed for this specific purpose and supervised by the Department for National Road Databank provides information on the traffic flow and accidents incurred on the national public road network and on the condition thereof.

i. On-going developments and researches

The Hungarian Public Road Non-profit PLC - striving to reduce and prevent the effects of extreme weather



DEPARTMENT OF ROAD USER INFORMATION SERVICES; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC

conditions - has several international cooperation agreements in force along the TEN-T corridors. These agreements are aimed at on-site data collections and the consequent establishment of the DATEX II based automated information flow.

Traffic management plans were drawn up (along the borders and within the country) and a countrywide truck parking management system for heavy vehicles was created. The company aims to create a parking space for heavy vehicles with a coverage of approx. every 100 km, which would also include up-to-date occupancy information (e.g. VMS, mobile device, web, in form of DATEX data). The development is carried out in the framework of the CORCODILE II project (financed by CEF).

Another big future plan is the creation of the National Access Point through which road traffic information will be accessible.

In 2017, Hungary joined the international C-ROADS consortium with the C-ROADS Hungary „Infrastructure for connected and Automated Driving” project. The cooperation aims at the creation of a coordinated and harmonized C-ITS (cooperative intelligent transport systems) interoperable service in the European Union. Striving towards this goal, participant countries are working to establish the essential standards, agreed methods for the vehicle to infrastructure communication (e.g. on road closure, temporary weight restriction, traffic deviation etc.) on a personalized way.

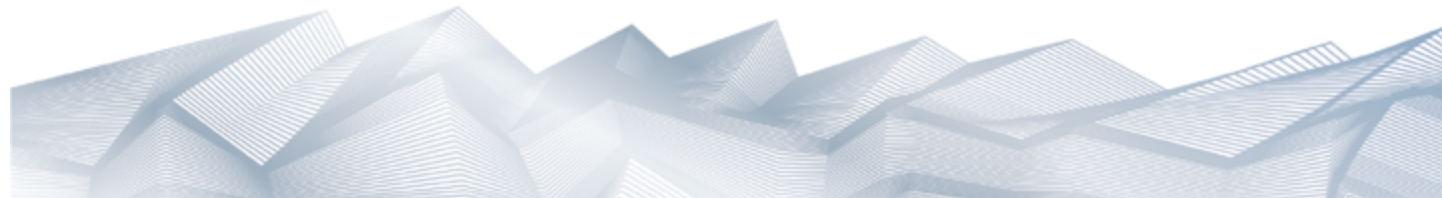
In the framework of CROCODILE I-II-III and C-ROADS Hungary projects, several sections of the M1 motorway will be equipped with C-ITS devices.

Besides the above - in response to the increased data demand related to the connected and automated driving - Hungary also takes part in the TN-ITS GO project. Precise information (on temporary speed, weight, height restrictions and signboards) related to the roads managed by the Company is provided to the manufacturers of digital maps and navigation systems.

Hungary also takes an active part in the FRAME NEXT project, which is about to up-dating of the EU ITS framework, which is a tool supporting the planning of ITS developments. Furthermore, a centralized traffic management system is currently being created which will also considerably improve winter road management.



ITS-DEVELOPMENTS; HUNGARIAN PUBLIC ROAD NON-PROFIT PLC



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Area	103,000 km ²
Latitude	64°08'N
Population	320,000
Density	3.1 per km ²

Iceland is situated in the middle of the North Atlantic Ocean, approximately 290 km east of Greenland and 970 km west of Norway. Consisting mainly of a plateau, Iceland's average height above sea level is 500 m, the highest point being 2,110 m. Only one quarter of the country lies below the 200 m contour line. The island is mountainous, surrounded by coastal lowlands, fjords and valleys shaped by marine abrasion and glacier erosion.

The economy depends mainly on export of products from power intensive manufacturing (24%), fishing industry (27%) and tourism (20%). The road network plays an important role in local transport of marine products for processing and export and for the increasing tourism.

1.2 ROAD NETWORK AND TRAFFIC

The Icelandic Road Administration, ICERA, is responsible for the road network, whereas the municipalities take care of roads within populated areas. The ICEARA road network includes 12,898 km, thereof 5,252 km of paved roads. The road network is divided into:

Road type	Length of road
Total ICERA road network	12,898 km
Primary roads	4,425 km
Local access roads	3,091 km
Primary highland roads	505 km
Highland roads	1,921 km



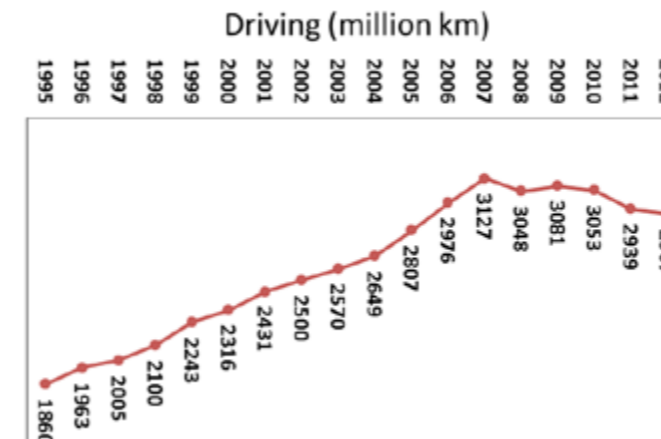
Primary roads connect areas of 100 or more inhabitants, secondary roads interconnect primary roads or connect primary roads to mountain roads, smaller villages and popular tourist destinations, local access roads connect farms or public places outside of populated areas to secondary and primary roads, and finally primary highland roads and highland roads, across mountains and moors, with limited service and often closed in winter.

Most of the traffic finds place in a 40 km circumference around the capital area in the southwest, where approximately half of the population is living. This map shows the traffic distribution on the road network:

NUMBER OF VEHICLES BY DECEMBER 31ST 2012:

- 242,500 vehicles total, thereof
- 210,000 passenger cars
- 32,500 commercial vehicles

Heavy vehicle commercial traffic has increased considerably since sea transport along the coast ceased by the end of year 2004. However, traffic growth has ceased following the economic recession. The following diagram shows estimated total traffic on the Icelandic road network.



2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS, MAIN WINTER EVENTS TO BE MASTERED

Iceland has an oceanic climate and doesn't undergo the extreme temperature conditions of continental climates. The winters are mild, but the summer is cool. There is a considerable difference between respectively the coastal lowland climate, the climate of the main highland plateau and the climate of the highest mountain areas.

There is also some difference between the north and south. Temperature decreases and precipitation increases with height above sea level. The north of Iceland is generally cooler than the south in wintertime and has more snowfall while mid-winter rainy periods are more frequent in the south.

Strong winds occur frequently, especially during the winter. Road service is challenged by icing, snowfall and drifting snow, which due to sparse vegetation and absence of forest is acting on the whole road network. Snow avalanches threaten a few low-traffic volume roads in rural areas. Reduced bearing capacity and road damage during thaw periods in wintertime is a growing concern on old roads.

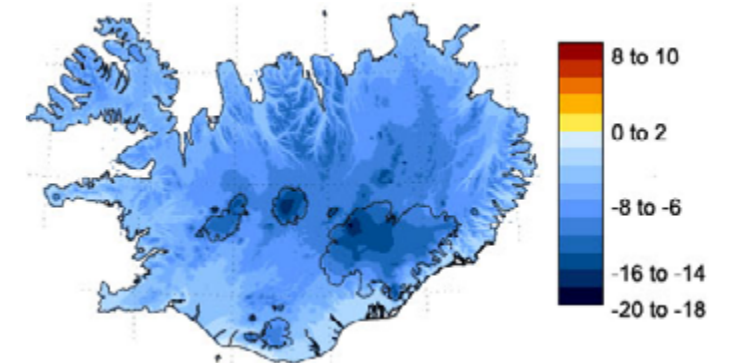
2.2 STATISTICS ON TEMPERATURES, ICING AND PRECIPITATION

According to experience, snow is covering the ground during most of the mid-and late winter in areas where the mean temperature of the coldest month is

below -4 °C. At the station of Reykjahlíð in the northeastern inland the snow is covering the ground completely for 135 days per year. In Reykjavík in the southwest this number is 55 on the average.

The temperature minimum drops below 0.0 °C on 123 days per year on the average in Reykjavík, 161 days in Akureyri in the north. These are typical lowland values.

The north is on the average drier than the south, although significant exceptions can be found locally. Usually the precipitation is light. Reykjavík thus has some precipitation on 221 days per year, but on 148 of these the precipitation exceeds or equals 1mm. In Aku-

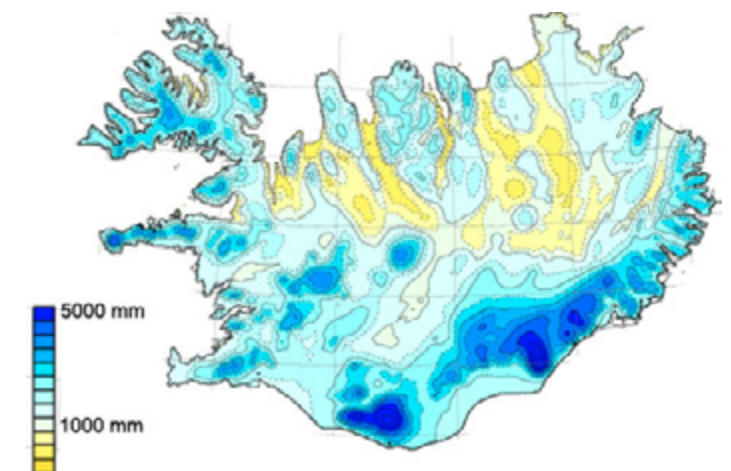


MEAN MINIMUM JANUARY TEMPERATURE

reyri the corresponding numbers are 171 and 103.

Snow or sleet is recorded on 82 days per year in Reykjavík, but 96 in Akureyri. Freezing rain occurs, circa once per year, per location. Blowing snow is a significant traffic problem, especially outside the main towns.

The conditions outlined above are only valid for the lowlands. The winter problems increase considerably



MEAN ANNUAL PRECIPITATION

with height above sea level. In the vicinity of Reykjavík the frequency of total snow cover days thus e.g., increases from 55 in Reykjavík (52m a.s.l.) to 91 at Stardalur (a few km to the East, at 185 m a.s.l.). Mean annual precipitation in Reykjavik for the period 1961-1990 is 800 mm, for Akureyri it is 490 mm and for Eyrarbakki on the south coast the mean annual precipitation is 1,370 mm.

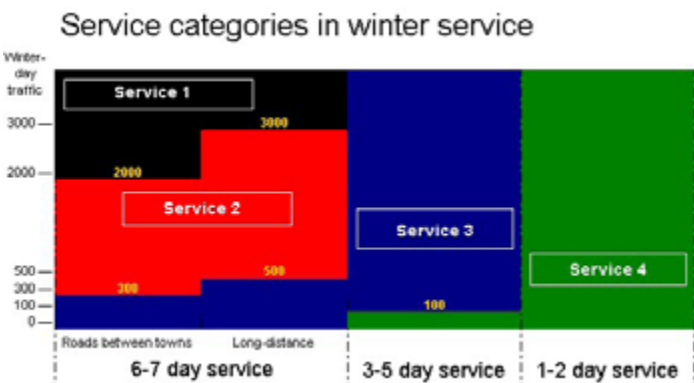
2.3 WINTER INDEX

A winter index was developed by ICERA for distributing winter budget between the different regions. The index reflects critical values and trends in temperature, humidity, and wind.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Snow and ice control, traffic information and winter road management is carried out by ICERA according to rules set by the Ministry of The Interior. Operation of the winter service is outsourced to private entrepreneurs. ICERA is financed by state budget and road-user taxes.



THERE ARE FOUR SERVICE CATEGORIES/CLASSES CONSIDERING ROAD FUNCTION AND TRAFFIC VOLUME.

Quality requirements for winter services concern the following factors:

- Service aims;
- Service level/category;
- Timing of actions;
- Maximum snow depth and road surface evenness criteria;
- Ice conditions/friction;

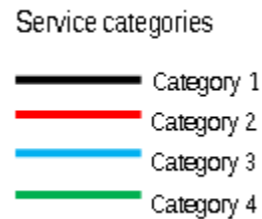
- Visibility at intersections and levelling of snow banks.

Besides the service class categorisation, roads in the lower service classes are subject to different number of service days pr. week.

Service class 1 implies a “bare road” strategy and relies on continuous use of de-icing chemicals, only NaCl is used. Pre-wet salt is the main application method.

Summary of the service requirements for roads in service categories 1 and 2 is as follows;

Service classes 2, 3 and 4 allow a certain amount of packet snow and ice with minimum friction criteria. Salt is used in these lower classes only when reasonable due to the weather conditions e.g. in autumn and spring.



3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE MANAGEMENT AND ORGANISATION

ICERA runs two control and surveillance centres that share the overall organisation of the winter service, and

Summary of Winter Service Quality		Service Class	
Standards		1	2
Service hours	In town	24 / 7 service	06:00 - 22:30
	60 km from town		08:15 - 22:00
	120 km from town		10:30 - 21:30
Critical snow depth for service		2 cm	4 cm
After snowfall, ploughing		2 hours	3 hours
After road closure, snow removal is completed within		-	3 hours
Max. service cycle duration		2 hours	
Max. service route pr. vehicle		50 km	
Maximum snow depth		5 cm	12 cm
Maximum track depth		1 cm	2 cm
Min. friction coefficient	Generally	$\mu > 0.25$	$\mu > 0.15$
	Curves and slopes	$\mu > 0.25$	$\mu > 0.25$



monitor weather and road conditions on a 24/7 basis from October 15th until April 30th. Countrywide there are 18 regional service centres co-ordinating the force of contractors responsible for the operational tasks and the on-site road condition assessment are carried out by contractors.

In larger towns the ICERA is serving the major roads according to the ICERA standards based on contracts with the local municipal authorities.

The service equipment fleet is mainly trucks with snowploughs and salt spreaders, pay loaders and graders. Rotary blowers are very important in winter service on mountain roads and exposed primary roads. Grader works, such as removal of hard snow and ice are increasingly overtaken by plough-trucks with under-body blades. Graders are, however, still important to level snow banks on the road shoulder in exposed areas.

Depending on the service category, the service route



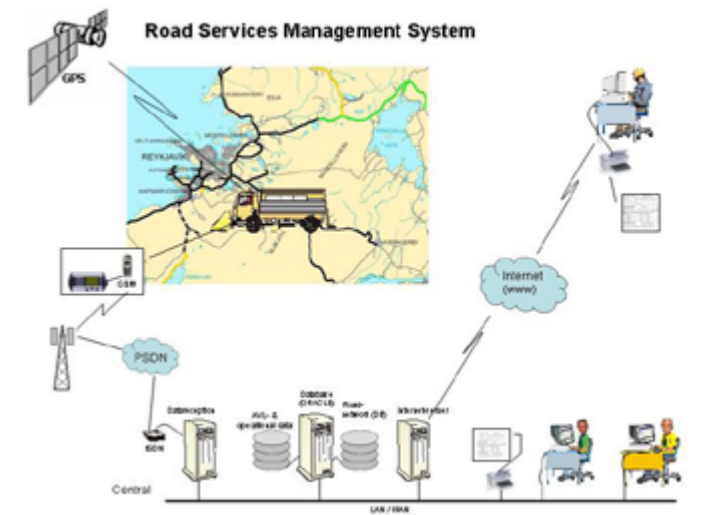
per vehicle is 50-120 km. Usually there are 1 or 2 men per truck.

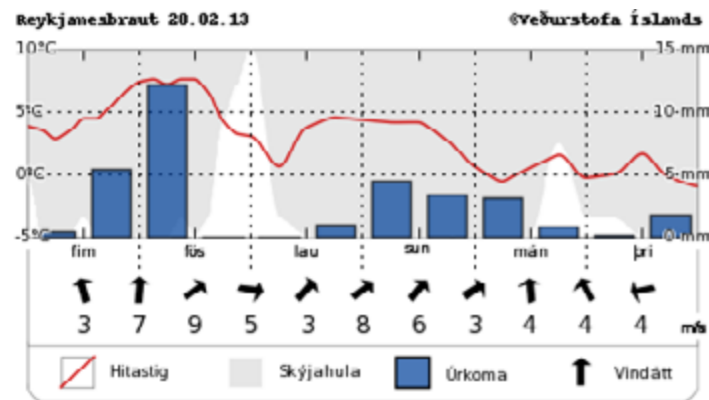
The ICERA’s internal codes define the responsibility for different tasks concerning winter services:

Unit	Tasks / Responsibility
ICERA Management Service Department	Overall service procurer Central planning and organisation Service standards and rules Assign service category to roads Operation of RWIS and other information systems Training and education
Control and Surveillance Centre 2 centres countrywide	Monitor weather and road conditions Planning and coordination Registration and information processing Service assessment
Regional Service Centre 18 centres countrywide	Inventory Daily operation management Control: - Road condition in-situ - Service quality - Budget
Contractors	Operational tasks - Snow ploughing - De-icing, sanding

Road closures are enforced by the police under adverse weather conditions according to the ICERA’s evaluation. Snow-Avalanche hazard, flooding, etc., may also lead to road closure.

Automatic vehicle location and activity registration is used for settlement of winter services and as well as for quality control. AVL equipment, consisting of a telecommunications device (GSM) and sensors, is installed in snow removal equipment with a salt and brine spreader as well as front and under-body blades to automatically collect information about location, activities, speed, distance and time. Upon receipt of data from a device, the grid position is plotted into the road system,





along with information on salt/sand use, length of road cleared, etc.

ROAD WEATHER INFORMATION

ICERA has contracts with the Icelandic Meteorological Office. In the current information system for the ICERA, data is gathered into a central database. Forecast period up to six days is used. There are approximately 100 road weather stations (approx. 100 RWIS stations countrywide). For 19 road stations, a six day forecast meteogram is issued (illustration).

Operators in the two control centres monitor weather forecast and observations as well as the approximately 100 camera-points on the roads.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

COST & BENEFITS OF WINTER MAINTENANCE ACTIVITIES

The annual cost of the winter maintenance in 2011-2012 on the road network (excluding highland roads) is:

Road network open for winter service	10,472 km
Total winter service costs 2011-2012	1,200 EUR/km/year
Road network treated with salt, Σ(2-lane kilometres)	1854 km
Amount of salt used	27,600 t/year
14,9 t/km/year	2,3 kg/m ² /year

The winter index mentioned in previous chapter turns out to reflect the actual annual cost reasonably

well each winter.

Methods to decrease use of salt while maintaining the service levels

Through observations of water amount, residual salt and road surface temperature, and considering the weather outlook, salt dosage for concurrent actions is defined. The use of automatic sensors and manual measurements for this purpose is in a development phase.

3.4 TRAFFIC SAFETY AND INFORMATION INFORMATION PROVISION TO THE ROAD USER

Information is provided through various media. Information provided is; condition of road (slipperiness), weather (wind speed, gust and wind direction, temperature), road temperature, humidity and dew-point,



traffic (last 10 minutes, traffic from midnight), estimated time of opening if road is closed, maintenance works, axle-load restrictions, ferry schedules etc. The one hundred camera-points are available to the general public through internet.

Use of weather related road sensors and variable road signs

Most of the ICERA's weather stations have temperature sensors in the road surface, and some have road surface humidity sensors for management use only. Frost depth sensors are used to determine weight restrictions on roads. Variable message signs are used to show wind speed, wind direction, temperature and in extremely exposed areas wind gust. Variable road signs are also used to show if a road is closed.

Use of information technologies for efficient management and for avoidance of danger by providing in-

formation to road users

Information and warnings are provided through radio, internet, text-TV, phone service and message signs.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY

ICERA is developing different models and instruments to enhance the availability of road weather information. Among the systems that have been developed and are under validation are;

Wind gust forecast, for chosen sites. The model utilizes historical statistics on the relationship between measured wind gust on road weather stations and the forecast for atmospheric conditions. The model indicates the probability of wind gust over a certain threshold for the particular site the next 28 hours.

Frost depth forecast, for freeze-thaw conditions in the road sub-base. The model takes readings from the frost depth monitoring system previously developed for ICERA, as an initial condition and extends the five day weather forecast through the road sub-base to indicate when axle load restrictions are necessary for the low-bearing capacity roads.

Road surface temperature and icing forecast is under development. The model gives accurate prognosis for road temperatures under the most critical conditions for sudden icing on the road network. This prognosis is important e.g. when road temperatures drop below



the freezing point due to long wave emission from the surface due clear sky, even when air temperatures are still significantly above the freezing point.

Residual salt and ice detection sensor has been developed. The sensor indicates the road surface temperature, the freezing of liquid present on the surface and gives estimate on the residual salt left on the pavement surface.

Customizing salt dosage. A new procedure for defining dosage for salt spreading is under trial at the control and surveillance centre for the capital area. The aim is to use available information on road condition, including residual salt, weather and traffic pattern to define the salt dosage. The goal is to use less salt without compromising service quality.

Modelling Residual Salt (MORS-project). ICERA participates in the NordFoU MORS project. The aim is to develop a model which is capable of predicting the residual salt development on the road, taking traffic, road and weather parameters into consideration.

4.2 NEW MANAGEMENT AND ORGANIZATION APPROACHES

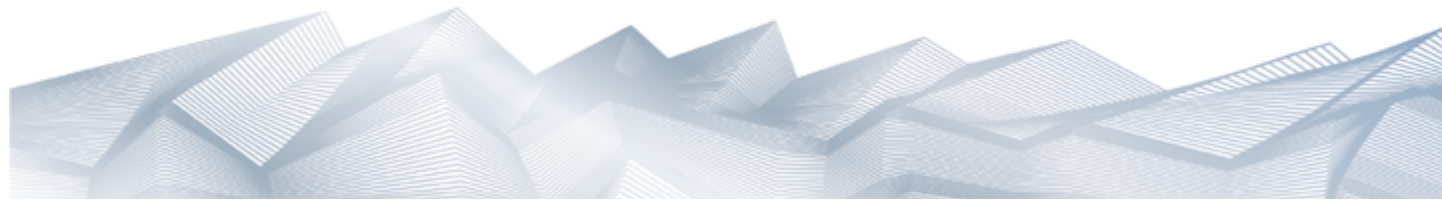
The hierarchy describes in chapter 3.2 describes a new organisational approach adopted by ICERA in 2012. The new structure facilitates a more centralized management in order to harmonize practise in the regions and enable a more flexible use of the workforce without administrative boundaries. Centralizing surveillance and call-out has economic benefits and is believed to be more reliable.

Training. Since autumn 2012, it is decided that all staff engaged in winter management and operations shall undergo a training course.

5 REFERENCES

Traffic and weather information in English on ICERA's internet site:

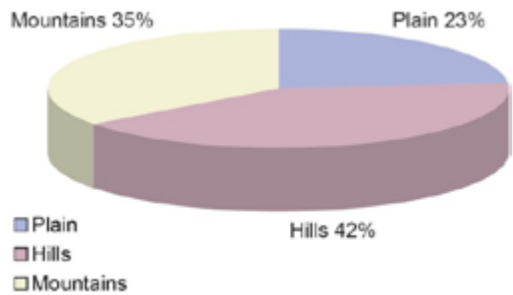
- <http://www.vegagerdin.is/english/>
- Statistics Iceland: <http://www.statice.is/>
- The Road Traffic Directorate: <http://www.us.is/umferdarstofa/english>



1. DEMOGRAPHICS AND ROADS

Area	301,302 km ²	
Population	60 millions	
Length of roads	National roads and highways	31,000 km
	Prefecture roads	141,000 km
	Municipal roads	300,000 km
Latitude (capital)	41°53'N	

COUNTRY AND ROAD STATISTICS



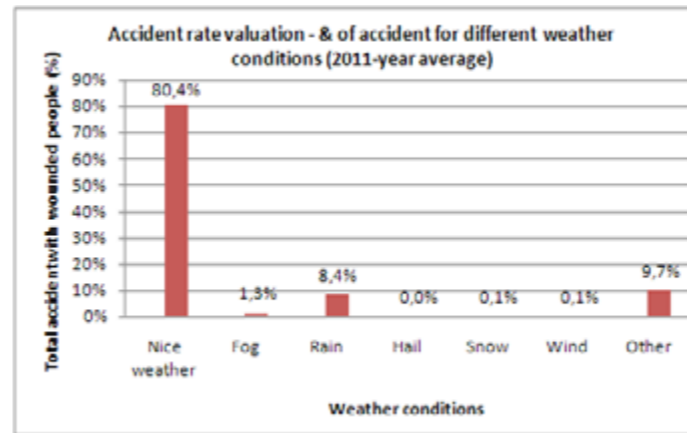
	Plain	Hills	Mountains	Total
Area (km ²)	69,902	125,342	106,058	301,302
%	23.2	41.6	35.2	100,0



OROGRAPHY

2. CLIMATE

TEMPERATURE AND PRECIPITATIONS STATISTICS		Alt. (m)	Monthly mean temperature (5-year average) (°C)				Daily minimum temperature (5-year average) (°C)				Snowfall (4-year average) days	Precipitation (5-year average) mm.
			Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.		
Lombardia (North)	Milano	107	3,6	3,4	4,7	9,3	-4,0	-4,9	-3,2	0,3	3	720
	Monte Bisbino	1.319	2,4	1,3	1,2	3,6	-2,7	-5,3	-7,7	-3,8	21	1363
Lazio (Centre)	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	1045
Calabria (South)	Reggio Calabria	11	13,1	13,4	11,9	13,4	5,9	6,4	5,7	6,9	1	341
	Monte Scuro	1.710	0,5	-0,2	-1,3	1,1	-7,3	-6,9	-7,9	-7,4	4	841
Sardegna (Islands)	Cagliari	4	11,0	10,3	9,8	11,9	3,8	1,5	2,3	3,6	1	378
	Fonni	1.022	6,8	6,5	5,8	6,5	0,8	-2,5	0,5	-0,4	5	808



Accident rate valuation - % of accident for different weather conditions (2011-year average)	
Nice weather	80%
Fog	1,3%
Rain	8,4%
Hail	0,0%
Snow	0,1%
Wind	0,1
Other	9,7

ANNUAL ROAD ACCIDENTS / WEATHER CONDITIONS (2011-YEARS AVERAGE)

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

The Ministry of Infrastructure and Transport established the minimum standards and rules for snow and frost removal service on state road and motorways.

AIMS

The main aim of Winter road management is to keep road users on the move and/or to rapidly re-open to traffic in winter when traffic must be discontinued. This is to be achieved also by means of very urgent interventions along the managed road and motorway network subject to snow falls and frost.

Description

Winter road management embraces the following activities:

Snow removal: it includes the removal of the layers of snow, mud, ice from the pavement, from the

verges of the carriageways endowed with New Jersey or guard-rails, from bridges and viaducts and tunnels (entrance-exit portals)

De-icing treatment: it consists in spreading, beforehand, de-icing salts on roads and/or anti-icing mixtures (salts and aggregates) in order to prevent ice formation on pavements, on bridges and viaducts, near tunnels (entrance/exist portals)

Emergency assistance: it consists in snow removal and anti-icing treatment by means of ad hoc teams operating for urgent interventions to be carried out (upon a call)

Felling of dangerous trees and removal of the discarded material;

Removal of the trees damaged by snow showers by the cutting of branches at the slinging and subsequently cutting them to pieces

SERVICE SUPPLY

The Departmental Offices provides for a constant planning of such activities according to the weather and altimetric characteristics of the relevant areas.

The availability of men and means to tackle sudden emergency and/or unforeseeable situations is guaranteed apart from bad weather conditions (snow falls and/or frost) and considering the need of keeping a high standard level of service, while reducing the risks on the managed road and motorway networks.

All these activities are carried out by means of trained teams equipped with mechanic means, snow blowers, snow blowers and cutters, salt spreaders.

The foreseen activities are normally carried out continuously for a 6 month period (November-April) all day long and in working days and holidays.

All such activities are carried out in such a way to provoke the least traffic congestion possible. Furthermore they are all carried out by means of ad hoc signals and barriers

SUPPLY TIMES

The above activities are generally implemented according to the following scheme:

Snow removal and anti-ice treatment, according to the frequency of snow falls and frost formation for a period of 4 up to 6 months, following the orographic characteristics of the network;

Emergency activation: upon call (ANAS monitoring

personnel, police etc) due to emergency situations, generally within 60 minutes from the call all day long in working days and holidays).

PERFORMANCE INDICATORS AND RELEVANT INDICATORS RELATED TO ROAD AND MOTORWAYS SERVICE

Performance indicators related to the national roads network:

Snow removal index

$$I_{SN} = 2 - \frac{SN_{cons}}{SN_{rif}}$$

Snow removal indicator (I_{SN}) is a ratio between performance in snow removal (SN cons), measured in number of roads closed for traffic over than 12 hours, without exceptional cases, and the expected maximum value.

Where:

SN cons = (SN cons1 + SN cons2 +.....+ SN cons n)
(Total traffic closing over 12 hours)

SN rif = allowed maximum value number of roads closed for traffic over than 12 hours, without exceptional cases.

Exceptional are scheduled roads closing (e.g. crossing place in mountains) or during exceptional snow falls (more than last 5 years average).

Indicator	Incidence
Mowing Grass I _{SE}	20%
Clear Snow I _{SN}	10%
Markings I _{SO}	20%
Reconditioning operations Technological Systems I _{IL}	10%
Reconditioning operations flooring emergency I _{PAV}	20%
Infomobility I _{IM}	20%

SYNTHETIC INDEX

Same index as well as for snow removal there are for Grass cutting (I_{se}), Orizontal road signs (I_{so}), Tecnological plants work-service (I_{il}), roads paving emergency work-service (I_{pav}), traffic informations (I_{im}) too.

To each specific indicator is associated with a decimal weighting factor to take into account the different size of the reference measurements associated with each of them.

In this way Synthetic index is calculate and the formula is:

$$I = (0,2 * ISE + 0,1 * ISN + 0,2 * ISO + 0,1 * IIL + 0,2 * IPAV + 0,2 * IIM)$$

A lower value of the unit may lead to the application

Penalty	Value indicator	Scope of the penal annual value of resources acquired pursuant to art. 19, paragraph 9-bis of Law 102/2009 and subsequent amendments and the intended operating activities
Nothing	0,95 = I < 1	0
Minimum	0,9 = I < 0,95	0,01% up to a maximum of € 100,000
Middle	0,8 < I < 0,9	0,02% up to a maximum of € 50,000
Maximum	I < 0,8	0,03% up to a maximum of € 200,000

of a penalty under the following terms:

ROADS UNDER INSPECTION

The calculation of the indicators for measuring the performance of Anas in the performance of activities subject to inspection will be carried out on a sample of roads assigned under management.

The choice of roads must be guided by the use of appropriate selection parameters that allow to identify a significant sample.

The selection of the roads then may be made taking into account the following parameters:

- Type of road (highway, junction, highway);
- Traffic volumes;
- Strategic importance of the road;

- Geographical distribution throughout the country.

3.2. METEOROLOGICAL INFORMATION AND FORECAST

Meteorological information and forecast are provided by Italian Air Force (Aeronautica Militare Italiana) which sees to the collection, processing of data and meteorological products (analyses, forecasts, advice and so on) all over the national territory.

3.3. TRAFFIC SAFETY AND INFORMATION

Meteorological and traffic information to users broadcasted by radio are processed and spread by the information centre CIIS by means of the following national networks:

RTL (102.5 MF) updated every 30 mts between 06.30 and 21.00

RADIO RAI : updated maximum every 30 mts

ISORADIO: (103 Mhz): every 30 mts covering the motorway network

The information Centre CIIS was created in 1990 on the initiative of the Ministry of Infrastructure and Transports (the then Ministry of Public Works) and of the Interiors Ministry, as and information means for road safety regulated by law n.556 of 30.12.1998 and subsequent rugulations.

This service is carried out in co-operation with ACI, ANAS S.p.A., Autostrade per l'Italia S.p.A., Arma dei Carabinieri, Polizia Stradale, RAI and Polizia Municipale in Rome



3.4. ORGANIZATION AND OPERATIONS FOR WINTER MAINTENANCE

With regards to winter climatic conditions, Italy has very different features along the territory. The northern borders of the Italy territory flank countries with old seasons longer than its own, whilst the south is characterized by a long hot and sunny season. Mountains are in all the Italian regions and so the territory and climate are variegated everywhere. Only 23% of the Italian territory is on a plain. The Alps cross all the Italian northern regions with Mount Blanc at 4,810 m as the highest mountain. The Apennine mountain chain runs north to south. Here many mountains are over 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 the possibility of snowfall as well as where it appears unlikely in regions located in the southern latitude and near the sea. The snow is different in the northern regions, where it is dry and light, compared with, wet and heavy snow in the southern regions.

ANAS (the Italian Agency for National Road construction and management), highway management organizations, local authority and municipality offices carry out winter maintenance with their own equipment and with the assistance of private firms to ensure safety for

road users in winter.

3.5. METEOROLOGICAL INFORMATION AND FORECAST

Meteorological information and forecast are provided by Italian Air Force (Aeronautica Militare Italiana) which sees to the collection, processing of data and meteorological products (analyses, forecasts, advice and so on) all over the national territory.

The surveys are carried out by satellites and by a strict network of meteorological stations along the national territory.

3.6. TRAFFIC SAFETY AND INFORMATION

Meteorological and traffic information to users broadcasted by radio are processed and spread by the information centre CIIS by means of the following national networks:

RTL (102.5 MF) updated every 30 minutes between 06.30 and 21.00

RADIO RAI : updated maximum every 30 minutes

ISORADIO: (103 Mhz): every 30 minutes covering the motorway network

The information Centre CIIS was created in 1990 on the initiative of the Ministry of Infrastructure and Transports (the then Ministry of Public Works) and of the Interiors Ministry, for road safety regulated by law n.556 of 30.12.1998 and subsequent regulations.

This service is carried out in co-operation with ACI, ANAS S.p.A., Autostrade per l'Italia S.p.A., Arma dei Carabinieri, Polizia Stradale, RAI and Polizia Municipale in



Rome

4. REFERENCES

ISTAT – Statistiche Meteorologiche
www.istat.it

ANAS – Carta dei Servizi Stradali e Autostradali
www.radio.rai.it

www.autostrade.it

www.meteoam.it

ANAS- Fog alert project

www.stradeanas.it



1 DEMOGRAPHICS AND ROADS



FIGURE 1 - LOCATION OF JAPAN

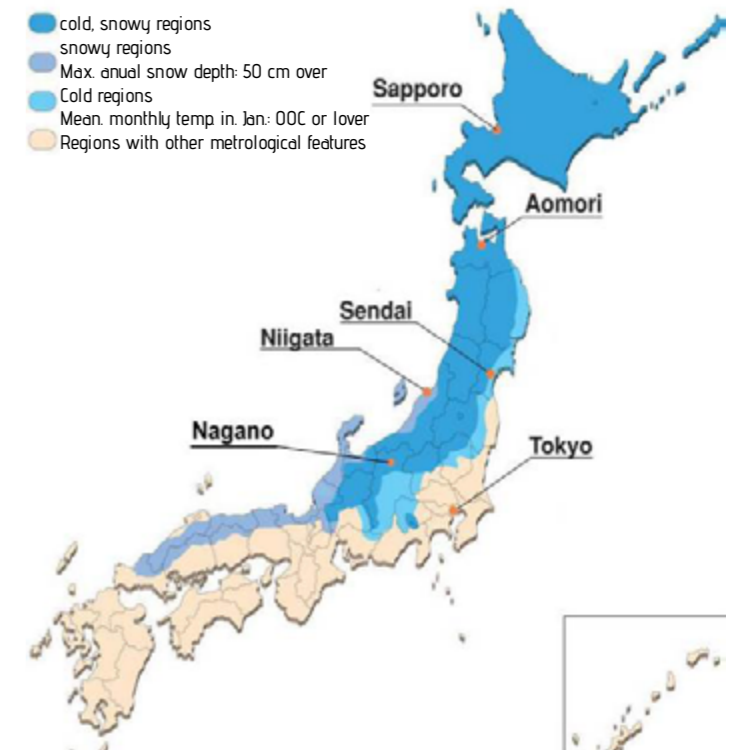
Some of the urban areas of Japan receive much more snowfall than urban areas anywhere else in the world. In the cold, snowy regions of Japan, when it snows, traffic is often paralyzed. Roads are damaged by freezing in extremely cold regions.

To ensure the safe, reliable flow of road traffic in severely cold, snowy regions of the country, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted in April 1956. Cold, snowy districts account for nearly 60% of Japan's land area, some 40% of its municipalities, and about 20% its population (Figure 2).

TABLE 1 - AREA, POPULATION AND ROADS IN JAPAN

Area	377,971 km ²	
Population	127,095 mil. people	
Length of Road	National expressway	8,652 km
	National highway	55,645 km
	Prefectural road	129,446 km
	Municipal road	1,026,980 km
Latitude (capital)	35° N. Lat. (Tokyo)	

SOURCE: POPULATION: MINISTRY OF INTERNAL AFFAIRS AND COMMUNICATIONS STATISTICS BUREAU WEBSITE (FY 2015); ANNUAL REPORT OF ROAD STATISTICS 2016, MINISTRY OF LAND,



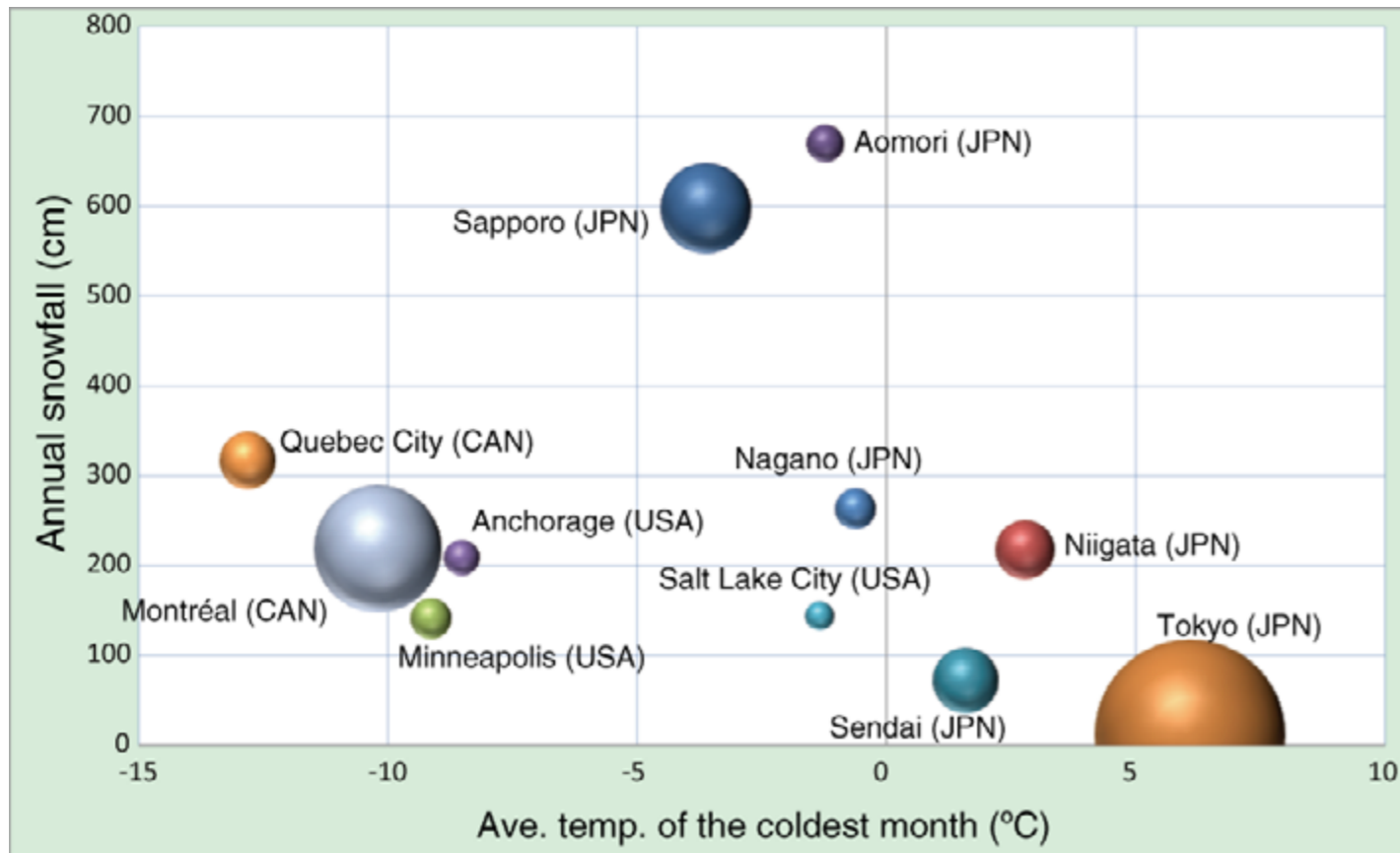


FIGURE 3 - AIR TEMPERATURE OF THE COLDEST MONTH, AND ANNUAL SNOWFALL

INFRASTRUCTURE, TRANSPORT AND TOURISM

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

Japan is more southerly than most other cold, snowy countries. Even so, most of the country receives snowfall, expect for the southern part of Kyushu Island. The

areas indicated as cold and snowy on the map (Figure 2) are those designated as such by the Law. The climate in these areas is much colder than elsewhere in Japan. Temperatures drops far below freezing, and winters see extreme snowfall. As shown on the map, snow falls heavily in the northern Japan Sea coastal area (Hokuriku Region). This is one of the features of winter in Japan.

The heavy snowfall on the Japan Sea side occurs when cold air from Siberia absorbs great amounts of

2.2 STATISTICS ON TEMPERATURE, SNOWFALL AND PRECIPITATION

TABLE 2 - TEMPERATURE AND PRECIPITATION (30-YEAR AVG., 1981 - 2010)

	Daily min. temperature [°C]				Snowfall [cm]			Precipitation [mm]				
	Dec.	Jan.	Feb.	Mar.	Daily maximum snowfall	Maximum snow depth	Cumulative snowfall	Dec.	Jan.	Feb.	Mar.	Total
Sapporo	-4.1	-7.0	-6.6	-2.9	37	100	597	111.7	113.6	94.0	77.8	1106.5
Aomori	-1.4	-3.9	-3.7	-1.3	34	111	669	150.8	144.9	111.0	69.9	1300.1
Sendai	0.9	-1.7	-1.5	0.9	15	17	71	36.6	37.0	38.4	68.2	1254.1
Niigata	2.7	0.2	0.1	2.3	24	36	217	217.4	186.0	122.4	112.6	1821.0
Tokyo	5.1	2.5	2.9	5.8	5	6	11	51.0	52.3	56.1	117.5	1528.8
Nagano	-1.6	-4.1	-3.8	-0.8	22	31	263	45.5	51.1	49.8	59.4	932.7

SOURCE: JAPAN METEOROLOGICAL AGENCY

Policies for winter road control in Japan



Roads in regions designated as cold/snowy under the Law and that meet the traffic volume criteria set by the Minister of Land, Infrastructure, Transport and Tourism are designated as roads subject to the Law. Securing of traffic on such roads is especially important for the promotion of socioeconomic activities.

FIGURE 4 - OUTLINE OF THE SPECIAL MEASURES LAW FOR ENSURING ROAD TRAFFIC IN SNOWY AND COLD AREAS

moisture over the Japan Sea and then meets the high mountains that make up the northeast-by-southwest backbone of northeastern Honshu Island. The rising air cools, forming snow clouds.

Many Japanese cities are among the snowiest in the world. More than two million people live in and around Sapporo, the capital of Hokkaido, despite an annual snowfall of nearly 6 m. It is the only city in the world where such a great number of people live amidst such extreme snowfall.

Source: United Nations Demographic Yearbook; Japan Meteorological Agency

Note: The size of the globe indicates the population of the city.

3 WINTER ROAD MANAGEMENT

3.1 HISTORY AND BACKGROUND OF SNOW- AND ICE-CONTROL PROGRAMS

In 1956, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted. Snow- and ice-control programs were established to ensure smooth winter traffic that supports winter living in cold, snowy regions, because snowfall causes road closures

and traffic accidents including skidding accidents on icy roads, and the roads are damaged by frost heave in such regions. The Law was legislated to reduce local governments' mounting financial burdens and to provide measures against these hindrances amidst a rapid increase in vehicle ownership.

The need for measures against the extremely slippery roads that have emerged since studded tires were banned has been an issue. Such roads have caused increases in vehicle skidding and pedestrian fall accidents.

3.2 LEVEL OF SERVICES (LOS)

Criteria for the deployment of snow- and ice- control staff and vehicles and winter road LOS are set for each road category according to the snowfall, air temperature and traffic volume in each cold, snowy region. Winter management, including the plowing of newly fallen snow, the application of anti-freezing agents and of snow hauling, is based on such criteria and on LOS.

The Hokuriku Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism sets deployment criteria for each type of winter mainte-

nance operation (Table 3). The City of Sapporo sets LOS (Table 4) by road type.

TABLE 3 - CRITERIA FOR DEPLOYING SNOW- AND ICE-CONTROL OPERATIONS

EXAMPLE ON NATIONAL HIGHWAYS IN THE HOKURIKU REGION

Operation	Deployment criteria	
Patrol	1. Monitor snowfall and freezing forecasts, and dispatch patrols as necessary. 2. Dispatch additional patrols as necessary, especially when... 1) Snow/ice-related traffic disruption is anticipated. 2) Traffic disruption is reported by police, road condition monitors, other road users or local residents.	
Snow removal	Plowing	There is 5 to 10 cm of snow on the road, and further snowfall is expected.
	Surface leveling	1. The great amount of snow on roads is anticipated to cause traffic disruption unless it is leveled. 2. This is done to prevent the compacted snow layer from thickening and to eliminate unevenness.
	Compacted snow and ice scraping	Due to temperature fluctuations and the load of passing vehicles, compacted snow has become uneven enough to disrupt traffic.
Widening effective road widths with rotary blower	1. Heavy snowfall has prompted the need for plowing to secure the effective road width. 2. Snowbanks at the shoulder have become so large that they are expected to disrupt traffic when wind moves the snow.	
Hauling	Roadside snowbanks have become so large that they hinder vehicles passing each other in opposite directions, and further snowfall is forecast. Or snow removed from roofs of houses along the road is expected to enlarge the snowbanks.	
Sidewalk snow removal	At the instruction of a supervisor	
Salting	Road icing is forecast or has been reported.	
Operation of snow-melting facilities	1. Snow has fallen. 2. Icy roads have been reported (road heating operation is necessary).	
Other operations	At the instruction of a supervising personnel	



FIGURE 5 - MULTI-LANE SNOW REMOVAL

TYPE IN THE CITY OF SAPPORO (CARRIAGEWAYS)

TABLE 5 - WINTER ROAD SERVICE LEVEL BY ROAD TYPE IN THE CITY OF SAPPORO (SIDEWOLKS)

Road type	Criteria	LOS	Criteria for securing road width
Side-walk	2 m < Effective width	Maintain the surface so that walking on the sidewalk is not hindered	Length of the blade of sidewalk snow remover (1.3 - 1.5 m); enough width for pedestrians to pass by each other

3.3 SNOW- AND ICE-CONTROL MEASURES

SNOW REMOVAL

SNOW REMOVAL ON ROADWAYS

To maintain the trafficability of national highways and principal prefectural roads and to promote inter-regional exchanges and living activities, snow removal on roadways is conducted around the clock.

SNOW REMOVAL ON SIDEWALKS

Road type	Roles of the road	Typical road structure	Depth of compressed snow layer	Criteria for securing road width
Major arterial	Linking cities and major destinations within the city	6-lane road	Within 3 cm (no rutting formed)	4 lanes or more (about 13 m); enough width so that right/left turning vehicles do not interfere with other vehicles
Arterial	Collecting traffic between major destinations in the city/major facilities;	forming frameworks of residential areas	4-lane road Within 5 cm (no rutting formed)	3 lanes or more (about 9 m); enough width so that right-turning vehicles do not interfere with other vehicles
Secondary	Collecting traffic in residential areas and directing it to arterial roads; providing links between rural roads and arterial roads, and access to major facilities within the residential area	2-lane road	Within 25 cm (no driving interference)	1 1/2 lanes or more (about 4 m); enough width for small automobiles to pass by each other
Tertiary / rural	Access to/from dwellings	8 m ≤ road width < 10 m	Within 30 cm	1 lane and pedestrian space (about 3.2 m); enough width for an emergency vehicle to drive through

Snow removal on sidewalks is promoted around schools, railway stations, downtown and social welfare



FIGURE 6 - SIDEWALK SNOW REMOVAL

facilities, to ensure the safety and reliability of walking spaces in winter.

APPLICATION OF ANTI-FREEZING AGENTS

Since the ban on studded tires, extremely slippery road surfaces frequently have emerged in winter. Anti-



FIGURE 7 - APPLICATION OF ANTI-FREEZING AGENTS

-freezing agents are efficiently applied to reduce traffic congestion and slip accidents.

SNOW-CONTROL MEASURES

Various facilities are constructed as countermeasures to avalanche and snowstorm.

SNOWBREAK WOODS

These catch snow particles carried by winds and hold them in snowdrifts within the woods or on their windward side to prevent snow from blowing onto roads



SNOWBREAK WOODS

SNOWFENCE



AVALANCHE CONTROL FENCE

SNOW SHED

FIGURE 8 - SNOW-CONTROL FACILITIES

on the downwind side.

SNOWFENCES

These keep snow from blowing into drifts on the road, and they mitigate height increases of roadside snowbanks with snow plowed from the roadway, thus improving visibility of the road.

AVALANCHE CONTROL FENCES

These are constructed on avalanche-prone roadside slopes.

SNOW SHEDS

These are constructed over roads so that avalanches will pass over them without endangering the safety of the roads.

LIGHT-EMITTING DELINEATORS

The delineators, which run on eco-friendly solar energy, are easily recognized, and they improve the ef-



FIGURE 9 - LIGHT-EMITTING DELINEATOR:

DIAGRAM AND ONSITE INSTALLATION

iciency of snow removal.

SNOW-MELTING FACILITIES
ROAD HEATING

Road heating systems melt snow or prevent road icing by heating the pavement using heating pipes or



WITHOUT ROAD HEATING WITH ROAD HEATING
FIGURE 10 - EFFECT OF ROAD HEATING SYSTEM

electric coils, rather than by sprinkling the road with water.

SNOW-MELTING SPRINKLER

Groundwater is pumped up and sent through pipes



FIGURE 11 - EFFECT OF SNOW-MELTING SPRINKLER
SNOW-FLOWING GUTTER

for sprinkling from nozzles to melt snow. The pipes and nozzles are embedded in the road.

SNOW-FLOWING GUTTER

The City of Sapporo has constructed eight snow-flowing gutters to dispose of snow with the cooperation of local residents. These gutters are constructed at the roadside. Residents dump snow on the street into the openings of a covered box culvert, where snow is swept away by water running down a natural incline. In general, the water source is river water. However, at seven gutters out of the eight snow-flowing gutters, Sapporo

also uses processed sewage effluent at 10°C from sewage-treatment plants.

The use of processed sewage water has the advantage of requiring less discharge capacity than in the case of

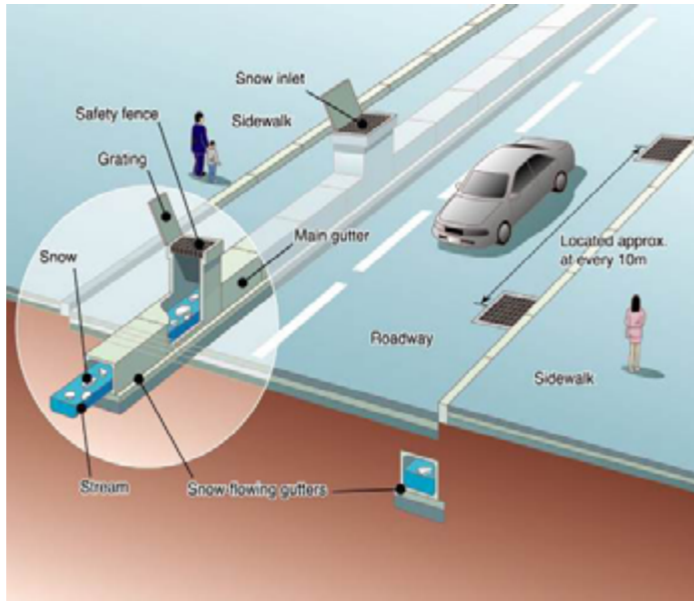


FIGURE 12 - DIAGRAM OF SNOW-FLOWING GUTTER



RESIDENTS DUMPING SNOW INTO THE SNOW-FLOWING GUTTER
MAINTAINING THE SAME EFFECTIVE ROAD WIDTH IN SUMMER AND WINTER

FIGURE 13 - EFFECT OF SNOW-FLOWING GUTTER

using river water, because the higher temperature of sewer water reduces the snow volume by melting the snow.

SNOW-MELTING TANK

Snow-melting tanks melt large quantities of snow while occupying relatively small areas of land. Such tanks dispose of snow that is removed from roads, carried by dump trucks and dumped directly into heated water. The energy used to melt snow is from sources previously considered as waste. These sources include 1) heat of processed sewage effluent, and 2) residual heat from district heating and cooling plants. The tanks are used not only during winter, but also during other

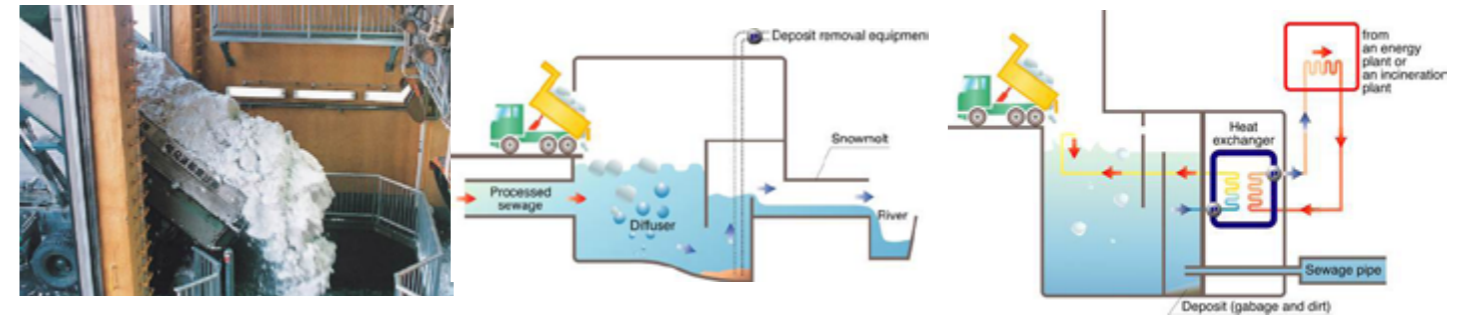


FIGURE 14 - SNOW-MELTING TANK
HEAT SOURCE OF SNOW-MELTING TANK: WARM PROCESSED SEWAGE, RESIDUAL HEAT FROM INCINERATION PLANTS, ETC.

seasons, as fire-fighting water tanks and balancing reservoirs to retain rainfall and sewage.

3.4 TRAFFIC SAFETY & INFORMATION
WINTER ROAD INFORMATION PROVISION

The Road Bureau and the Regional Development Bu-

reau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) have been running a portal website for the purpose of providing detailed road information based on the situation in each area. The portal website contains links to regional road information websites and MLIT's website (Figure 15).

FIGURE 15 - WEBSITE FOR WINTER ROAD INFORMATION

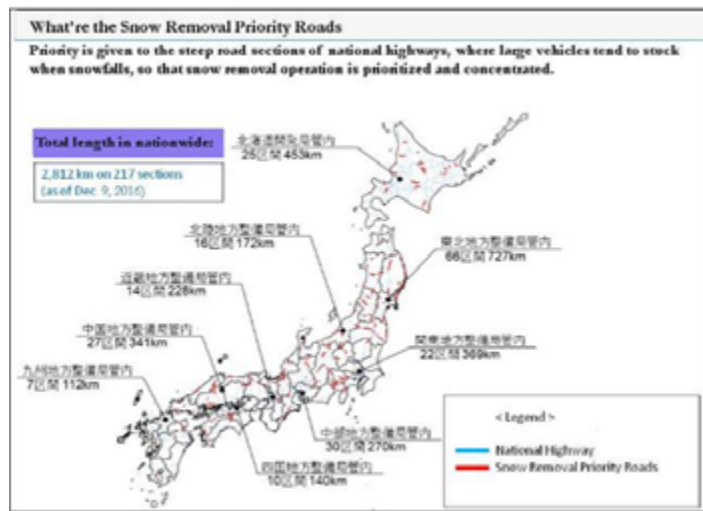


FIGURE 16 - WEBSITE SHOWING PRIORITY ROAD SECTIONS FOR SNOW REMOVAL

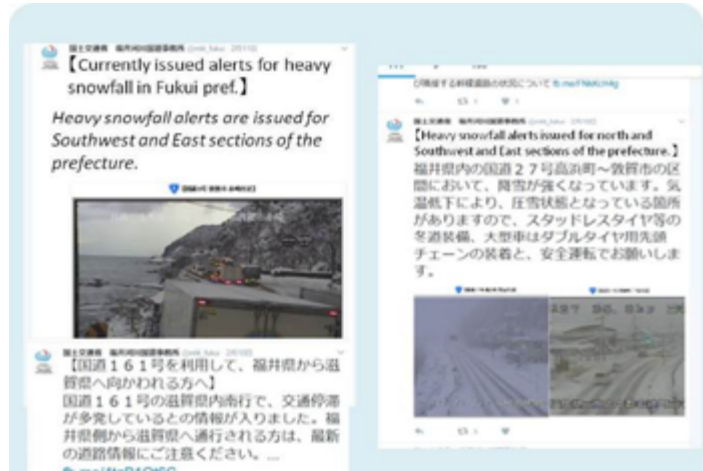


FIGURE 17 - INFORMATION PROVIDED ON A SOCIAL NETWORKING SITE AT THE TIME OF HEAVY SNOW

These websites provides information that is useful to drivers traveling on snow-covered roads, including webcam images, current temperatures and snowfall, and snowfall predictions. Regarding national highways and expressways, steep uphill road sections where large vehicles are likely to get stuck in the snow due to heavy snowfall are identified, and information about these road sections is posted on a relevant website. Road users are informed that snow is to be removed intensively and efficiently from these road sections (Figure 16).

At the time of heavy snow, Fukui Office of Rivers and National Highways provides information about congestion on roads and weather conditions on Twitter at fixed intervals (Figure 17).

The Civil Engineering Research Institute for Cold

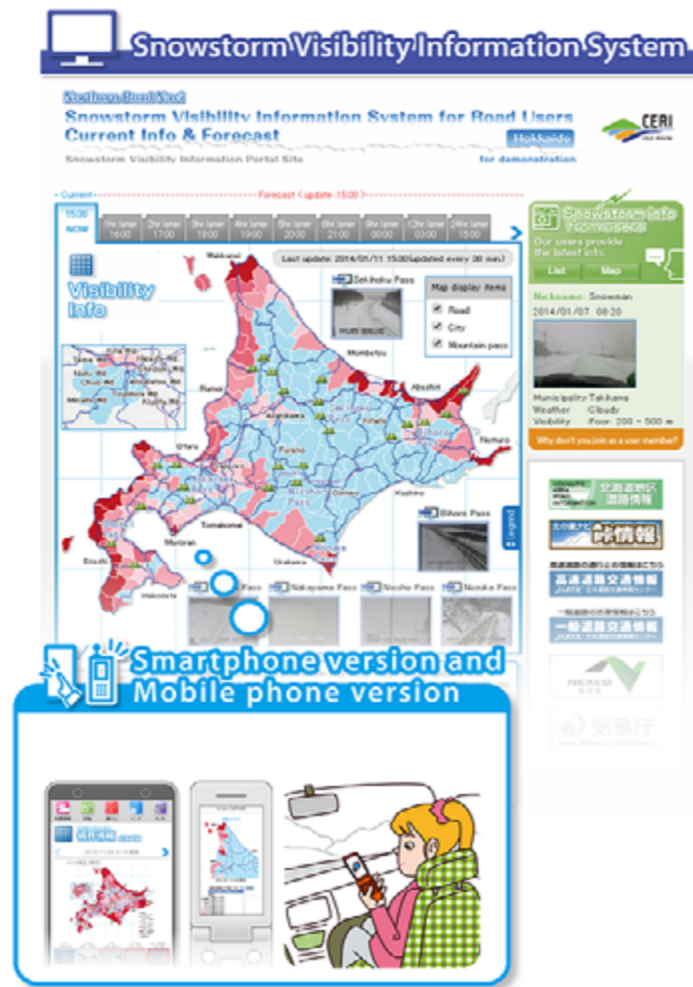
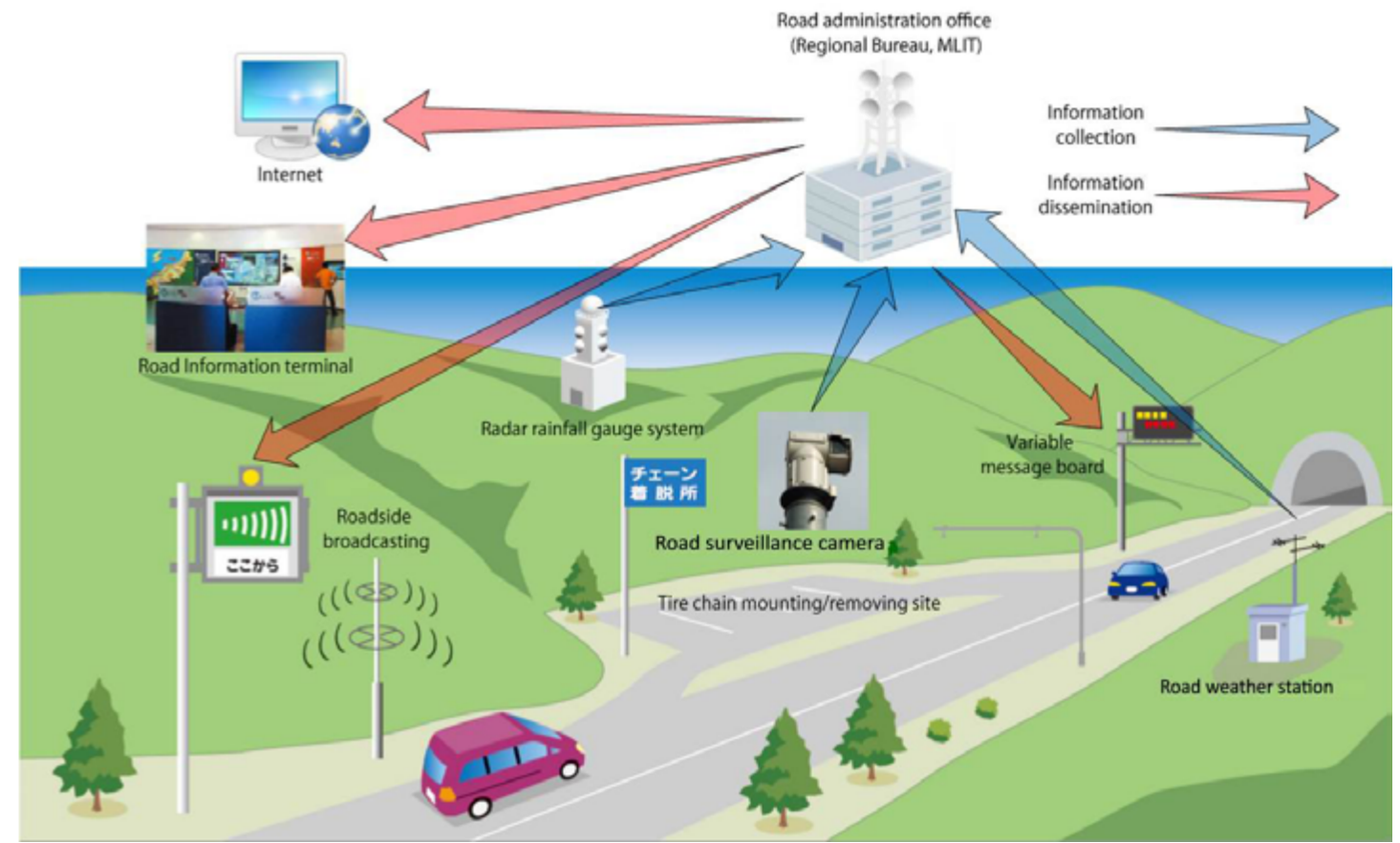


FIGURE 18 - PORTAL WEBSITE OF SNOWSTORM VISIBILITY INFORMATION

Region (CERl) has been conducting an experiment in which information about snowstorms is provided to drivers to help them to make decisions regarding traveling during a heavy snow storm. This experiment is part of CERl's research on the measures for preventing and mitigating disasters caused by snowstorms (Figure 18).

ROAD WEATHER INFORMATION SYSTEM

National Highway 17 is a major arterial highway connecting the Tokyo metropolitan area and Niigata, the largest city in the Hokuriku Region of northwestern Honshu. The highway passes through areas of severe meteorological and topographic conditions. The 25 km of this highway between the Mikuni and Kandatsu areas, on the border between Niigata Prefecture and Gunma Prefecture, run through one of the snowiest areas in Japan. The geography of part of the highway is complex: There are seven sharp curves, with radii of 50 m or less, and there are 14.4 km of steep sections, with gradients of 4% or more.



ROAD WEATHER STATION



SNOW GAUGE AND THERMOMETER



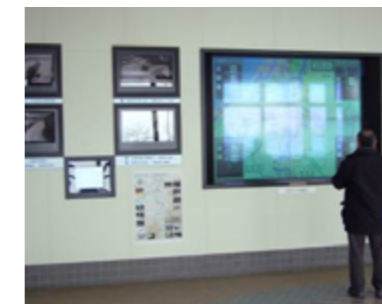
ROAD SURVEILLANCE CAMERA



ICE SENSOR



MANAGEMENT USING REAL-TIME IMAGES



ROAD INFORMATION DISPLAYS



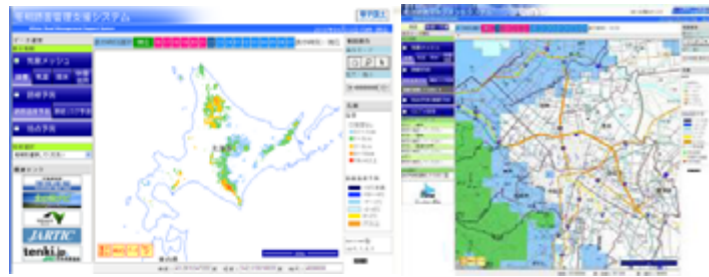
VARIABLE MESSAGE BOARD

FIGURE 19. ROAD WEATHER INFORMATION SYSTEM

Because the section is designated as a pilot area due to its harsh winter conditions, the Ministry has implemented advanced snow- and ice-control measures.

Winter Maintenance Support System

CERI has developed the Winter Maintenance Support System to support winter maintenance against slippery, icy winter roads, including de-icing prior to the emergence of such road conditions. The system provides



(LEFT: HOME; RIGHT: ENLARGED MAP). HOME DISPLAYS ALL OF HOKKAIDO REGION. WHEN AN AREA AND A FORECAST ITEM (WEATHER OR ROAD ICING) ARE SELECTED, THE SYSTEM DISPLAYS A MAP WITH THE SELECTED INFORMATION ON ANY SCALE.

FIGURE 20 - WINTER MAINTENANCE SUPPORT SYSTEM

des weather and road icing forecasts to road administrators and managers (Figure 20).

4 ON GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

Website of winter road friction monitoring data

The road surface condition in winter varies by time and location. To quantitatively evaluate the road surface condition, CERI has been developing a system that monitors the road surface friction continuously by a vehicle in motion and that distributes the monitored results

Intelligent Salting Control Optimization System (ISCOS)

East Nippon Expressway Company Limited (NEXCO East Japan) has been using sodium chloride (i.e., pre-wetted salt) as an anti-freezing agent that helps to prevent road icing and to ensure winter traffic safety. In order to minimize damage caused by sodium chloride to expressway structures and also to enhance efficiency of winter maintenance operation with reduced costs, NEXCO East Japan developed Intelligent Salting Control Optimization System (ISCOS). This is the world's first system that automatically spreads an optimum amount of salt. Salting control is optimized by utilizing road surfa-



TOP: WINTER ROAD FRICTION PROVISION SYSTEM DISPLAY LEFT BOTTOM: TEST VEHICLE WITH A CONTINUOUS SKID-RESISTANCE MEASUREMENT DEVICE. RIGHT BOTTOM: ENLARGED ROUTE MAP SHOWING MEASURED SKID RESISTANCE

FIGURE 21 - WEBSITE OF WINTER ROAD CONDITION MONITORING DATA

ce data from Contact Area Information Sensing (CAIS) developed by Bridgestone Corporation. ISCOS has been used on expressways in Hokkaido (Figure 22).

Alternatives to sodium chloride

With an aim to prolong service life of expressway structures for reducing their life-cycle costs, Central Nippon Expressway Company Limited (NEXCO Central Japan) has been collaborating with Toyama Prefectural University and CERI in analyzing the applicability of new anti-freezing agents that can be used instead of sodium chloride.

Promotion of measures for barrier-free winter mobility

Comprehensive snow-removal measures have been formulated and implemented to remove barriers to wintertime mobility, such as the increased danger of pedestrian slip and fall accidents on icy roads, reduction of walking space due to snowfall, and other inconveniences.

Toward barrier-free mobility, thorough snow removal on sidewalks around railway stations has been promoted and road heating has been installed.

5 REFERENCES

Website of the Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism at <http://www.mlit.go.jp/road/>

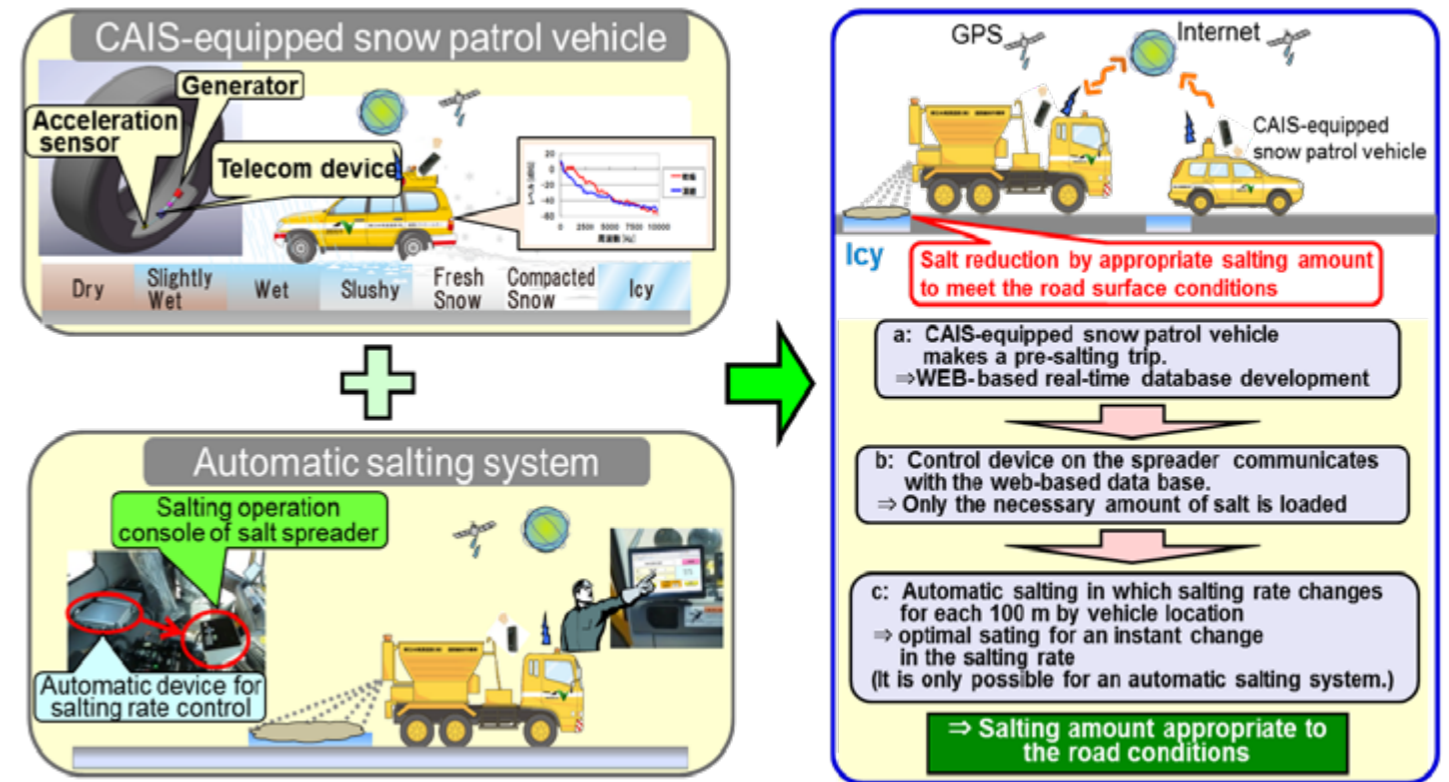


FIGURE 22 - INTELLIGENT SALTING CONTROL OPTIMIZATION SYSTEM (ISCOS)

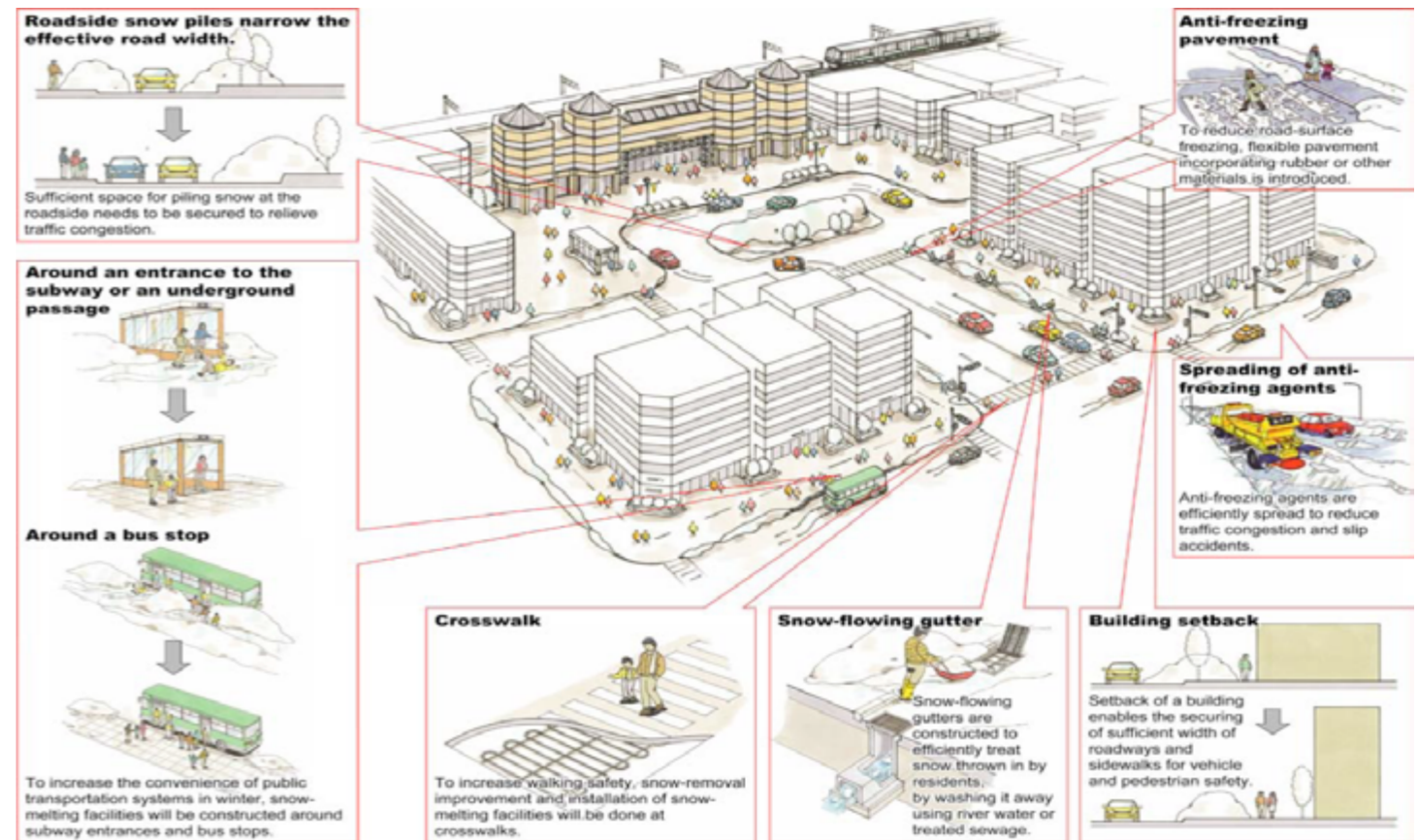
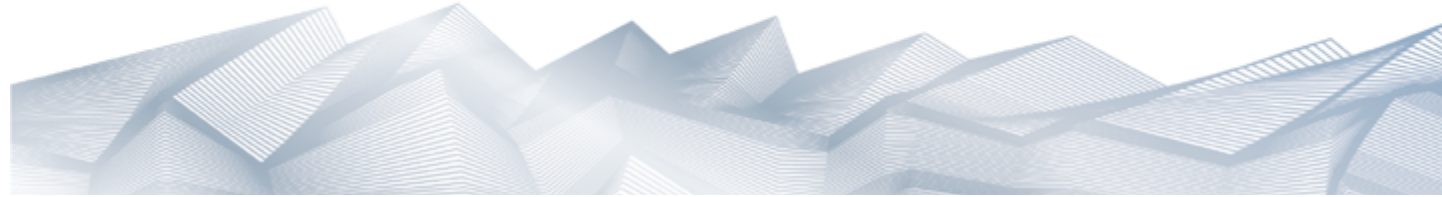


FIGURE 23 - MEASURES FOR BARRIER-FREE WINTER MOBILITY TAKEN IN CONJUNCTION WITH VARIOUS OTHER PROJECTS FOR SNOW- AND ICE-CONTROL



1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY



Latvia is in north-eastern Europe, on the east coast of the Baltic Sea. It borders with Estonia, Lithuania, Russia and Belarus. Most of the Latvia's territory is little higher than 100 metres above sea level and ground cover is formed by sedimentary soils. The highest point is Gaizinkalns, 312 metres. There are thousands of rivers and lakes in Latvia, and about 8 % of inland territory is covered by swamps. Approximately one third of

population of Latvia (697 thousand) lives in the capital Riga. In 2016 the unemployment rate was 9.6 %.

1.2. ROAD NETWORK AND TRAFFIC

Area	64,589 km ²	
Population	2.0 million	
Density of population	30.8 pers/km ²	
Total road and street length	State roads	20,081 km
	Municipal roads	38,149 km
	Forest roads	11,693 km
	Total	69,923 km
Latitude (Capital)	57° N Riga	

The total length of paved roads is 14,605 km. The average density of roads is 0.92 km per km².

In 2015 average daily motor vehicle intensity on state main roads was 5,405 vehicles, including 1,112 (20.5 %) trucks.

2. CLIMATE

2.1. OVERVIEW OF THE CLIMATIC ZONE

Latvia's climate is influenced by the Baltic Sea. It is a moderate oceanic climate with pronounced cyclone activity that influences changes in weather 190 - 200 days a year. The western part of Latvia is characterized by maritime climate with milder winters and considerable temperature variations; in the east the climate is more continental. Winter in Latvia usually lasts from the second part of November till the end of March. It starts gradually, usually moderate frost, clouded days, lots of snow and sometimes rain. In recent years, climate changes can be observed here as a higher probability of certain extreme meteorological events (precipitations, temperature peaks) from their long-term statistic level.

2.2. STATISTICS

The average temperature in January in coastal regions is -2.0 C, in eastern parts -7.0 C. Sometimes sharp short-term decrease of temperature down to -40.0 C is observed. This is explained by the inflow of high-pressure air masses from the North or East.

Consistent snow cover lasts from the middle of December until the middle of March. In western parts it lasts 80 - 90 days on average, in eastern parts – up to 100 - 120 days. Due to frequent thaws, snow cover is not thick. It may reach 30 – 50 cm, on the coast 15 – 20 cm. In years of heavy precipitation and during cold winters it may reach 1 m, while during warm winters snow cover is inconsistent. The average number of days with thawing is < 60 days per year.

2.3. WINTER INDEXES

Winter severity indexes for broad socioeconomic needs are not calculated in Latvia. However, there is a possibility to do it, since Latvian Hydrometeorological Centre handles all necessary data and provides information about actual deviations from the average values: decade or monthly temperature, precipitation, as well as, thickness of snow cover.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

Road routine maintenance standards, including requirements for winter works, are defined in the Road Traffic Law and State Regulation "Requirements for Routine Maintenance of State and Municipal Roads and Performance Supervision Procedure" (updated in 2010).

Roads are divided into 5 winter service classes according to road importance and traffic flow:

AADT (vehicle per day)	Main roads	Regional roads	Local roads
> 5,000	A	-	-
1,000 – 5,000	A1	A1	A1
500 – 1,000	A1	B	B
100 – 500	-	C	C
< 100	-	-	D

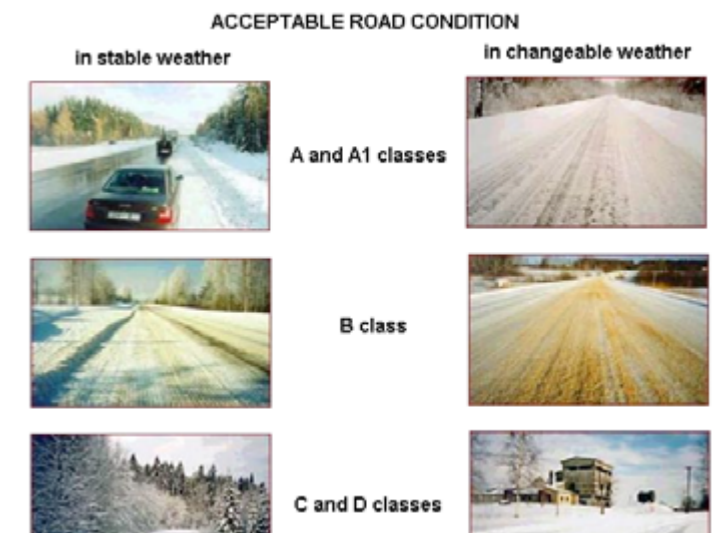
Each service class has definite requirements for the state of road during certain weather conditions:

Requirements	Maintenance class				
	A	A1	B	C	D
Acceptable conditions					
Average snow depth					
No precipitation slush	snow free	snow free	4cm	10 cm	no limits
during snowfall fresh	6 cm 3 cm	6 cm 3 cm	8cm 5cm	10 cm 6 cm	no limits
Ruts	up to 10 mm	up to 20 mm	up to 40 mm	up to 50 mm	No limits
Time for cleaning	3 h	4 h	6 h	18 h	No limits
Time for skid prevention	3 h	4 h	6 h	no	No limits

In practice it means, that for A and A1 classes "bare pavement policy" will be provided with intensive use of snow melting agents, while B class allows anti-skid treatment mainly with abrasives. C and D classes provide only passability, without predefined anti-skid measures:

In the winter of 2015/2016 service level for state main and regional roads can be seen in the following map:

Requirements for equipment, materials, work performance and expected results are defined in the-



se specifications. Snow ploughing on state roads is mostly performed by trucks equipped with front and side ploughs. Wet salt is used for skid prevention on A and A1 class roads. Maximum dimension of a salt particle may not exceed 6.3 mm; various dashes may not exceed 2 %. Wet salt, salt & sand mix or pure sand is used, as well as, grooves are worked in the road surface for skid prevention on B class roads. 1 m³ of salt and sand mix has to contain at least 10 % of salt. Maximum dimension of a mix particle may not exceed 6.3 mm. On C class roads skid prevention activities are performed only in separate sections – in intersections, on steep elevations and sharp turns, by spreading sand or working in grooves in the road surface. Wet salt is used to melt ice on streets in bigger cities. In the case of heavy snowfall, streets are cleared by making snow banks along the side of the streets. Snow removals are organized later. Rural municipalities mainly clear their own roads and streets.

3.2. ORGANISATION AND OPERATION OF WINTER MAINTENANCE

The state-owned maintenance company (the contractor) is responsible for maintenance of state roads in winter, while respective municipalities are responsible for maintenance of municipal roads and streets. State road maintenance in winter is financed from the state budget, and maintenance of municipal roads and streets is financed from municipal budgets that receive earmarked subsidies from the state budget.

SJSC “Latvian State Roads” (LSR) prepares a programme of winter road maintenance, classifies road network and calculates the necessary funding. In the winter of 2015/2016 state roads were classified as follows:

Class	Total km	Including		
		Main roads	Regional roads	Local roads
A	689	599	90	-
A1	2,396	1,156	1,171	69
B	2,899	-	2,423	475
C	12,449	-	1,789	10,660
D	1,814	-	10	1,804
Total	20,247	1,755	5,483	13,008

The programme is approved by the Ministry of Transport. Basic data for the programme is prepared by the

LSR local offices, while the central office summarizes and makes the necessary corrections to provide unified maintenance policy.

Contract for road routine maintenance (incl. winter works) was granted by law to a state owned contractor. The state road network is divided in 26 maintenance districts. Principle of “unit price” payment is used for performed works.

The contractor undertakes full responsibility for road conditions to comply with the defined maintenance class, performs regular supervision and decides on activities to be performed, based on visual inspections, weather forecast, RWIS data and experience. During winter, each district has a person on duty, who keeps in contact with the contractor and the road users, transport enterprises, emergency services, LSR TIC and local municipalities. There are 60 road weather stations (RWIS) along state main and regional roads. Future plans include the renewal of existing RWIS, as well as, installation of new, fully and partly equipped (IP camera and air temperature sensor) RWIS.

Information on temperature and moisture, precipitation and visibility, wind speed and direction, as well as, road temperature and condition is updated on a regular basis in a database. All RWIS are equipped with IP cameras. Some RWIS are equipped with soil temperature probes. All road maintenance units have access to data through the Internet. Persons on duty (contractor’s staff) provide regular (every 2 hours) announcements about current road conditions based on the data from RWIS, as well as, periodic field observations. This information is accessible to everybody on LSR web page and is used to inform drivers through other media channels,



including Waze and Twitter.

3.3. ASSESSMENT OF SNOW AND ICE CONTROL MEASURES

The aim of winter road maintenance is to ensure traffic flow for functioning economy. So far the losses and benefits to the economy influenced by the winter road maintenance have not been precisely measured.

LSR keeps the register of all complaints and applications of road users; they are processed and replied to. For anti-icing and de-icing, mostly wet salt technology, as well as, salt and sand mix is used. Sand spreading and forming of grooves in compacted snow are used for skid prevention on low intensity roads.

Used technologies	Percentage
Wet salt	88 %
Salt and sand mixture	9 %
Sand	1 %
Grooves	2 %

At present, mostly heavy-duty trucks equipped with several ploughs are clearing roads of snow. Their efficiency is many times higher than that of slow equipment used in the past.

About 80 % of spreaders are included in a fleet management system (including technological sensors). This system provides the contractor and LSR with real-time and recorded information on performed activities through web interface. Another tool is data input in an electronic work log. Records of performed road routine maintenance measures and corresponding procedures of work approval lead to more pro-

ductive communication between the contractor and the supervisor.

LSR local offices supervise the quality of performed works and approve the work. The final decision on payments is made by the Ministry of Transport. LSR personnel inspects the compliance of state roads to the maintenance classes and check the quality and quantity of performed works.

3.4. TRAFFIC SAFETY AND INFORMATION

LSR has founded a Traffic Information Centre. The person on duty at the Traffic Information Centre follows the situation on state roads, replies to road user inquiries and informs the contractor about road user claims. Road users can receive information about current driving conditions on state main roads and general information about driving conditions on roads in each district in the LSR webpage, mobile application Waze and social media.

LSR is working on schemes for effective and unified distribution of traffic information to the society with other authorities, which have or generate their own road data (emergency services, local and urban road departments, etc.). Data from LSR monitoring systems is also accessible to road users (RWS, traffic profiles, camera images) through convenient web interface (GIS). LSR webpage forms a national platform for all public traffic data. Another direction is providing traffic data for commercial services, which are dealing with on-route informative applications (interfaces: navigators, smartphones, etc.).

Before the start of winter season, LSR prepares information campaign on road maintenance policy in winter for drivers, as well as, distributes the information in the monthly newspaper “Road Newspaper”, available free of charge in petrol stations and other public places.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

LSR is working on different ITS implementation and pilot projects that are closely related to road winter maintenance. One of the benefits of the SMART E67 project will be VMS (variable message signs) along the Via Baltica route that will complement the existing and new RWS with visual warning information about road

conditions. There are also some commercial R&D projects in this field that aim to support the process of decision making for anti-icing (preventive treatment) strategy. Another direction is the constant work on the improvement of overall methodology for road winter maintenance (level of service, evaluation criteria, payment system, etc.).

5. REFERENCES

www.lvceli.lv
www.csb.gov.lv



1 DEMOGRAPHICS & ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The Netherlands is a country small in size (41,528 km²) with a population of 17.02 million inhabitants. That is an average of 409 inhabitants per 1 km².

The Netherlands is located in Northwestern Europe, and bordered by the North Sea to the north and west, Belgium to the south, and Germany to the east.

The capital is Amsterdam and the seat of government is The Hague. It also has one of the most free market capitalist economies in the world.

The Netherlands is a geographically low-lying country, with about 27% of its area and 60% of its population located below sea level. Significant areas



have been gained through land reclamation and preserved through an elaborate system of polders and dikes.

The estuary of three important European rivers, which together with their tributaries form the Rhine-Meuse-Scheldt delta, forms a great part of the Netherlands. Most of the country is very flat, with the exception of foothills of the Ardennes in the far southeast and several low-hill ranges in the central parts created by ice-age glaciers.

1.2 ROAD NETWORK AND TRAFFIC

Area	41,528 km ²	
Population	17.2 million	
Length of road	Motorway	5,357 km ¹
	Regional main roads	7,757 km ¹
	Local Roads	126,180 km ¹
Latitude	51°53'N	

The road network comprises 5,357 km of motorways, 7,757 km of regional roads and 126,180 km of local roads, amounting to a total of 139,294 km of paved roads. The national fleet of 11,2 million vehicles includes 9,03 million passenger vehicles. Transport of freight is of great importance to the Dutch economy. A great deal of this transport takes place at night and in the early morning, particularly commercial traffic.

The economic importance of roads cannot 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 extends from October to May. The most severe winter conditions take place from the end of December until the beginning of March.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Netherlands has a temperate maritime climate influenced by the North Sea and Atlantic Ocean, with cool summers and moderate winters. Daytime temperatures vary from 5 °C – 7 °C in winter and 19 °C – 22 °C in summer. Because the country is small there is little variation in climate from region to region, although the marine influences are less inland. Rainfall is distributed throughout the year with a dryer period from April to September. Especially in fall and winter strong Atlantic low-pressure systems can bring gales and uncomfortable weather. Sometimes easterly winds can cause a more continental type of weather, warm and dry in the summer, but cold and clear in the winter with temperatures sometimes far below zero. The Netherlands is a flat country and has often-breezy conditions, although more in the winter than in the summer, and more among the coastal areas than inland.

2.2 STATISTICS ON TEMPERATURE

Amount of precipitation (rain)	App. 805 mm/year
Number of days below 0 °C	App. 55-60 days/year
Number of days with snowfall ¹	App. 26 days/year
Number of days with freezing rain (black ice)	App. 1 day/year

¹most of these days the amount of snow is not enough to cause serious traffic problems.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

The Dutch authorities are legally obliged to maintain their roads (care obligation as written in the road and civil code). Winter maintenance is part of this obligation. **RWS/Province-level (motorways, primary and regional roads)**

RWS/Provinces use the uniform treatment times put up nationwide by CROW.

For national and regional highways and other roads up to a maximum speed of 80 km/h the following treatment times are used:

Pre salting:	2 or 3 hours;
Post salting:	2 hours;
Plowing/post salting:	1.5 hour

Municipality-level (urban roads)

Municipalities often work by priority of roads. This is put down in a yearly-renewed plan, which is published to inform their inhabitants. First main-/bus routes are spread. Then roads, which enclose quarters and next roads within quarters are treated. Also important social locations like hospitals, schools, shopping centers, and the like, get priority.

There are no standards on manpower.

Equipment

RWS has a national contract for the delivery, installation, maintenance, etc. for demountable spreaders and snowplows. It's of great importance that all equipment works in wintertime. It should be available for 100%. So fixed times are used for repairs and if a machine cannot be fixed the supplier has to supply the authority with one of their own machines.

This national contract describes:

- Requirements concerning construction and design standard's (EEG, NEN) of spreaders and plows;
- Requirements concerning placing the demountable spreaders on trucks;
- Requirements concerning spread rate, width, distribution, etc.;
- Requirements concerning drive;
- Requirements concerning liquid (brine) tank;
- Requirements concerning operation;
- Requirements concerning mounting the plow on a truck.

Material

RWS also has a national contract for the delivery of road salt (evaporated, rock salt, solar salt etc.) all according to NEN-EN16811-1. In this contract minimum requirements are placed, like:

- Composition of the product;
- Grain distribution;
- Presence of moisture;
- Presence of heavy metals;
- Delivery times.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization of the Dutch Ministry of Infrastructure and Waterworks, Rijkswaterstaat concerning winter maintenance:

- level 1: Ministry of Infrastructure and Waterworks
- level 2: Rijkswaterstaat (RWS);
- level 3: dep. Traffic and Water management
- level 4: Highway Management Center;
- level 5: Operation Center.

RWS VWM is the dep. of Traffic and Water management of RWS. Concerning winter maintenance, RWS VWM is responsible for:

- The national and regional organization winter maintenance
 - The development of RWIS's, consultancy and research concerning winter maintenance (de-icing materials, equipment and methods);
 - National tendering for equipment, road salt and brine;
 - Coordinating Winter maintenance on a national and regional level
 - Communication about winter maintenance together with traffic information center;
 - Coordination in case of calamities (lack of salt; employing of 1 snow blower/cutter and special ice fighting machines as Firestorm and lavastorm);
- The VWM also facilitates the purchase of winter maintenance equipment on a technical level and makes the „Guideline Winter Maintenance RWS“ and consults the Ministry and the Rijkswaterstaat and is in charge of the regional winter coordinators.

The regional coordinators are responsible for operational (winter) maintenance. They consult the RWIS and other weather information sources and decide when to start a run (winter maintenance/spreading/plowing action).

Road Weather Information System

Since the 70's RWS has been experimenting with the RWIS. Traffic safety, cost reductions and a more limited use of salt have been the main starting-points of these experiments. Starting in the end of the 80's, The Netherlands (RWS and Provinces) has placed the RWIS on their roads and bridges (330 measuring stations in the year 2018).

Within winter maintenance the role of the weather bureaus or in case of RWS the KNMI (Royal Dutch Meteorological Institute) is important, because in the RWIS only a few persons (winter maintenance coordinators) are detached to the winter maintenance night watch. In the case of RWS 12 winter coordinators monitor the

whole country. The winter coordinator has access to a road surface model, weather precipitation radar-image, which is very useful in case of precipitation conditions. Actual local weather-reports for the coordinator specially focused on winter maintenance are accessible. A meteorologist of the KNMI or a weather bureau can be consulted by phone 24 hours and 7 days a week (only if contracted). The KNMI or a weather bureau makes an actual local prediction, which is presented by a user interface or sent to the coordinator by mail. The final decision is always made by the coordinator (always an employee of the road authority), based the RWIS, meteorological predictions, precipitation radar, own experiences, contacts with coordinators from other regions or road authorities.

The coordinator is at home (at night) and will be warned by the RWIS when slipperiness might be expected. Per region/area (12 in the case of RWS) a winter maintenance coordinator is stand by during one week (varies per road authority).

The RWIS station measures:

1. Air temperature and relative air humidity (1.5 meter above the earth surface);
2. Presence of precipitation;
3. Road surface temperature measured on the left (fast traffic and coldest) lane;
4. Sub-soil temperature measured under the asphalt layers of the left (fast traffic) lane;
5. Surface condition: dry, presence of moist and/or salty (passive sensors) measured on all lanes.



PART OF RWIS STATION AT THE ROADSIDE

The dew point is calculated from the measured values. Some measuring stations also measure wind speed and wind direction. On critical locations a camera is available for visual inspection of the road surface. The measuring stations are situated on locations which are critical under winter conditions.

These locations are not necessarily the coldest, but the combination of moist and low temperature makes the location critical for example roads through woods and near water. Also steel bridges can be critical especially at the start and in the end of the winter season. On most steel bridges a RWIS station is available. Distance between the stations is about 15 km (varies between 5 and 40 km).

In some situations measuring stations are used to start an automatically spraying action on bridges (using brine (NaCl) with a higher purity than the normal used brine).

For finding the most suitable location for a new measuring station, experience of road inspectors and thermal mapping are used.

The user interface is cloud based and an access to the system is possible from anywhere with a personal computer, laptop, tablet or smartphone with Internet connection and Internet browser. Measuring stations are wireless (3G/4G) linked to the system. The user interface takes care of a large number of functions. It manages the data communication with the measuring stations, and communicates real time with the winter maintenance coordinator. The RWIS send out alarms to the winter maintenance coordinators and can be seen in the user interface as well. Alarms can also be received by voice message or a mobile phone by SMS.

The information of the measuring stations is stored on the local measuring station for seven weeks. After seven weeks the data is stored for unlimited time in the cloud.

When the coordinator is connected to the system, the computer presents predictions of the KNMI or a weather bureau automatically in the user interface (only if contracted). The KNMI and weather bureaus have access to the central server and use the actual and historical information of the measuring stations and actual weather information to have input for the predictions and road surface models. The coordinator can use the output to make a decision. The KNMI and most weather bureaus also have their own winter weather forecast

web interfaces. These provide the winter coordinators with additional meteorological information.

The coordinator can also use the images of the user interface integrated weather radar (precipitation). It is also possible to consult a meteorologist of the KNMI or a weather bureau. Some weather bureaus offer a „total surveillance“. Specialized meteorologists then guards an RWIS (receives alarms) and use the other actual weather information (models, precipitation radar, satellite pictures). When the situation exist that slipperiness is predicted or occurs, he or she will immediately warn the coordinator. (In the case of RWS this task remains with its own personal. RWS is convinced this makes for a better understanding of the situation and thus a better winter coordinator. A quick survey suggests that RWS spreads less often and more accurate due to this better understanding of the situation. All winter coordinators of RWS are licensed coordinators).

The collected data from the measuring stations are wireless (3G/4G). When the winter maintenance coordinator decides to start a run (spreading- and/or plowing action), a process will start which will take several hours. The process contains:

- Warning involved personal;
- Calling in equipment (commercial trucks from e.g., contractors). Demountable spreaders and salt (in barns) are stored on the property of the local surveillance centers;
- Inform neighboring winter coordinators/road authorities;
- Inform police, VCNL (National Traffic Management Center, whether this is done depends on the agreements).

RWS-level (motorways and primary roads)

Communication between the different levels takes place by phone, whatsapp group or a message board, which is available in the user interface and accessible for participants in the RWIS.

The alarm coming from the RWIS is connected to a mobile phone used by the winter maintenance coordinator. The time between the calling of the contractor and spreading the last square meter is 2 hours. This concerns a preventive spreading action.

Province-level (regional roads)

Also at Province-level winter maintenance is arranged per region by a winter maintenance coordinator.

Most of them use RWIS in combination with meteorological reports and local knowledge of the area. When there is doubt, patrols are carried out.

Municipality-level (urban roads)

Municipalities do sometimes use information from regional weather bureaus like airports and consult meteorological services. Also inspections from local police are important. Sometimes the decisions are made together with the coordinator of the Province or RWS. Some of them use RWIS-data.

EQUIPMENT

The preparative program before winter activity consists of:

- Equipment checks (checklists and test protocols exist);
- Driver instructions, including test drives on the salt routes;
- Courses for winter maintenance personnel.

Prevention, for example, snow fences are not used in The Netherlands. The only used prevention is precautionary treatment (preventive salting). The spreaders drive fixed routes (on the basis of: economics, safety, spreader ratio, etc.). Optimizing the salting routes is very complicated and is contracted to a specialized bureau. RWS has developed an application, called SOS (Salting Route Optimizing System), which is used.

A spreading management program is in use to have an optimized administration and to check if the contractor is doing his job well.

Municipalities in The Netherlands own approximately 2,000 spreaders and snowplows. About 30% of the spreaders are used for bicycle roads. The machines for bicycle roads have a capacity up to 1.5 cubic meters



SPREADING-WIDTH IS 4-14 METERS.

and are very often mounted on trailers. Municipalities mostly use their own traction and personal.

The provinces have for about 450 spreaders also in a wide range from 1 cubic meter for bicycle roads up to 9 cubic meters for regional roads. RWS own about 550 demountable spreaders (5, 7 or 9 cubic meters), about 1200 snowplows and 1 snow blowers/cutters, 2 Firestorms and 1 Lavastorm.

In the Netherlands very often trucks of contractors are used to put on the spreaders and to build on the snowplows. Also the drivers on the trucks come from these contractors. RWS has agreements with contractors. These agreements lay down in a contract for several years (fixed for 3 years and possible to extend for 1 or 2 years). Most regional contracts have one contractor. This contractor usually has subcontractors. Per region there are several depots. Per depot several spreaders (6-12) and snowplows (12-20) are present. But there are also big ones and joint ones with for instance a province and a big city there the number of spreaders and plows may amount to 80 or more.

The contractor gets a fixed price per season for all preventive spreading actions including a big check of all equipment before the start of the winter. Post/curative salting is done per hour. When the contractor does not react on a call-out, does not salt the route within a certain time period, if slipperiness occurs during the



time the contractor actually had to spread salt and when the contractor cannot be reached at all, high fines have to be paid.

Materials

Since the early 80s the Netherlands uses mostly pre-wetted salt (the wet component is sodium- or calcium chloride solution; as dry salt (NaCl) evaporated or rock salt is used). The wet component and dry salt are mixed just before spreading on the spreading disk and spread on the road. The ratio between dry salt/fluid is 2.5:1. Fluid means a 20%-NaCl-solution or a 16%-CaCl₂-solution.

Properties NaCl

	rock salt	evaporated salt
NaCl amount	98.5%	99.9%
Grain size (80%) [mm]	0.8 – 3.15	0.20 - 0.45
Grain size (X50) [mm]		0.38
Grain size (max. <)	< 0.125mm : 5 ± 1%	< 0.125 mm : 5%
Grain size (max. >)	> 3.15 mm : 5 ± 2%	> 1 mm : 1%
Anti-caking	75 ppm	75 ppm
Heavy metals	< 4 ppm	< 1 ppm
Unsolvable parts	< 1.5%	< 0.01%
Moisture	0.3%	< 2.5%

These salts are according the specifications.

Effectiveness: 12 kg ice per kg 100% pure sodium chloride (NaCl) at -5 °C;

Depression of freezing point temperature is - 7 °C;

NaCl (dry): summer price about 40 Euro/ton

Wet-component (16% CaCl₂): Approximately 35 Euro/ton.

There is a about a 70/30 mix of depots that use CaCl diluters and depots that produce the wet-component out of dry salt (NaCl) already present in high volumes in the salt barns.

Salt is stored in barns. These barns are situated on the depots or in the strategic salt barns of RWS (opening of the barn is situated in the southeast direction). RWS has 56 depots with salt barns with a total capacity of 70.000 tons. In last 10 winters an average amount of 90,000 tons per winter is used. It varied in between 15,000 and 160,000 tons.

In The Netherlands annually circa 36-38 runs are necessary. 60% of the actions are pre-salting (anti-icing) and 40% considers post-salting actions (de-icing)).



Using these figures in combination with the road area to be spread the necessary storage facilities of salt can be calculated. For example, when the local highway agency maintain 260 km road lane (medium width of the road lane is 15 meters), 1,440 ton salt is necessary for one winter.

There is a national guideline for the amount of stored salt in the local depots and the total amount incl. the strategic salt barns. RWS stores about 200.000 tons in total.

RWS VWM is responsible for the national contract for salt. The storage capacity of the local depots is included in this contract as well as salt for third parties such as participating provinces and municipalities. RWS use the salt from the depots and during winter delivers salt from their strategic barns/warehouses to the depots. At the end of the winter RWS fills the depots and then contracts one or more suppliers to fill the strategic barns/warehouse during the summer. The warehouses (4 in total) are situated at the waterfront and are supplied by ships. This relates into a big bulk contract for salt that creates a low bulk price and no risks for eighter contractor nor RWS. As there is enough time to supply the warehouses (from 1 of May to 1 October) and they know exactly how much to bring. RWS has no risk because the warehouses and depots are full at the start of winter.

Provincial-level

The provinces are dealing with winter maintenance; the use of salt; the spreading actions and times within their road network should be treated in general in the same way as Rijkswaterstaat does.

Municipality-level (urban roads)

The use of pre-wetted salt is mostly used but there

are still a few that use dry salt. There is also one or two that use brine spraying.

The RWS and Provincial personnel working with the RWIS, are educated by following an RWIS-course provide by CROW. There is also a course for the truck drivers that is mandatory. And a course for the winter coordinators that is also mandatory and one receives a diploma when they pas the test. Without this diploma you cannot be a winter coordinator.

Privatization

In The Netherlands operational winter maintenance on RWS-level is organized by the national winter coordinator from VWM. Per region one winter maintenance coordinator is in service during one week(s). The same week there is also a back up winter coordinator. They work in a 50% roster with 4 people. The coordinator uses the winter maintenance facilities and initiates the winter maintenance action when necessary. The decision for a spreading action stays at RWS. In case of preventive spreading no RWS personnel is involved anymore. In case of post/curative salting personnel is available on the highways (road inspectors) for visual road inspections. They act as the eyes and ears of the winter coordinators who direct the contractors.

RWS supplies, the depot, demountable spreaders, snowplows and the salt. The trucks and drivers are contracted (see paragraph 2.4).

Getting information

RWIS

The RWIS contains actual and historical local information. The winter coordinator will be warned by the RWIS (mobile phone, SMS) if slipperiness is expected in a couple of hours.

Meteorological

A prediction is presented in the user-interface of the RWIS and the web interface from KNMI or weather bureau. This information supports the coordinator when making a decision.

Precipitation Radar

The coordinator has access to images from the precipitation radar, which is integrated in the RWIS user interface or available on the web interface of the KNMI or weather bureau. This is especially useful to start precautionary salting because of, for example, coming snow.

Meteorological information

Several times a day, meteorologists, working for the KNMI or weather bureaus, make an actual local weather-report for the coordinator. This information is specially focused on winter maintenance in the region of the highway surveillance center.

Consults

It is possible to consult a meteorologist at a weather bureau by phone for 24 hours a day, 7 days a week. (only if contracted)

Patrols

Sometimes, if the winter coordinator thinks it is necessary visual inspections of road conditions are done.

Methods, equipment and materials for snow control

In The Netherlands heavy snowfall is rare. Nevertheless, RWS can on demand use 1 snow blowers/cutters (Unimog U1750 or U2150 with Schmidt FS 5-Z snow blower/cutter). The snow blowers can also be used to remove large amounts of snow from the hard shoulder.

The concept of white roads does not exist, as prolonged snow on roads is unusual. In fact the policy of RWS is to keep the roads black at all times even under snowy conditions. In case of extreme slipperiness (icy conditions; black ice or snow) the policy can order to reduce the maximum driving speed to 50 km/h. Dynamic road signs show this information. When slippery occurs on porous asphalt roads, traffic can be concentrated on a single lane to have enough wheel passages, which keeps the salt on the surface. But this is something we try to avoid as the demand for all lanes is evident. For the extreme conditions such as black ice and or ice plates that occur with compressed polished snow. We have three special machines that can take care of these extreme situations where spreaders and plows have no effect. These machines are the Firestorms and Lavastorm. They work on the principal of hot brine spraying at high pressures to cut thru the ice. The way we use the machines and how we deal with extreme and normal winter conditions is written in the RWS regulations/guidelines on winter maintenance and the CROW guidelines on winter maintenance.

Methods, equipment and materials for ice control

Demountable spreaders are used. The driving speed on motorways is circa 70 km/h using pre-wetted salt and ploughing is done at a speed of 40 km/h.

Table 3.1 recommended average rate of spread

TYPE of SLIPPERINESS	PREVENTIVE	
	NON POROUS	POROUS*
Freezing of wet roads (parts)	7 g/m ² -,pre-wetted'	14 g/m ² -,pre-wetted'
Condensation and/or freezing fog	7 - 14 g/m ² -,pre-wetted'	7 - 14 g/m ² -,pre-wetted'
Precipitation - snow	14 - 20 g/m ² -,pre-wetted'	14 - 20 g/m ² -,pre-wetted'
Precipitation - black ice and enough traffic	14 - 20 g/m ² -,pre-wetted'	14 - 20 g/m ² -,pre-wetted'
Precipitation - black ice and low traffic volume	14 - 20 g/m ² -,pre-wetted'	14 - 20 g/m ² -,pre-wetted'

CURATIVE / REPEATED ACTIONS	
NON POROUS	POROUS*
7 g/m ² -,pre-wetted'	7 g/m ² -,pre-wetted'
7 g/m ² -,pre-wetted'	7 g/m ² -,pre-wetted'
14 g/m ² -,pre-wetted'	14 g/m ² -,pre-wetted'
20 g/m ² -,pre-wetted' if precipitation stays on	20 g/m ² -,pre-wetted' if precipitation stays on
20 g/m ² -,pre-wetted' if precipitation stays on	20 g/m ² -,pre-wetted' if precipitation stays on, additional traffic measures necessary

Under specific weather conditions with a lot of salt on the road slipperiness can occur due to salt. It does happen although very rare. Three different kinds of appearances are known. If the problem occurs it can be solved by spraying brine (NaCl or CaCl₂).

The equipment (dismountable spreaders and plows) is stored at the local depots. Also the salt barns are situated there. The extreme ice fighting machines (the Firestorms and Lavastorm) are situated strategically in the country ready to move out on a moments notice. RWS aims to enlarge the fleet of these machines as more extreme situations seem to occur more and more and RWS wants to reduce the travel time. We aim to grow to about 12 machines in the next 5 years.



LAVASTORM

Methods, equipment and materials for special problems

Porous asphalt will be, under some conditions, treated differently (see table 3.1). The road user will usually not feel or see any difference. Only, when the combination glazed frost & porous asphalt & minimal traffic occurs, it is possible that on the spots where there is a changeover from non-porous asphalt to porous asphalt, there is a difference in slipperiness. This can lead to dangerous situations.

Several bridges in The Netherlands are supplied with a fixed anti icing spray (brine) system connected to a RWIS. The highway management center (road manager) did choose this solution because of economic and safety reasons.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

All spreaders are equipped with a GPS system. When the trucks return to the RWS depot the winter coordinator can look in the system to check if everything went correctly or even follow the spreaders live. The system shows the route, the spread-width and the used amount of salt. The system is used to evaluate the run. The contractor can also use the system to check his progress and to adjust the operation where/when necessary. At the end of every winter season, a survey is done about salt-use, personnel, equipment etc. The general public can also follow the progress of the spreaders of RWS and follow them live or see where the roads have been salted in the last 6 hours. This information is accessible via the Rijkswaterstaat national website. <https://www.rijkswaterstaatstroot.nl>

3.4 TRAFFIC SAFETY AND INFORMATION

The information of drivers is given by the national traffic center and the ANWB. The ANWB gets this information from the national traffic center (VCNL).

Ways of possible dissemination:

- 1) radio;
- 2) journals (radio and TV);
- 3) teletext;
- 4) telephone;
- 5) Internet/twitter/facebook etc.

Information on the roads (signs) is possible; if necessary a speed reduction is put on the signs. In worst cases lanes can be closed by putting a red cross on the road signs above the road lane.

Education/information to drivers about driving in winter conditions etc. is a task of the headquarters of RWS. Technical questions can be asked to RWS VWM national winter team.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

Co-operations between road operators and administrationCo-operations between road authorities /operators and administrators

It's growing concern to uniform winter maintenance on different roads of different operators/administrators. On national level guidelines are made to categorize roads in means to treat them uniform.

There is also co-operation in the field of tendering. For instance RWS buys the salt for 4 provinces and about 12 municipalities. In several regions RWS and provinces together use a contract for the actual winter maintenance.

Training course personnel

In most contracts there are demands for capable personnel working in winter maintenance. Two courses are set up. One course especially for winter coordinators and another course for truck drivers of contractors or own organization. Content of last course consider aspects as: forms of slipperiness, using equipment (spreader and snowplow) and spreading management system, weather conditions, dosage of salt, driving aspects under winter conditions (slippery course), etc. In the end an exam is giving. In case of sufficient result, a driver is given a certificate, which allows him to do his job in winter maintenance.

Research on right decision spreading action

Matching information out of the RWIS and the spreading management system makes it possible to check if a decision for a spreading action was made in the right way. Background of this study is to support the coordinator in a better way, to uniform the process to make a decision, save costs and the environment.

RWIS

Research on several sensors of a road weather information system with the idea to diminish sensors in the road surface. Road sensors and the road itself need to be maintained. Under the severe Dutch traffic conditions a reduction of road works/closures is of great significance.

Also information out of the RWIS in combination with weather information is used to predict if every part of the spreading route has to be treated with the same amount of salt. It's research done under the name of "dynamic spreading".

Salt

Research is set up to measure the effectiveness of spreading different kind of salts on different kind of road surfaces for instance bicycle roads. There is research planned on the subject of residual salt.

5 REFERENCES

- Literature list
- [1] : Standardization of Salt Spreaders
 - [2] : Organization and execution of Winter Maintenance
 - [3] : Winter, Weather and Roads
 - [4] : Guideline Winter Maintenance Code RWS
 - [5] : Winter maintenance below sea level
 - [6] : Extreme ice fighting machines

Terminology

RWS: Ministry of Transport, Public Works and Water Management; Directorate-General of Public Works and Water Management. RWS is responsible for (winter) maintenance on all motorways and primary roads.

VWM: Center for Transport and Navigation.

Province: The Netherlands are divided in 12 provinces. A Province is responsible for (winter) maintenance on regional and local roads.

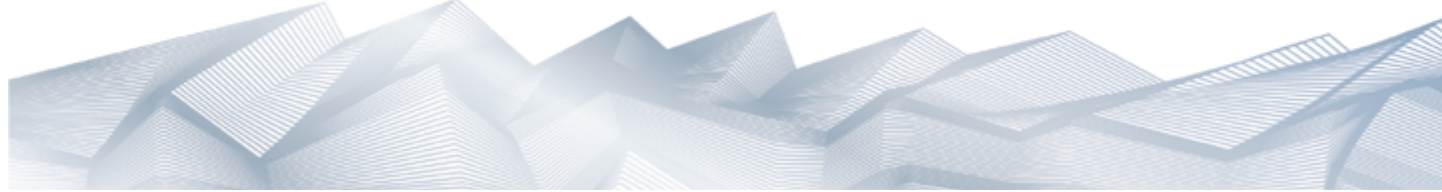
Municipality: Is responsible for urban roads (town).

ANWB: Dutch Automobile Administration.

VCNL: Traffic Information Center.

RWIS: Road Weather Information System.

CROW: Information and Technology Platform for Infrastructure, Traffic, Transport and Public Space.



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT COUNTRY

New Zealand (NZ) is an island country in the south western Pacific Ocean comprising two main land masses, the North Island and South Island, and numerous smaller islands more notable being Stewart island and the Chatham Islands. The total land area of the North and South Islands is 268,021 square kilometres.

The South Island is the largest land mass and is divided along its length by the Southern Alps with 18 peaks over 3000 metres the highest being 3,754 metres. The North Island is less mountainous but is marked by volcanism with the central North Island a highly active volcanic zone containing the highest mountain at 2797 metres.

The population is about 4.7 million of which 77% live in the North island. Auckland is the most populous area with 1.5 million.

1.2 ROAD NETWORK & TRAFFIC

The NZ Transport Agency (NZTA) is a Government entity and has responsibility for a wide range of land transport issues including the management of the 10,906kms of State highway network. There are 13 City and 53 District Councils responsible for 83,000kms of local roads the maintenance and construction of which are subsidised by the Government through NZTA. The State highway network carries 50% of all NZ traffic.

There are 22.6 billion vehicle kilometres travelled (VKT) on New Zealand state highways each year and 22.7 billion on local roads. State highways in the Auckland area carry 22% of the VKT.



NORTH ISLAND STATE HIGHWAYS
(SOURCE NZTA)

Maintenance of State highways are procured through competitive tenders based on a consistent contract model known as Network Outcomes Contract which is a performance based model. Currently, these performance based contracts are for 7 and 9 year terms. City and District Councils follow similar competitive procurement processes.



SOUTH ISLAND STATE HIGHWAYS
(SOURCE NZTA)

2 CLIMATE

2.1 OVERVIEW OF CLIMATE AREAS

NZ's climate varies from subtropical in the far north to cool temperate in the far south. The Southern Alps provide a barrier for prevailing westerly winds dividing the South Island into different climate regions with the west coast the wettest area and the east coast just over 100kms away is the driest.

The central North Island's volcanic plateau and the mountainous area of the South Island receive most of the snow fall in NZ. Snow rarely falls in the coastal areas although the east and south of the South Island may experience snow from time to time in winter. Frosts can occur anywhere in NZ with cold nights, clear skies and little wind.

New Zealand's temperate climate provides winter temperatures that do not generally remain below freezing during the day. This climate provides sometimes daily freeze/thaw cycles during the winter season with temperatures hovering around 0°C.

2.2 STATISTICS

The average winter temperature ranges from 10 to 15C (50 to 60F) and from 20 to 25C (68 to 77F) in summer. Temperatures rarely get above 35C or below -10C. The highest recorded temperature was 42C and the lowest -26C. Ground frosts mainly occur in the central North Island (about 70 days per year on average) and across the South Island ranging from 70 days per year on average in the coastal areas up to 150 days on average inland.

The weather is extremely variable and can provide 4 seasons in one day. The warmest months are December through to February and the coldest June to August.

2.3 WINTER INDEXES

A winter comparison through an indexing system is not undertaken in NZ. The NZTA defines three winter maintenance periods as:

1. high. (June, July, August and September where likely conditions are moderate to very severe),
2. marginal (May and October for light to severe conditions) and
3. low. (fine to light conditions) with conditions categorised into the following:
 - Fine: no frost or ice
 - Light: frost and/or light snow
 - Moderate: freezing conditions after rain or snow
 - Severe: continuous snow, packed ice
 - Very severe: hard packed snow/ice with further snow falls

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

The NZTA and Local Councils have a statutory obligation to take all sufficient precautions for the general safety of the public which extends to the requirement to identify potential hazards and remove them. Without having any specific references to winter services it is clear that removal of snow and ice hazards falls within these obligations. There are also specific powers given to close roads to execute repairs, remove obstructions or for the safety of road users.

The NZTA has developed levels of service for State highways

1A	Open to all vehicles	24 hour treatment
1B	Open with some restrictions e.g. chains	
2A	Open to all vehicles	Treatment 7am to 7pm. Pro-active treatment before 7 am if required
2B	Open with some restrictions e.g. chains	
3	Close road until able to make safe	

Where there is extreme snow or ice which closes highways a priority system based on the importance of the highway is used to manage treatment and apply resources.

Local roading authorities each have their own levels of service and maintenance strategies.

3.2 ORGANISATION AND OPERATION OF WINTER MAINTENANCE

Winter services for State highways are managed by the NZTA. City or District Councils are responsible for local roads within their territory. The NZTA is fully funded by Government for all roading matters and the Government provides financial assistance through the NZTA to all local roading authorities with the balance being met by the local population through property rates.

The NZ roading expenditure for maintenance and operations is \$560 million for State highways and about \$990 million for local roads.

The State highway network is managed on a Regional basis centered on Auckland, Hamilton, Wellington and Christchurch. These Regions are further subdivided into network areas for contract purposes.

Outsource Contracts

With the tendering of contracts for all types of maintenance work the NZTA sets the specified services, delivery and outcomes required including the levels of service. Winter services are included within the maintenance contracts.

For the central North island and all of South island where winter services are required the contract model currently uses a single supplier made up typically of consultants and contractors to monitor and manage the operation of the networks with contractors carrying

out the day to day physical works.

These contracts are currently based on a maximum 9 year term. The Contractors are required to provide all plant and equipment necessary to provide the levels of service required. This can vary from Region to Region depending on local requirements.

Included in contracts are local operational strategies for winter services which set out the management process, monitoring, treatment, emergency procedures and communication protocols in more detail.

These strategies determine the priority routes for treatment based on importance for the road user and the community it serves. Where adverse weather conditions may close highways the priority may change based on time taken to establish either the prime route or an alternative.

Following a significant review of state highway operations to achieve further efficiencies, the NZTA has moved to a system where suppliers of road maintenance services, including ice and snow management, are managed directly by the NZTA.

Ice Management

Due to environmental and public concerns, de-icing using salt was discontinued in the early 1980's leaving grit as the only treatment for ice conditions. In the mid 1990's calcium magnesium acetate (CMA) was introduced. This is now widely used on the highway network and for some local roads. Extensive monitoring of its application in various environments for over 10 years has shown that there have been no significant effects from the use of this chemical.

CMA is used in both solid and liquid form for anti-icing and de-icing situations. The NZTA purchases CMA each year based on historical usage and is distributed to Regional storage. Stocks are replenished through the winter if necessary. The main supply is in the form of 1 Tonne bags however a quantity of 25kg bags is purchased for distribution to outlying depots where handling equipment is not available.

CMA application rates will vary to suit the weather conditions and residual chemical on the road. Pretreatment application rates range from 7.55mg/m² for light frosty conditions up to 30mg/m².

CMA is used in areas where there are a significant number of frosts or snow on major or significant routes. Alternative de-icing products are currently



GRIT SPREADER



LIQUID CMA SPREADER



SOLID CMA SPREADER

being investigated. NAAC is an alternative de-icer that is used in the coldest parts of the road network where road temperatures drop below -7°C.

Abrasives or grit is also used either by itself or in conjunction with CMA. It is the main treatment on minor routes or roads with infrequent frosty conditions.

The contractors resources include purpose built plant for spreading grit and CMA.



CMA MIXING PLANT

Mixing equipment has been provided at the contractors main depots for preparing liquid CMA. A storage tank adjacent provides sufficient quantities when required. This liquid chemical can also be transported in a tanker direct to where it is needed to refill the spreading trucks while on their treatment routes. Contractors are required to calibrate all spreaders prior to winter.

Snow Management

The main snow removal equipment used is a simple front-mounted truck plough to remove snow as far as possible followed by a rotary broom to clear remaining slush. CMA is used to break down any snow pack.

Treatment Monitoring

Contractors have been introducing GPS to their fleets and Automated Vehicle Location (AVL) is available via the internet. This system indicates when vehicles are spreading and captures the spread rates and locations and also when and where trucks are ploughing.

Road Weather Forecasting

The highways in central North Island and a large part of the South Island have been thermally mapped to provide spatial variations of road surface temperatures. The mapping also identified the varying climatic domains with 11 in the South Island and 6 in the central North Island.

In order to develop nation-wide road weather ice prediction forecasting the establishment of a network

of automatic road weather stations across the country was necessary. Identifying the climatic domains has allowed for the strategic positioning of these weather stations.

The NZTA decided not to build and own weather stations but to contract for the supply of the required information and weather data only. This national road weather service is now provided by the NZ MetService which has installed the network of weather stations to deliver the information and data required.

MetService provide forecasting including ice prediction and observation data for each climatic domain via the internet. MetService has partnered with Finnish based Foreca to provide an integrated ice prediction service.

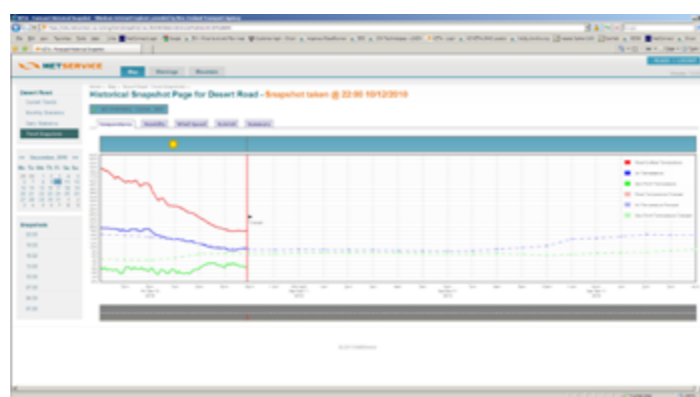
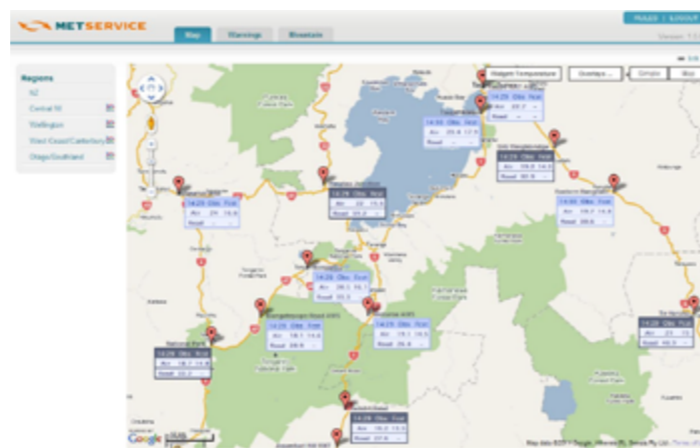
The specific web site also brings together all publicly available weather information from MetService such as radar, satellite images, charts, general weather forecasts and warnings issued in addition to observation data from many other weather stations managed by MetService. This provides ready access to a wide range of weather information for road managers each day to plan their operations, treatment selection and treatment locations.

The objective is „just in time in the right place“ This is critical to using CMA as the chemical is imported and relatively high cost and so must be carefully managed. The site also provides access to archived information for post event and seasonal analysis.

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

Control measures are set out in the contract specification and in NZTA's Winter Service Requirements specification. Local areas also have regional specific operations strategies. It is expected that the contractor will be proactive in response to oncoming storms, with a requirement to monitor the weather using the forecasting system operated by the NZTA and confirming with the contract manager the management plan for the next 24 hours. For forecast large events, snow clearing plant is expected to be pre-positioned to maximize effectiveness and shorten response times.

The contractors' performance is then monitored through the GPS AVL system, by contact directly with the contractor during the event for updates and by on-



WEATHER STATION FORECAST AND OBSERVATIONS

-site inspections. The contractors are required to maintain the road surface in a safe condition in accordance with the Levels of Service requirements.

The contractor is also required to submit records documenting ice monitoring and activities carried out during an event. This includes printouts from the AVL system detailing for each vehicle their time and location when CMA, gritting or ploughing commenced and finished, the application rates and the quantity used. This is particularly valuable along with the road weather forecasting and observation data to support the decisions and to validate the performance requirements where Court enquiries are made as a result of crashes and fatalities on the road. The contract allows for auditing the contractors records in more detail if required.

3.4 AVALANCHE MANAGEMENT

State Highway 94, the highway into Milford Sound and a popular tourist route, is particularly susceptible to avalanches. In order to better manage the risk, and provide improved availability, an avalanche management programme was initiated in the early 1980's and has gradually been upgraded to a state where, today, it provides a world-recognised system to monitor snow conditions, predict likely avalanche conditions and locations, and precipitate controlled releases. Details can be found on the NZTA website.

3.5 TRAFFIC SAFETY AND INFORMATION

Contractors are required to erect temporary warning signs where road treatment is carried out. The NZTA operates a number of Variable Message Signs which are used where roads may be closed or restrictions to vehicles are in place advising motorists of alternative routes.

The NZTA also operates a 24 hour national call centre to receive reports from the public and Police about hazards on the road. This is recorded in a web based Traffic Road Event information System (TREIS). The call centre then passes the information to the appropriate contact (usually the contractor) for attention. If the incident warrants public notification the event is marked accordingly in TREIS and the information is automatically sent to the NZTA public website.

The NZTA website also carries general weather warnings provided by MetService specifically related to road weather. Once the event has cleared

TREIS is updated which automatically updates the web site. The TREIS information is also directly available to others who wish to use the information such as the Automobile Association to include on their own road information web site and to provide traffic information through text or navigation systems.

4 ONGOING RESEARCH

Snow fences

Snow fences are used within ski field areas but have not been a feature on highways. A small scale trial is underway in the central North Island, although generally milder winters have not yet put the trial to the test.

Decision Guide

With the introduction of the road weather and ice prediction forecasting nationally, better decision making is expected on treatment selection both prior to and during an event. Decisions need to be made whether to apply chemical treatment prior to an event or during an event and at what application rates.

A Winter Service Decision Guide, which is a simple chart covering various temperature and weather scenarios with suggested treatments, is being tested and refined in operational conditions. The guide is incorporated within the best practice guides for the use of CMA. It may then be incorporated into the MetService weather data and forecast delivery to automatically provide suggestions for frost, ice or snow pre-treatment when the appropriate triggers are met. The Guide also provides suggested treatment during snow events.

Performance and reporting

A simple matrix to record the decision made prior to and during an event together with the eventual observation is being trialed to provide a performance measure on the accuracy of the pre-event decisions. This will be personalized to those decision makers and will assist in determining success rates and training requirements. Again, generally milder winters have not yet provided a really testing environment to prove the value yet.

NEW ZEALAND

Comparing the forecast ice prediction against the GPS recorded treatment sections will also provide a measure of performance.

Initial testing FAST

A fixed automatic spray treatment system using CMA was installed prior to the 2012 winter on a bridge deck in the central North Island. Operation and testing so far of this system has found this technology to be very beneficial in such remote locations that take time to establish and respond particularly if freezing events are not well forecasted. Currently assessments are being made as to whether such technology can be employed elsewhere.

Geofencing

Using GPS/AVL together with ice prediction and maintenance decision guidelines the use of geofencing can be used to automatically control the placement

and application rate of anti-icing chemical only to the sections of the road requiring treatment. This technology is still under investigation and development to test its benefits.

Real Time Weather Sensors

Vehicle mounted temperature and road state sensors are being routinely used now to assist winter plant operators in making more informed onsite decisions in regard to when and when not to treat sections of road.

5 REFERENCES

New Zealand Transport Agency www.nzta.govt.nz
 NZMetservice
www.metservice.com

NZ Metservice
www.metservice.com

NORWAY



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The Kingdom of Norway is a constitutional monarchy. Area of the Kingdom of Norway is 385,178 km². Population was 5,3 million in May 2017. Monetary unit is Norwegian kroner (NOK). One Euro was 9,30 NOK in May 2017. Length of coastline is 25,148 km, including fjords. Largest lake Mjøsa is 362 km². Highest mountain Galdhøpiggen is 2,469 m.

Much of Norway is mountainous. The western coast is gouged by deep fjords and dotted with islands along the coast. Norway is the country with longest coastline in Europe. The most important economic factor is oil-related activity.

Norway's administrative units are the Regjering (government) and Storting (parliament) with elections every 4 years. There are 19 counties and 426 municipalities. The latitude of the capital Oslo is 60° north.

1.2 ROAD NETWORK AND TRAFFIC

The categories of roads in Norway are the following:

Road type	Length of road
National roads	10 700 km
County roads	44 500 km
Municipality roads	39 400 km
Total public roads	94 600 km
Private, forest, farm roads	97 000 km

In addition, Norway have 10 000 km public pedestrian and cycle tracks.

All national roads are paved. In the other types there are a lot of unpaved roads. There are 3,2 million vehicles including 2,7 million passenger cars.



Nine-tenths of the country's area is located north of 60° latitude, where there is heavy snowfall six months of the year. Winter road traffic (November through April) accounts for about 35% of the annual yearly traf-

fic volume. In Norway 20% of the maintenance budget is connected to the winter condition.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS, MAIN WINTER EVENTS TO BE MASTERED

The Gulf Stream makes the climate in Norway much milder than other parts of the world at the same latitude. The country rises with a mountainous area inside the coastline.

Norway experiences large climatic variations within short distances. In the lowland on the eastern part of the mountains the climate is drier with low temperatures down to -20 °C, occasionally down to -30 °C and -40 °C. While the winter temperatures will vary around 0 °C along the coast, and rarely below -10 °C.

In the western part of the mountains there is a lot of snow and wind, and often extremely difficult conditions for winter maintenance. There is a lot of precipitation along the coast, often as snow, and also a lot of wind. The moist climate along the sea creates a lot of problems with humidity freezing to black ice on the roads.

As an average in the south-eastern part of Norway there is 20-25 snowfalls during a winter. The number of snowfalls is much higher along the coast and especially in the north of Norway. In recent years problems with freezing rain and rain on frozen roads has become more frequent. The roads get extremely slippery and it is very difficult to handle for the road users. For the road operators it is also very difficult to handle as the rain very rapidly reduces the effect of the salt.

There are many snowstorms during winter in the mountains and especially in the north of Norway. On roads crossing the mountains, there are many road closures and periods where vehicles only can pass in convoy due to snowstorms.

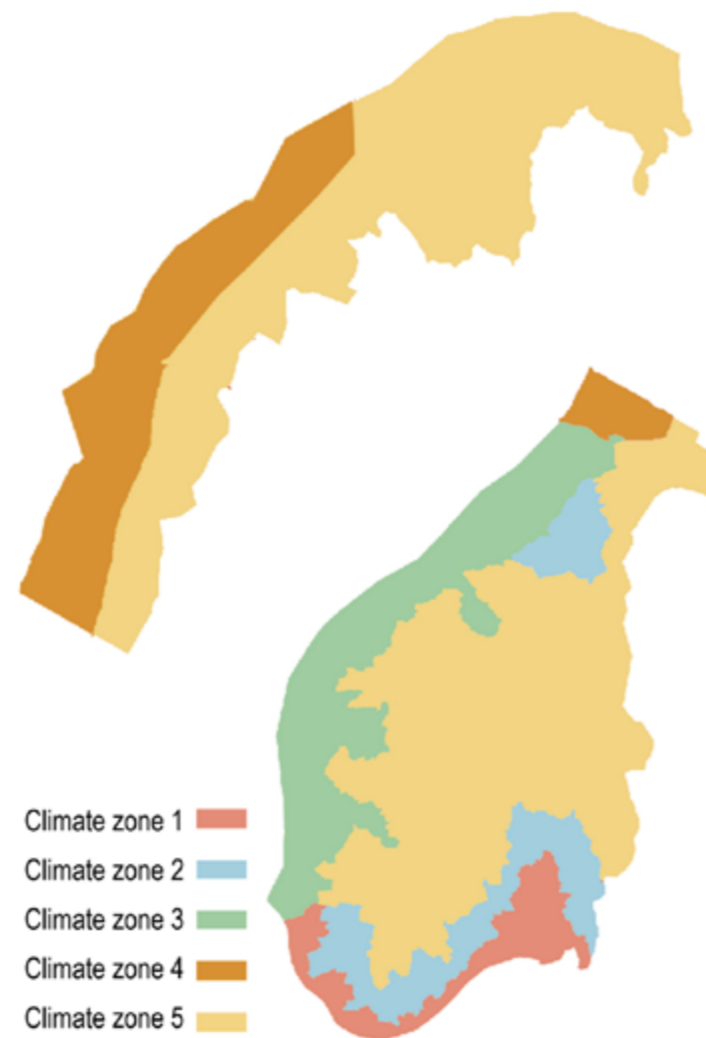
2.2 STATISTICS ON TEMPERATURES, ICING, PRECIPITATIONS

For winter maintenance purposes the country may be divided into five climatic zones, as shown in tables below.

CLIMATIC PARAMETERS IN DIFFERENT CLIMATIC

ZONES CLIMATE-ZONES

	Zone 1	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 as snow (mm water)	158	225	258	332	248
Precipitation as rain (mm water)	830	734	1632	860	603
Mean temp. January °C	-3	-6	0.7	-3.3	-7.8
Mean temp. March °C	1.1	-1.4	2.6	-1.6	-3.3



2.3 WINTER INDEXES USED IN THE COUNTRY

A winter index system was established in 2003.

The index was a theoretical calculation of the need for winter maintenance operations. It was under testing, where the theoretical and actual numbers of actions were compared. Information about precipitation, wind, temperature variations around zero, humidity, etc. was collected from meteorological stations in the area. The computer then calculated the theoretical number of necessary winter maintenance actions based on the actual weather information. The conclusion from the tests was that the quality of the model was not good enough to be used for compensation of the payment for the winter contracts.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

LEGAL OBLIGATION TO PERFORM WINTER MAINTENANCE?

According to the Norwegian Road Law the Ministry of Transport gives guidelines for maintenance of national roads and finances the maintenance of these roads. The Norwegian Public Roads Administration (NPRA) acts on behalf of the Ministry of Transport. NPRA also manages maintenance activities on county roads for the County Councils.

The municipalities finance and manage maintenance of the municipal roads.

Classification of the roads - Levels of service - Route optimization

The road classes are:

- National roads connect different part of the country, and also Norway to other countries and connect the different counties to important centers and are the main transport roads for goods and traffic within the country
- County roads brings traffic from the countryside to the national roads and county centers
- Municipal roads take care of traffic from the homes and businesses within towns and municipalities to the other roads
- Private roads include forest roads and

farm roads.

QUALITY STANDARDS, PERFORMANCE INDICATORS

LEVEL OF SERVICE

The level of maintenance standards for national roads is described according to the importance of the roads and the annual average daily traffic flow. Traffic safety, traffic volume (average annual daily traffic (AADT)) and environmental effects are the parameters considered to make the most cost-efficient standard. The level of service for national roads in Norway is described in the maintenance manual, handbook R610 "Standard for Maintenance of National Roads", dated 2014. The county roads and municipal roads have their own levels of service, but most of the county roads follow the national standard. Below is a translation of the main principles of handbook R610.

Purpose of winter maintenance

Winter maintenance should provide:

- Safe and accessible roads to the roads users during winter time with small impact to the environment
- Visibility, readability and function of road equipment, especially with regard to traffic flow quality, traffic safety and accessibility
- Clear visibility for all road users
- Accessibility to road equipment for maintenance personnel

Winter maintenance should shorten periods with adverse road conditions due to snow and ice on the road surface and secure adequate road grip and surface smoothness in periods when the road surface is covered with snow and ice.

Areas dedicated to pedestrians and cyclists should be passable and attractive to the users in a way that pedestrians and cyclists prefer to use the dedicated areas instead of using the roadway.

Maintenance cycle

Level of service for winter maintenance is described for a maintenance cycle related to the period before, during and after a weather event.

A weather event is defined as weather condition or a change in weather condition that affects and changes the winter road conditions. Weather events will primarily be related to precipitation, white frost, wind or temperature changes. Determination of when a weather event occur, should be based upon an assessment of

	Maintenance cycle			
	Before weather event	Weather event alert	During weather event	After weather event
	Steady state			Clearing
Road condition	Approved road condition	Approved road condition	Accept of deviation from approved road condition	Reset of approved road condition within specified time limits
Activity	Monitor Maintain approved road condition	Monitor Maintain approved road condition Preventive efforts	Reduce deviation from accepted road condition Monitor	Re-establish approved road condition Monitor
Level of service	Approved road condition should be obtained	Approved road condition should be obtained	Deviation from approved road condition: Labour input at agreed level	Deviation from approved road condition: Labour input at agreed level until approved road condition is obtained.

the extent of changes in road condition compared to the necessary resource use for maintaining the road condition specified in the standard (approved road condition). There should be available specified procedures for determining and warning of start and end of weather events.

Approved road condition defines the road condition that should be maintained in periods between weather events and that should be aimed at during weather events.

If the requirements set forward by the described approved road condition are satisfied on a road section, the requirements for labour input during weather event do not apply.

If the requirements set forward by the described approved road condition are not satisfied on a road section, the requirements for labour input during weather event do apply, and the winter maintenance resources should be in operation.

WINTER MAINTENANCE CLASSES

Winter maintenance should be carried out according to a classification of road sections in winter maintenance classes. The following winter maintenance classes are used:

Winter maintenance class	General specifications – approved road condition
WmA	Bare road surface– wet or dry
WmB	Bare road surface– wet or dry Compacted snow and ice surface between wheel tracks accepted during limited time periods
WmC	Bare road surface– wet or dry during mild weather - compacted snow and ice surface during cold periods
WmD	Compacted snow and ice surface

WmE	Compacted snow and ice surface Road friction down to 0.20 accepted
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Classification of a road section is based primarily upon the traffic volume (AADT), as shown below.

Class	AADT			
	0 – 1500	1500 – 5000	5000 – 20000	20000 –
WmA				
WmB				
WmC				
WmD				
WmE				

The classification of road section into winter maintenance classes should, in addition to AADT, also take into account road category (national, regional, local route), traffic composition, public transport routes, road alignment and width, weather and climate, road accidents and environmental issues.

A continuous route should be maintained according to the same winter maintenance class for the whole route. Frequent changes in winter maintenance class should be avoided.

The transition between different winter maintenance classes should be located at places where the transition does not create difficulties for the road users. The winter maintenance routines at a transition should be performed with great care in order to minimize the effect of the change of standard to the road users.

The requirements for approved road condition, methods for friction improvement and required equip-

ment resource input at weather event are given for each winter maintenance class in a format as described below.

WINTER MAINTENANCE CLASS WMA

Method for friction improvement	De-icing with chemicals, When de-icing is not possible, winter maintenance should be carried out according to special specifications.
Approved road condition	
Road condition	Bare road surface (wet or dry)
Friction - general	Bare road surface
Friction – special road sections	Bare road surface
Snow/ice-surface: Thickness Unevenness	According to special specifications if salt cannot be used due to weather situation
Resource input at weather event	
Maximal cycles-time for snow removal	1.5 hours
Maximal cycles-time for de-icing	1.5 hours
Time to re-establish approved road condition	AADT>6000: 2 hours AADT<6000: 4 hours

WINTER MAINTENANCE CLASS WMB

Method for friction improvement	De-icing with chemicals, When de-icing is not possible, sand should be used.
Approved road condition	
Road condition	Bare road surface– wet or dry in wheel tracks. Compacted snow and ice surface between wheel tracks accepted during limited time periods, loose snow less than 1 cm.
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 2.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	2 hours
Maximal cycles-time for de-icing/ gritting	2 hours
Time to re-establish approved road condition	In wheel tracks: 2.5-5 hours Road as a whole: 1-5 days

Snow removal should be carried out on the road shoulder as well as in the road lanes, and close against road objects as guardrails, curb stones, etc. Accessibility and safety should be preserved in all crossings and bus stops along the road. Snow should not be placed in piles that reduce visibility.

During the thaw period, snow should be removed from ditches in order to allow free flowing of melting water.

WINTER MAINTENANCE CLASS WMC

Method for friction improvement	Sand De-icing chemicals during light snowfall or mild periods
Approved road condition	
Road condition	Bare road surface– wet or dry during mild weather - compacted snow and ice surface during cold periods, loose snow less than 2 cm
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 2.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	2.5 hours
Maximal cycles-time for de-icing/ gritting	3 hours
Time to reestablish approved road condition	3 hours

WINTER MAINTENANCE CLASS WMD

Method for friction improvement	Sand De-icing chemicals on thin ice and white frost
Approved road condition	
Road condition	Compacted snow and ice surface, loose snow less than 2 cm
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 3.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	3 hours
Maximal cycles-time for de-icing/ gritting	4 hours
Time to re-establish approved road condition	4 hours

In bus stops snow removal should maintain the standard height between roadway and area for passengers.

For bus stops and parking areas the requirement for bare road surface can be deviated from if the friction on snow and ice is maintained higher than 0.25.

Special requirements apply for road sections in high mountain areas.

WINTER MAINTENANCE CLASS WME

Method for friction improvement	Sand De-icing chemicals on thin ice and white frost
Approved road condition	
Road condition	Compacted snow and ice surface, loose snow less than 3 cm
Friction - general	Higher than 0.20
Friction – special road sections	Higher than 0.25
Snow/ice-surface: Thickness Unevenness	Less than 3.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	3 hours
Maximal cycles-time for de-icing/ gritting	4 hours
Time to re-establish approved road condition	4 hours

Areas for pedestrians and cyclists

Winter maintenance should be carried out according to a classification of the area in winter maintenance classes. The following winter maintenance classes are used:

Winter maintenance class	General specifications – approved road condition
WmA-PC	Urban areas with many pedestrians and cyclists, main route for cyclists, areas specially equipped for people with disabilities
WmB-PC	Remaining area for pedestrians and cyclists

The requirements for approved road condition, methods for friction improvement and required equipment resource input at weather event are given for each winter maintenance class in a format as described below.

WINTER MAINTENANCE CLASS WMA-PC

Method for friction improvement	De-icing with chemicals, snow removal with sweeping or ploughing, when de-icing is not possible, sand should be used.
Approved road condition	

Road condition – day-time	Bare road surface (or snow/ice with max 1 cm loose snow when de-icing cannot be used)
Friction – night-time	Bare road surface (or friction higher than 0.30 snow when de-icing cannot be used)
Snow/ice-surface:	Unevenness less than 2 cm
Cross fall	As for bare road surface
Resource input at weather event	
Maximal cycles-time for snow removal	As for adjacent road, but not more than 2 hours
Maximal cycles-time for de-icing	As for adjacent road, but not more than 2 hours
Time to re-establish approved road condition	As for adjacent road, but not more than 2 hours

WINTER MAINTENANCE CLASS WMB-PC

Method for friction improvement	Sand De-icing with chemicals on areas with disability indicators
Approved road condition	
Road condition – day-time	Snow/ice surface with max 1 cm loose snow
Friction – night-time	Higher than 0.30
Snow/ice-surface:	Unevenness less than 2 cm
Cross fall	As for bare road surface
Resource input at weather event	
Maximal cycle-time for snow removal	As for adjacent road, but not more than 3 hours
Maximal cycle-time for de-icing	As for adjacent road, but not more than 3 hours
Time to re-establish approved road condition	As for adjacent road, but not more than 3 hours

Stairs, access ramps and platforms: Snow removal and de-icing/sanding should be carried out for the complete area.

The height of ice edges at area with ground heating should be less than 2 cm.

Winter maintenance during summer

Local plans for handling winter maintenance when winter weather events occur during summer should be developed and maintained.

The period between two winter seasons is categorized like this:

Winter season: Standby readiness

Reduced standby readiness

No standby readiness

Reduced standby readiness

Winter season: Standby readiness

The length of the periods with reduced standby re-

adiness is defined according to local needs.

During the periods with reduced standby readiness there should be available at least one machine unit for snow removal and de-icing/sanding for each 100 km road. Higher requirements can apply according to local needs. Time to mobilize the machine unit during the periods with reduced standby readiness should be less than 5 hours.

Special winter works

Clearing after snow avalanche

Clearing and mending should be done as soon as it can be done safely.

Permanent repair should be done as soon as possible.

SPECIAL REGULATIONS CONNECTED TO WINTER MAINTENANCE

De-icing products

Sodium chloride (NaCl) is used for chemical de-icing and is used where the approved road condition is “bare roads”. Sand, gravel or crushed stones are used where the approved road condition is “snow/ice surface”. The total amount of sand used for gritting the last five years has been between 540,000 and 870,000 ton per year. 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 on Winter Maintenance Class A and B. Salt is also used in special cases on other roads to prevent thin ice and white frost. The last five years the total amount of salt used has been between 190,000 and 260,000 ton per year.

The contractors can use NaCl for salting of roads. Other types of salt can only be used after approval by the NPRA.

Studded tyres

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 Norway today about 50% of the vehicles in average are using studded tyres. The studded tyres create dust, and air pollution is measured throughout the day in several cities. These measurements are used to make local restrictions if necessary. In the largest cities no more than 20% of the vehicles are supposed to use studded tyres. The two largest cities have now non-studded tyres on 80-85% of the vehicles in the winter season. In some of the largest cities the

users have to pay a tax for the use of studded tyres to ensure that not more than 20% of the vehicles use studded tyres.

During summer it is not allowed to use studded tyres, and users will be fined. There are no penalties for the use of summer tyres in winter. However, one will be penalized for not securing proper road-grip during the winter period. Winter speed limits have been tried out to reduce accident rates, and so far, it has given satisfactory results.

Working hours

There is a “law for the working environment” which gives allowed working hours and a “law for driving- and resting time” for professional drivers. The contractors have to obey to all the laws and if necessary apply for exceptions.

Winter maintenance equipment

There are no specific standards for winter maintenance equipment; they have to follow the standard rules and regulations for each type of equipment. If needed the contractors have to apply for exceptions for snowploughs and other equipment that are wider than the vehicle. The same goes for special headlight for trucks carrying snowplough. The maintenance vehicles have to use special warning light during operations, if they do not follow the traffic rules.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

ORGANIZATION OF WINTER MAINTENANCE

The NPRA is responsible for;

- planning, construction, maintenance and operation of the national and county road networks;
- vehicle inspection and requirement;
- driver training and licensing.

The NPRA is under the leadership of the Directorate of Roads, which is an autonomous agency subordinated the Ministry of Transport and Communications. The NPRA encompasses 5 regional offices and 20 counties/district offices. Since January 1, 2003, all construction, operation and maintenance of roads have been tendered and contracted after a competitive bidding procedure.

Cooperation with other levels of road manage-

ment organization

For matters pertaining to national roads, the NPRA is under the direction of the Ministry of Transport. On those related to county roads, the Regional Roads Officer is subordinated to the county legislature.

Operational management of winter maintenance

- The contractors are responsible for achievement of the maintenance standard and have to plan, inspect and take the necessary actions. The contractor cannot decide to close a road on his own. Roads can only be closed with the approval of the NPRA;
- The contractor must prepare and maintain a plan for winter operations. The plan should contain: Personnel, stand by teams, equipment, storing facilities, routes, prioritized roads, points of special attention, etc.;
- The contractors must keep a journal for all inspections and all enquiries received from the public. They should report each activity, all consumption of abrasives and salt and the number of ploughing kilometers;
- According to the contract, operators of snow ploughing and spreading equipment must have required competence and pass a theoretical test arranged by the NPRA.

ROAD CLOSURES AND TRAFFIC RESTRICTIONS

All trucks, trailers and buses are obliged to carry chains with them if there is a risk of slippery roads.

Roads crossing mountains may be temporarily closed during snowstorms. Sometimes the vehicles can only pass in a convoy between two snowplough trucks.

Some roads crossing mountains are closed during winter. They will be opened in May or June. Special equipment is needed to open a road that has been closed during winter. The layer of snow can be more than 4 meters thick. A special attachment for a snow cutter unit has been developed. The snow cutter is mounted on an excavator. The excavator has chains and can move on top of the snow and cut layer by layer. When the top of the snow can be reached from the road surface the unit will be shifted to a wheel loader for the last layers.

To open the closed mountain roads after winter, a road finding system based on GPS has been developed; it works very well. It replaces the poles that have been used up to now.

Avalanches are a big problem on many roads alongside the coast and in the north. They can be closed in

periods with danger of avalanche. In some cases, NPRA provokes the avalanche by the use of dynamite. Contractors who are working on roads that are exposed to the danger of avalanches have to undergo special training given by NPRA.

Also some roads and bridges along the coast can be closed during storms. Some bridges are closed automatically when the wind reaches above a certain speed.

ROAD INFORMATION PROVISION METHOD & SYSTEM**Meteorological information**

There is an agreement between the Norwegian Public Roads Administration (NPRA) and the Norwegian Meteorological Institute (met.no). Met.no provides NPRA with weather forecasts and climate data at a market value. It includes the following forecasts from met.no:

- Graphical prognoses for wind speed, wind direction, precipitation, air temperature, air pressure, dew point temperature and cloud cover
- Written forecasts
- Wind, temperature, and precipitation fields for ground level and 1,500 m above sea level;
- Weather radar images
- Satellite images
- Separate forecasts under special weather situations, like freezing rain

These products cover the whole country and are provided on a regular basis throughout the year.

The forecasts bought on a regular basis are spread to the internal users via NPRA intranet and presented in a web-application for external contractors.

The graphic forecasts, the written prediction and the meteorological fields are updated three times a day. The radar images and satellite images are updated every 15 minutes.

NPRA has approximately 300 road weather information stations spread throughout the country. Most stations have sensors for:

- Air temperature
- Relative humidity
- Precipitation
- Road surface temperature
- Picture

Some stations also have sensors for

- Road surface condition
- Wind direction

- Wind speed
- Long wave emission
- Salt concentration/freezing point
- Video

The thermal maps were used to locate difficult areas. This knowledge was used to determine where to locate RWIS. The RWIS are located at places the road gets slippery before other places; early black ice or early snowfall. There are a couple of stations in each maintenance district.

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

There are several research and development projects every year. In 1991-1994 a nationwide study to examine the effect of road salting on traffic safety was conducted. The result showed that road salting reduces the number of police reported accidents by 20%. A study of the environmental effects of salt on the area surrounding the roads was carried out in the period 1992-1996.

MAINTENANCE QUALITY THROUGH INSPECTION AND CONTROL OF CONTRACTORS

The contractor must report to NPRA if he has not achieved the requirement in the maintenance standard. The NPRA takes random inspection to see if the contractor has fulfilled the contract. Snow and ice thickness on the road surface are measured and compared to the contract requirements. Friction is measured with special equipment that is calibrated for this purpose. The inspection will also focus on the contractor's use of his quality system. If the performance is not according to the specification, a deduction in payment as a penalty can be demanded. The size of the penalty will depend on if it is a repeated problem, how serious the problem is, does it represent a danger to the road users, and how much money has the contractor saved by not doing the work.

3.4 TRAFFIC SAFETY & INFORMATION INFORMATION PROVISION TO THE ROAD USER

There are 5 Traffic Control Centres in Norway, one in each region. Their main tasks are control and monitoring, decision support and traffic information. The Traffic Control Centres provide information three times daily to the media about road conditions and road clo-

sures in winter season. This information is also available on Internet and text TV. The national radio stations give traffic information every morning and evening. Drivers can call 175 by telephone to get updated information about the road condition for special warnings the RDS radio will inform drivers.

The local radio stations very often have programs with a traffic theme at times when there is a lot of traffic on the roads. They give information about the traffic situation on the main roads and play music and give other traffic related inputs. These programs are quite popular. They are on the air morning and evening on weekdays, Sunday evening and in connection with winter holidays and Easter.

SYSTEMS IMPROVING TRAFFIC SAFETY

The NPRA is responsible both for maintenance and road safety. The Roads and Transport Department in NPRA is responsible for road planning, building and maintenance. The Road users and Vehicle Department is responsible for driving license and vehicle inspection. Together with the Traffic safety section they are responsible for investigating accidents and trying to reduce them. Assembling all these specialists on different aspects of traffic safety in one special Traffic Accident Investigating Group allows for the efficient improvement of traffic safety.

The cost connected to winter maintenance is roughly 20% of the maintenance budget for the country. It is more in the north. Winter maintenance has a great importance for traffic safety. Traffic safety has top priority. If the winter cost is higher than budgeted, money will be taken from summer activities to compensate.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENTZ**4.1 NEW TECHNOLOGY**

The last years and also today several research projects are going on with the aim to study:

- improved methods of spreading sand heated with hot water
- new methods for better snow and slush removing
- the effects of salt and residual salt on roads
- effects of different salt types and salting methods

NORWAY

- effect of salt when low temperature and during snow fall
- methods and equipment for measurement of friction
- better use of ITS in winter maintenance and follow up system of maintenance contracts
- better road maintenance for pedestrians and cyclists
NPRa is cooperating with the University of Science and Technology in Trondheim to improve the knowledge of winter technic and the education in this field. The university has established a Winter Research Centre and built up a new winter laboratory dedicated to winter research.

4.2 TRANS-NATIONAL COOPERATION TO IMPROVE LEVELS OF SERVICE BETWEEN NEIGHBOURING COUNTRIES

The Nordic countries have similar road-, traffic- and climate conditions and are cooperating to benchmark and share knowledge about roads and traffic. The Nordic Road Association (NRF), which can be compared to PIARC, has put this into its system. They have an own group working with road maintenance, including winter maintenance.

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Nord-FoU is a part of this cooperation where the Nordic countries finance and perform development and research projects together.

Information about the projects and reports can be found on their web-site.

5 REFERENCES

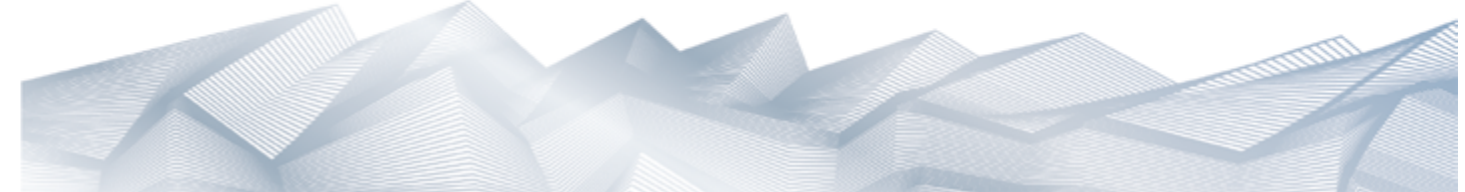
More information about Norway can be found on: www.odin.dep.no

The URL to DNMI's web site is: www.met.no

More information about NRF can be found on: www.nvfnorden.org

More information about Nord-FoU can be found on: www.nordfou.org

POLAND



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Poland (Polish: Polska [ˈpɔlska] (listen)), officially the Republic of Poland (Polish: Rzeczpospolita Polska,[a] listen (help·info)), is a sovereign country in

Central Europe. It is a unitary state divided into 16 administrative subdivisions, covering an area of 312,679 square kilometres (120,726 sq mi) with a mostly temperate climate. With a population of over 38.5 million people, Poland is the sixth most populous member state of the European Union. Poland's capital and largest city is Warsaw. Other cities include Kraków, Wrocław,



ław, Poznań, Gdańsk and Szczecin.

The establishment of a Polish state can be traced back to 966, when Mieszko I, ruler of a territory roughly coextensive with that of present-day

Poland, converted to Christianity. The Kingdom of Poland was founded in 1025, and in 1569 it cemented a longstanding political association with the Grand Duchy of Lithuania by signing the Union of Lublin. This union formed the Polish–Lithuanian Commonwealth, one of the largest (about 1 million km²) and most populous countries of 16th and 17th century Europe with a uniquely liberal political system which declared Europe’s first constitution.

Following the partitions of Poland at the end of the 18th century, Poland regained its independence in 1918 with the Treaty of Versailles. In September 1939, World War II started with the invasion of Poland by Nazi Germany, followed by the Soviet Union invading Poland in accordance with the Molotov–Ribbentrop Pact. More than six million of Poland’s citizens died in the war. After World War II, the Polish People’s Republic was established as a satellite state under Soviet influence. In the aftermath of the Revolutions of 1989, most notably through the emergence of the Solidarity movement, Poland established itself as a democratic republic.

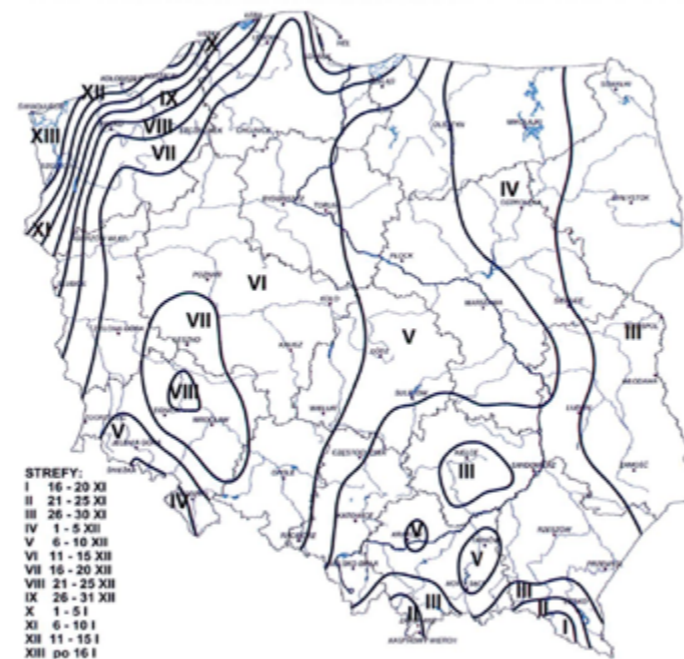
Poland has the eighth largest and one of the most dynamic economies in the European Union, simultaneously achieving a very high rank on the Human Development Index. Additionally, the Polish Stock Exchange in Warsaw is the largest and most important in Central and Eastern Europe. Poland is a developed and democratic country, which maintains a high-income economy along with very high standards of living, life quality, safety, education and economic freedom. According to the World Bank, Poland has a leading school educational system in Europe. The country provides free university education, state-funded social security and a universal health care system for all citizens. Situated between Eastern and Western European cultures and coined by a changing history, Poland developed a rich cultural heritage, including numerous historical monuments and 15 UNESCO World Heritage Sites. It is visited by approximately 17.5 million tourists every year (2016), making it the 16th most visited country in the world. Poland is a member state of the European Union, the Schengen Area, the United Nations, NATO, and the OECD.

2 CLIMATE

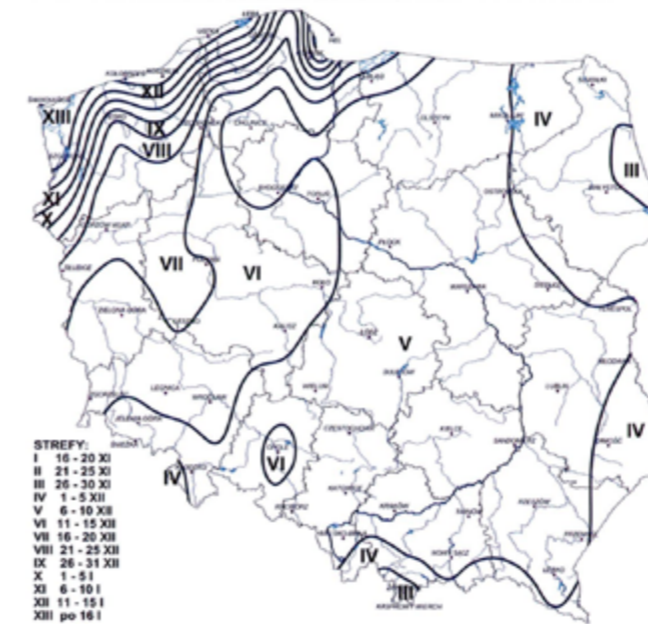
2.1 OVERVIEW OF CLIMATIC AREAS

The climate is mostly temperate throughout the country. The climate is oceanic in the north and west and becomes gradually warmer and continental towards the south and east. Summers are generally warm, with average temperatures between 18 and 30 °C (64.4 and 86.0 °F) depending on the region. Winters are rather cold, with average temperatures around 3 °C (37.4 °F) in the northwest and –6 °C (21 °F) in the northeast. Precipitation falls throughout the year, although, especially in the east; winter is drier than summer.

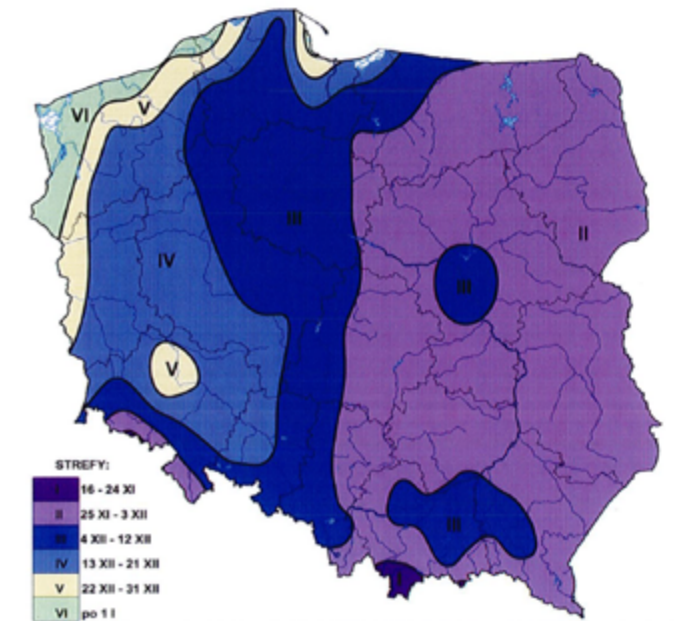
The warmest region in Poland is Lower Silesia located in south-western Poland where temperatures in the summer average between 24 and 32 °C (75 and 90 °F) but can go as high as 34 to 39 °C (93.2 to 102.2 °F) on some days in the warmest month of July and August. The warmest cities in Poland are Tarnów, which is situated in Lesser Poland and Wrocław, which is located in Lower Silesia. The average temperatures in Wrocław are 20 °C (68 °F) in the summer and 0 °C (32.0 °F) in the winter, but Tarnów has the longest summer in all of Poland, which lasts for 115 days, from mid-May to mid-September. The coldest region of Poland is in the northeast in the Podlaskie Voivodeship near the border



ZONE MAP FOR YEARS 1981-2010



ZONE MAP FOR YEARS 2001-2013



WINTER SEASON STARTING DATE ZONE MAP FOR YEARS 1981-2010.

2.2 WINTER SEASON DEFINITION

Winter is the coldest season of the year. In a temperate zone in the northern hemisphere calendar winter lasts from December till February. Thermal winter is defined as a period of time when the average daily temperature falls below 0°C. This definition is the base of the calculations below.

of Belarus and Lithuania. Usually the coldest city is Suwałki. The climate is affected by cold fronts which come from Scandinavia and Siberia. The average temperature in the winter in Podlaskie ranges from –6 to –4 °C (21 to 25 °F). The biggest impact of the oceanic climate is observed in Świnoujście and Baltic Sea seashore area from Police to Słupsk.





ily temperature below 0°C occurred. In order to set up the 6 zones it was decided that the winter should start no later than in the first days of January for the last zone (zone VI).

Table A shows the first day when temperatures fall below 0°C which indicates the start of the winter season.

Zone number	Winter season starting date (median)	Winter season length (median)	First day of winter season (temperature below 0°C)
I	16.11	127	4.10
II	25.11	94	1.10
III	4.12	77	15.10
IV	13.12	70	14.10
V	22.12	55	18.10
VI	1.1	32	1.11

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legal obligation to perform winter maintenance?

According to the Polish law the guidelines for maintenance of national roads and finances the maintenance of these roads are covered in the General Director's of GDDKiA directives.

Winter maintenance standards

GDDKiA maintains more than 19 000 km of national roads (excluding the roads crossing some cities). The preparation phase starts in the July when most of the people enjoy summer holidays. Then the roads are carefully checked in terms of surface, shoulders and drainage system condition. If necessary partial renovation works are scheduled as well as general check-up is maintained. One of the crucial elements is drainage system that is always inspected meticulously. General check-up also requires to check the sides of the roads and the condition of the trees that may have weakened since the last winter. It is especially dangerous when there is heavy snowfall and the tree branches may not be able to hold the extensive amount of snow. So, road safety will be decreased.

The direct winter maintenance works that involve snow-removal and deicing are performed 24 hours a day, 7 days a week by the GDDKiA regional divisions.

Poland's geographic location and land formation have crucial meaning for the climate and weather conditions. There are oceanic and continental air masses that collide over Poland. Moreover, local geological condition such as hilly area in the south and Baltic Sea in the north shape the winter season that could either be mild with oceanic influence or rigid with continental impact.

Winter season in Poland divided into zones for the years: 1981-2010.

Zone number	Start dates	Winter length (in days)
I	16-20. 11	>110
II	21-25. 11	>100
III	26-30. 11	>90
IV	1-5. 12	>85
V	6-10. 12	75-90
VI	11-15. 12	60-80
VII	16-20. 12	60-70
VIII	21-25. 12	50-60
IX	26-31. 12	45-50
X	1-5. 1	20-40
XI	6-10. 1	<20
XII	11-15. 1	<10
XIII	After 16. 1	

The map below shows Poland divided into 6 zones (I-VI) depending on when the first day of average da-



Usually, the works are contracted to outside companies via public tenders procurements.

The winter maintenance works are directed by 104 area managers and 273 Road Teams. Their main tasks among many belong: preparing the snow removal equipment, collect all necessary materials that help prevent the icing of the roads, such as salt mixtures and specific abrasive materials essential for the winter maintenance works.

All together there are 2400 snow ploughs, approximately 1400 salt vehicles and other necessary equipment. GDDKiA has 286 salt mixtures storages that can store up to 430 000 tons of snow. On top of that GDDKiA sets up to 1 500 km of snow curtains.

In 2017/2018 winter season GDDKiA plans to use:

- 460 000 tons salt mixtures
- 3 500 tons calcium chloride
- 83 000 tons abrasive materials

The winter maintenance works during the 2017/2018 season on the national road network will be kept according to the following standards:

- standard I – road surface free of snow and ice in all widths along with shoulders, no snow and mud slides - approx. 5 000 km
- standard II - road surface free of snow and ice in all widths along with -shoulders - approx. 11 000 km

- standard III - road surface free of snow in all widths, de-icing of crossroads, crossroads with railroads, roads with more than 4% inclination, bus stops, other specified places - approx. 2 000 km
- standard V – roads free of snow, at least one lane with possible alternation, sprinkled when there is a possibility of road traffic - approx. 1 600 km

Winter maintenance plan assumes to cover particular routes under the same winter maintenance standard during the whole winter season. In case of long-term extreme weather conditions, including heavy snowfall and winds, snow storms, blizzards that will cause the snow removal impossible and winter maintenance difficult to keep up to standards there might be deviation from the rules.

24 hours/day road conditions information

GDDKiA established round-the-clock Road Information Points (PID) that collect the information relating to road conditions and convey it to road users and media. Information about road conditions are also on GDDKiA website, under the tab: driver's services. Road users may also use the GDDKiA hotline where they can obtain current road conditions information (hotline 19 111).

On the other hand, GDDKiA uses the weather forecasts that allow to take some preventive actions such as salting the roads just before or shortly after the beginning of the snowfall on chosen road sections. For operational needs, there are 750 surveillance cameras and 500 meteorological stations installed. These devices provide the following data:

- live video on national roads
- temperature and humidity measurements
- surface temperature
- wind strength and velocity

Drivers tasks

The main task of the winter maintenance vehicles drivers is ensuring passage. The vehicles are broad, some of them take the whole lane's width and usually move slowly. They remove the snow, sprinkle it with salt thus ensuring a safer road and regular flow of the traffic. Even though the vehicles are equipped with yellow flashing service lights, they perform a crucial role, somewhat similar to that of police or fire fighters.

4 REFERENCES

More information about Poland's roads
www.gddkia.gov.pl



1. DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

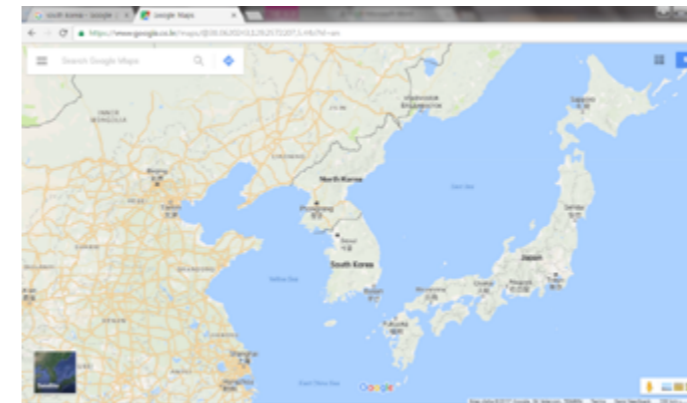


FIGURE 1- POSITION OF THE REPUBLIC OF KOREA IN EAST ASIA

The Republic of Korea (called South Korea) is a medium-sized country, (100,221.78 km²) but quite densely populated (around 50.8million in April 2016) and located in East Asia next to Japan. The Korean Peninsula was divided into two countries, South and North Korea, since World War II and Korean War during 1950-1953.

The capital city of Seoul is also the country's largest city and chief industrial center. According to the 2015 census, Seoul had a population of 10 million inhabitants. The Seoul National Capital Area has 24.5 million inhabitants (about half of South Korea's entire population) making it the world's second largest metropolitan area.

The 2018 Winter Olympics, commonly known as Pyeongchang 2018 and marketed as „PyeongChang“, is a major international multi-sport event scheduled to take place from 9 to 25 February 2018, in Pyeongchang, South Korea.

South Korea's "tiger economy" soared at an annual average of 10% for over 30 years in a period of rapid

transformation called the "Miracle on the Han River". A long legacy of openness and focus in innovation made it successful. Today, it is the world's fifth largest exporter and seventh largest importer with the G20's largest budget surplus

1.2 ROAD NETWORK AND TRAFFIC

The road network comprises 4,193km of Expressways, 13,948 km of National Roads, 4,727 km of Special City Roads, 18,087 km of Regional Roads and 50,985 km of County Roads. All of the Expressways, National Roads and City Roads are paved with asphalt



FIGURE 2- EXPRESSWAY IN SOUTH KOREA

or cement concrete and approximately 92 % of Regional Roads and 86 % of County Roads are paved roads. Road transportation accounts for 90.6% of total freight transport. The total registered vehicles as of 2015 were 20.99 million.

TABLE 1- ROAD NETWORK (IN 2015)

Area	Total	100,221 km ²
Population	Total	50.8 million
Registered cars	Total	20.99 million
Length of roads	Total	107,527 km
	Expressways	4,193 km
	National roads	13,948 km
	City roads	4,727 km
	Regional roads	18,087 km
County roads	50,985 km	

2. CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Republic of Korea is a peninsula state which faces oceans on the east, south and west directions and is loca-

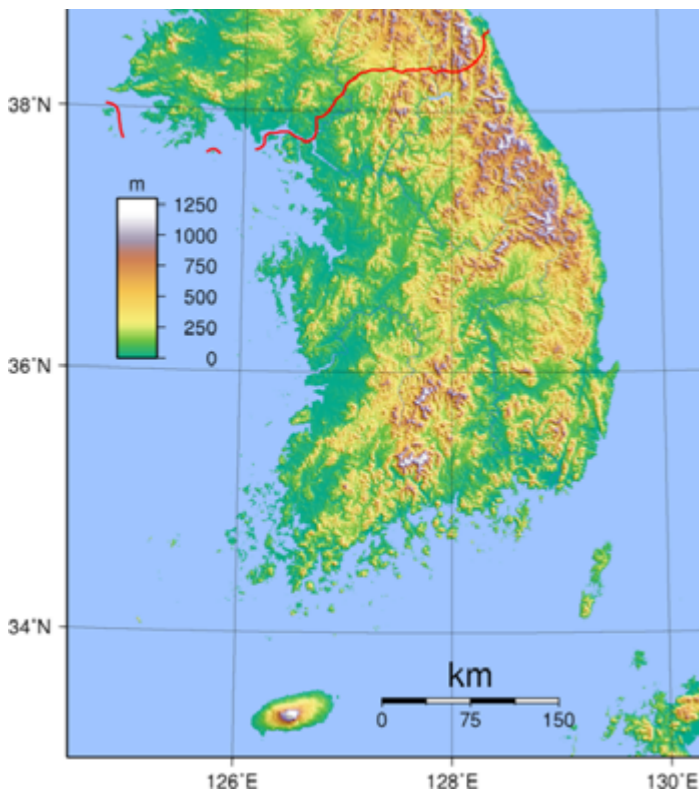


FIGURE 3- TOPOGRAPHY OF SOUTH KOREA

ted in the northern hemisphere. The range of geographical latitudes is 33~39 degrees north. The topographical features are mostly, approximately 70%, mountainous except flat farming area in the southwestern region.

South Korea tends to have a humid continental climate and a humid subtropical climate, and is affected by the East Asian monsoon, with precipitation heavier in summer during a short rainy season called jangma, which begins around the end of June through the end of July. Winters can be extremely cold with the minimum temperature dropping below -20 °C (-4 °F) in the inland region of the country: in Seoul, the average January temperature range is -7 to 1 °C (19 to 34 °F), and the average August temperature range is 22 to 30 °C (72 to 86 °F). Winter temperatures are higher along the southern coast and considerably lower in the mountainous interior. Summer can be uncomfortably hot and humid, with temperatures exceeding 30 °C (86 °F) in most parts of the country. South Korea has four distinct seasons; spring, summer, autumn and winter. Spring usually lasts from late-March to early-May, summer from mid-May to early-September, autumn from mid-September to early-November, and winter from mid-November to mid-March.

2.2 STATISTICS ON TEMPERATURE AND PRECIPITATION

The average air temperature is strongly dependent on seasons and the height above sea level. The annual average temperature over the country is 10~15°C and the average temperature in the hottest summer season of August and the coldest season of January is 23~26°C and -6~3°C respectively. But the highest temperature during summer in the central lowlands area rises up to 35°C and the lowest during winter in the high mountainous northeastern area falls below -30°C.

The overall average temperatures in the country are shown in the Table. 2.

TABLE 2- AVERAGE TEMPERATURE (°C)

Region	Winter	Spring (Autumn)	Summer
Central inlands	-6~4	4~13	22~26
Northeastern mountain	-11~-3	-1~8	17~20
Western coast	-5~7	3~13	20~25
Southern coast	-1~4	7~17	21~26

The annual precipitation is also markedly dependent on the height above sea level and the distance from the ocean. The annual average precipitation in most of the country is 1,000~1,500mm and that of the southern coast and islands area is 1,500~1,900mm. In relation to winter road maintenance, freezing or snowing period is relatively long and depends on region. Freezing period and snowing period in the whole country are 18~167days and 5~57days respectively. The detailed statistics of the annual average freezing and snowing days are shown in the Table 3.

TABLE 3- AVERAGE ANNUAL FREEZING AND SNOWING PERIODS / DEPTH

Region	Freezing period(-day)	Snowing period / cumulative depth
Central inlands	95~130	20~30days /55.3cm
Northeastern mountain	130~167	30~57days /178.2cm
Western coast	60~110	20~30days /44.7cm
Southern coast and islands	20~60	5~20days /16.8cm

2.3 WINTER INDEXES USED IN THE COUNTRY

There is not any special index or system to analyze and compare the road winter maintenance performances and costs. Each road managing organization performs its duty to maintain perfect road condition and serviceability based on winter maintenance regulations. The related regulations will be given in the following article.

The National Meteorological Office announces two type of winter events:

One is heavy snow, the other is cold wave.

TABLE 4- TYPE OF WINTER EVENTS

Type	Warning	Advisory
Heavy (in 24 hours)	Snow Above 15cm	Above 5cm (in 24 hours)
Cold (two days long)	wave Below -15°C	Below -12°C (two days long)

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Winter maintenance of roads in the Republic of Korea is regulated by laws and regulations. The related laws

are Road Law and Countermeasure Law against Natural Disasters. The roads are classified as Expressway, National Road, City Road, Regional Road, County Road or so based on the Road Law. The administrative road authorities based on the road classification are responsible for each level of road. The government established a state-run company, Korea Expressway Corporation (KEC), in 1969 and the KEC is responsible for all sort of things related to expressway design, construction, operation, management and maintenance in South Korea. Especially the KEC leads technological fields of road including winter service.

Each road authority operates, manages and maintains its roads according to the related regulations and specifications under the Countermeasure Law against Natural Disasters.

· Guideline of the road and level of service

According to the governmental guidance, road authorities perform winter maintenances to meet following standards and specifications.

TABLE 5- LEVEL OF SERVICE FOR WINTER EVENTS

Grade	Los	Countryside	Urban
Level A (chemical & plow)	2hours	expressway Over 4lane road (above 20,000veh/day)	City express-wayMain street
Level B (chemical & plow)	3hours	Over 4lane road (under 20,000veh/ day) 2lane road (above 5,000veh/ day)	the subsidiary main streets
Level C (plow)	5hours	2lane road (under 5,000veh/ day)	subsidiary roads
Level D	-	2lane road (under 500veh/ day)	etc

· RULES REGARDING TYPE AND CHARACTERISTICS OF MATERIALS AND EQUIPMENT.

Until late in 1990s, most of road maintenance and management authorities had used natural sand, solid calcium chloride or mixed one even in the big city area.

In the meantime, Korea Expressway Corporation (KEC), a state-run company, introduced spreading method of pre-wetted sodium chloride with calcium chloride brine, 30 % of concentration, in 2000. And thereafter, the KEC uses only small quantities of sand on special sections of steep slope. The purpose of applying chemical agents is to melt down snow and ice and prevent freezing on the pavement surface. The KEC

has been a front runner to develop new technologies in the fields of road transportation. After that, most of road authorities and contractors follow KEC's winter maintenance strategy, applying sodium chloride, calcium chloride and/or with mixed brine as an anti-icing or deicing chemicals in Korea.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Republic of Korea is a quite densely populated country, and the economic activities of the people have been really active day and night. And so, the road authorities are absolutely responsible for maintaining their roads in good condition and open to traffic. We cannot imagine any closing of roads under any circumstances. In a winter situation, the road administrator eliminates or at least reduces problems in road serviceability according to the schedule set in the winter maintenance plan.

• ORGANIZATION OF WINTER MAINTENANCE

Road maintenance authorities are organized based on the level of roads. Each road authority is divided into many branch offices and each branch office is responsible for winter maintenance in its own road network.

TABLE 5- ORGANIZATION OF WINTER MAINTENANCE

Level of road	Responsible	authority maintenance offices	Staff members and equipment per office
Express way	Korea Expressway Corporation	53 branch offices	46 employees, 14 units of equipment (12 spreaders, 1 wheel loader, 2 backhoes)
National road	National road maintenance office	18 maintenance offices	33 employees, 31 units of equipment (24 spreaders, 1 wheel loader, 6 backhoes)
City road	City road maintenance office	7 special city maintenance offices	53 employees, 68 units of equipment (55 spreaders, 2 wheel loaders, 7 dump trucks, 2 backhoes)
Regional road	Provincial office	9 provincial maintenance offices	50 employees, 56 units of equipment (26 spreaders, 1 grader, 24 dump trucks, 5 backhoes)
County road	County office	155 Counties	18 employees, 11 units of equipment (9 spreaders, 2 backhoes)

FIGURE 4- EQUIPMENT FOR WINTER EVENTS



• OPERATIONAL MANAGEMENT OF WINTER EVENT

Considering weather forecast and road condition, the road administrator shall make a decision to spread materials and/ or mobilize equipment on the roads. According to the governmental regulation, snow exceeding 3cm depth shall be removed by snow plow and applied by deicing chemicals on it.

Frost, ice, and snow up to 3cm of height shall be melted down or removed with the help of deicing chemicals and/or machineries. Some places on the steep slope section of the road, abrasives like sand, shall be additionally spread. We also distinguish just plowing, just spreading chemical materials or both activities carried out simultaneously based on road condition.

In the case of the Korea Expressway Corporation (KEC), each maintenance office covers 70~80 kms of

FIGURE 5- EQUIPMENT FOR WINTER EVENTS



AUTOMATIC SPRINKLING SYSTEM(BRINE)

ice control measures. And so, we can use only the statistics on the melting materials here and you can estimate the cost of a year with the consumption of the snow melting material.

TABLE 6 – SNOW MELTING MATERIALS (2015)

Road	Consumption (ton/year)			Consumption (ton/km)
	Total	NaCl	CaCl2	
Expressway (KEC)	206,329	174,986	30,143	49.2
National roads	136,874	109,923	24,281	9.8
City road (7special city)	82,286	45,439	36,829	17.4
Local authority	286,870	161,085	125,784	4.2

According to variable contract conditions in winter periods utilizing equipment for winter, maintenance show large differences as follows. All data is given for expressway and national road.

But city road and local authorities have different standards.

TABLE 7 – EQUIPMENT (2015)

Road	Winter service equipment		
	Total	Spreader	Loading equip
Expressway (KEC)	713	600	113
National roads	589	462	127
City road (7special city)	16,197	1470	14,727
Local authority	4,547	2821	1,726

3.4 TRAFFIC SAFETY AND INFORMATION

Road maintenance in winter season is an important thing, but providing road users with weather information and traffic information is more important to increase smoothness of driving and to prevent traffic accident.

Road authorities provide all sorts of information related to road situation to the users through mass media, internet service, smart phone, road auxiliary facilities and so on. Anyone who wants to travel somewhere can get all the necessary information using any of



FIGURE 6- ROAD SURFACE MONITORING SYSTEM

expressway and operates 12 units of spreader truck which is mounted with an accessory snow plow, 1 blower, 1 wheel loader, 2 backhoes, 1 calcium chloride brine manufacturing facility, and so on.

Each office especially operates several automatic calcium chloride brine sprinkling systems on the vulnerable sections such as interchange ramps and steep slopes. The sprinkling systems are automatically operated and controlled by smartphone and/or internet service.

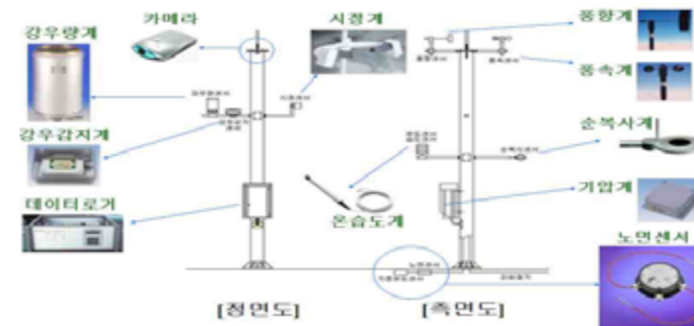


FIGURE 7- ROAD WEATHER MONITORING SYSTEM

WINTER MAINTENANCE MONITORING & CONTROL SYSTEM

Each maintenance office operates monitoring system and controlled winter service equipment.

ROAD WEATHER INFORMATION SYSTEM

There are over 100 road weather information stations in expressway.

3.3. ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES AND COSTS

We cannot use nationwide statistics of the snow and

the above sources before his or her departure. Timely acquisition and analysis of the road information helps the road users to choose a comfortable and safe route to travel in advance.

There are two kinds of communication means to transfer information. The first one is preliminary provision of information using the following tools.

TABLE 8 – COMMUNICATION TOOLS

Internet homepage	www.roadplus.com www.its.go.kr / www.utis.go.kr
Mass media	Local broadcasting station, TBN (Transportation Broadcasting)
Smartphone app	Expressway Transportation Information App., National road Transportation Information App.

The second one is the provision of real-time information on the road situation using road auxiliary facilities. The accessory facilities are Variable Message Signs(VMS), signboard and so on. Transportation control center provides real-time information about weather and road situation through the tools. Recognizing the real-time information, the road users can drive on the road without any difficulties. In total, 1,054 VMSs on the expressways and 580 VMSs on the national highways are respectively being operated in the Republic of Korea.

ROAD INFORMATION PROVISION METHOD AND SYSTEM

Road authorities provide all sorts of information including road condition, traffic information and weather information through SMS and road accessory facilities. Road users can get necessary information to travel anywhere and anytime through the above sources.

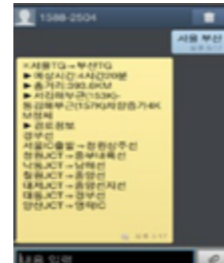
4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY

Korea Expressway Corporation had tried to apply electro-thermal snow melting system under asphalt concrete pavement until the end of 1990s. However, a big budget was required to install and operate the system because it consumed excessive quantity of electric energy and the initial investment for installation was



INTERNET SERVICE (ROAD CONDITION AND TRAFFIC INFORMATION)



SMS THROUGH CELL PHONE OR SMART PHONE (ROAD CONDITION)



APPLICATION FOR EXPRESSWAY TRAFFIC INFORMATION



VMS (ON THE ROAD)

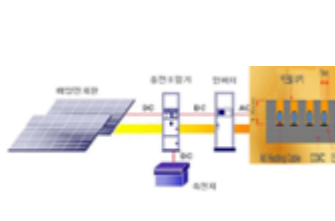
too expensive as well. After that, some researchers have tried to minimize the initial cost and operational cost of the system.

Nowadays, the solar energy and geo-thermal energy will meet the needs. We are on the way to develop a new snow melting system using geo-thermal energy.

The KEC experimentally installed snow melting systems on the expressway pavement using geo-thermal energy in 2010 and using solar energy in 2011. The geo-thermal energy was more economical and useful between the two. Therefore, the KEC is trying to develop a more useful energy for winter expressway maintenance.

4.2 NEW MANAGEMENT AND ORGANIZATIONAL APPROACHES

Each road authority prepares and uses its own winter service manual. According to the manual, the admini-



SOLAR ENERGY



GEO-THERMAL ENERGY

instrument and the object of measurement. This equipment delivers the following data: Road surface temperature, water film height, dew point temperature; road conditions: dry, moist, wet, snow, ice; ice percentage; friction; rel. humidity, air temperature.

ROAD SURFACE ICING PREDICTION SYSTEM

This system analyzes weather forecasts and displays the probability of the occurrence of freezing of highways, thereby playing a role in assisting the decision making function of road managers.

In addition, it provides road users with road surface information to assist drivers to drive more carefully in severe road conditions.

5. REFERENCES

- Eco-friendly Energy Green Snow-removal Plan. Korea Expressway Corporation, 2011
- Annual report on statistics of Land and Marine. Ministry of Land, Transportation and Marine, 2015
- Maintenance and rehabilitation manual (Snow removal). Korea Expressway Corporation, 2012
- Administrative division and population of District administrative authorities. Ministry of Administration and Safety, 2015
- The effects and countermeasures of Chlorides on cement concrete structures. Expressway and Transportation Research Institute, 2007

WEBSITES:

- www.roadplus.com
- http://metsky.kma.go.kr/(Anti-natural disaster and Meteorological Portal)
- research.ex.co.kr (Expressway and Transportation Research Institute)
- www.ex.co.kr (Korea Expressway Corporation)
- www.mltm.go.kr(Ministry of Land, Transportation and Marine)
- www.kma.go.kr(Bureau of Meteorology)



MONITORING DISPLAY (MARWIS-UMB IN LUFTT)



SURFACE DETECTING VEHICLE

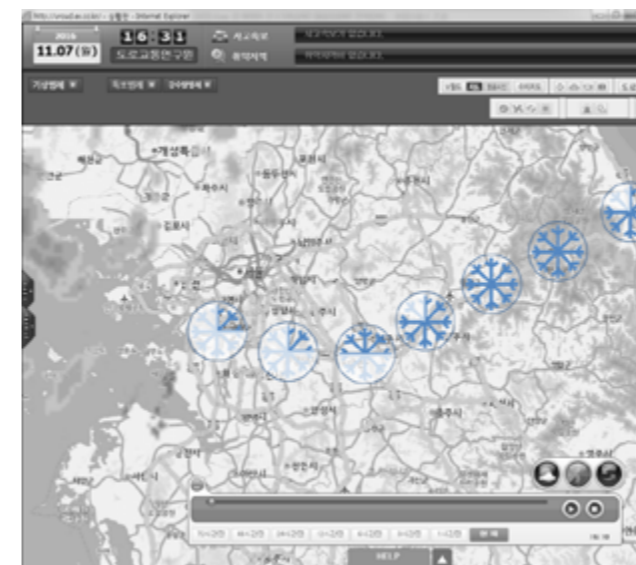
strators and contractors perform their road management and control the quantities of materials based on temperature change and snow depth.

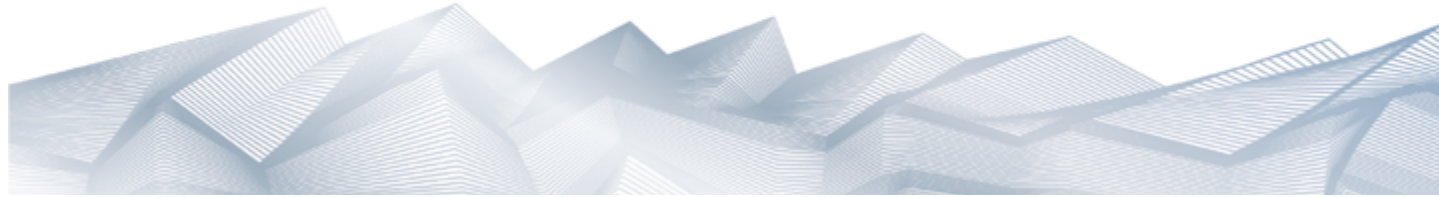
Especially, snow melting chemical materials such as calcium chloride and sodium chloride have a severe effect on road facilities and the environment.

So, Expressway and Transportation Research Institute of the KEC is on the way to perform a research project to establish standard specifications for eco-friendly snow melting materials.

ROAD SURFACE MONITORING SYSTEM

Prototype for the road surface detection of water, ice and snow as well as friction can be installed on vehicles with a distance of 1-2 meters between the measuring





1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Slovenia is a Central European country, situated in the heart of Europe between the Mediterranean Sea, the Alps and the Pannonian Plain. Slovenia became an EU member on 1 May 2004, adopted the euro on 1 January 2007 and has been a member of the Schengen area since 21 December 2007.

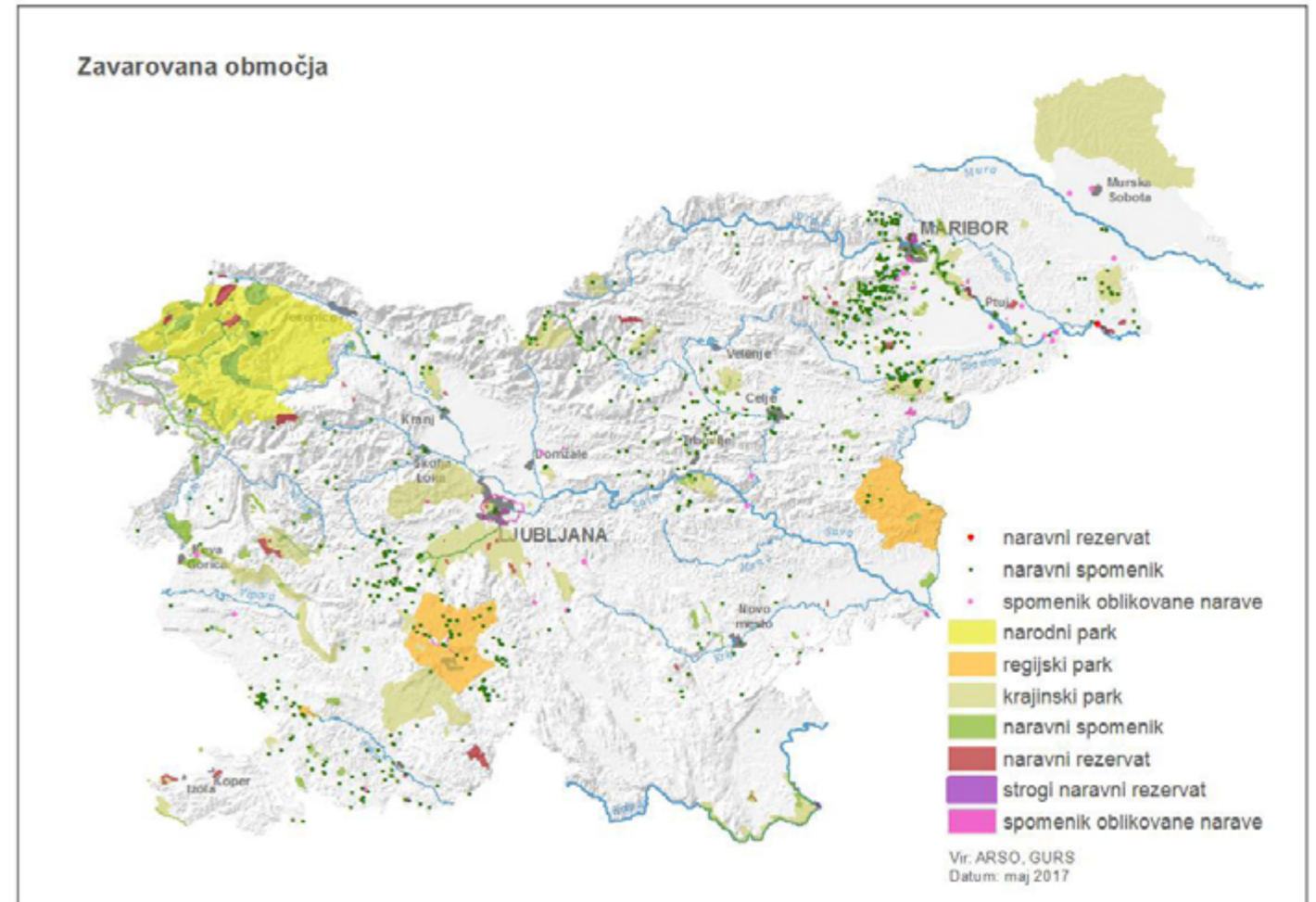
The country covers an area of 20,271 km², as much

as 58% of which is forested. This ranks Slovenia third in the European Union in terms of forest cover. Furthermore, 48% of its area is 500 m above sea level, which is characteristic of hilly topography. Slovenia borders four countries, all of which are members of the European Union: Italy (a 280-km border), Austria (a 318-km border), Hungary (a 102-km border) and Croatia (a 670-km border).

The country is a parliamentary representative democratic republic and its capital is largest city Ljubljana.



MAP OF SLOVENIA (SOURCE: [HTTP://WWW.MAPNALL.COM/SL/MAP/ZEMLJEVIDSLOVENIJA_3856.HTML](http://www.mapnall.com/sl/map/zemljevidslovenija_3856.html))



PROTECTED AREAS (SOURCE: [HTTP://WWW.ARSO.GOV.SI/NARAVA/ZAROVOVANA%20OBMO%20C4%8DJA/KARTA/](http://www.arso.gov.si/narava/zarovovana%20obmo%20c4%8dja/karta/))

On April 2018, the country had a population of 2,067,284 inhabitants, dispersed in 6,035 settlements and 212 municipalities. Although most of its inhabitants are Slovenes, two national minorities – the Italian and the Hungarian National Communities, as well as the special Roma Community, live in Slovenia.

In Slovenia the average population density is 102 people per km², with a GNP (Gross National Product) 20.815 EURO/inhabitant.

Slovenia's natural resources are well preserved and there are 269,475 (13,29 %) hectares of protected areas and natural parks, divided between:

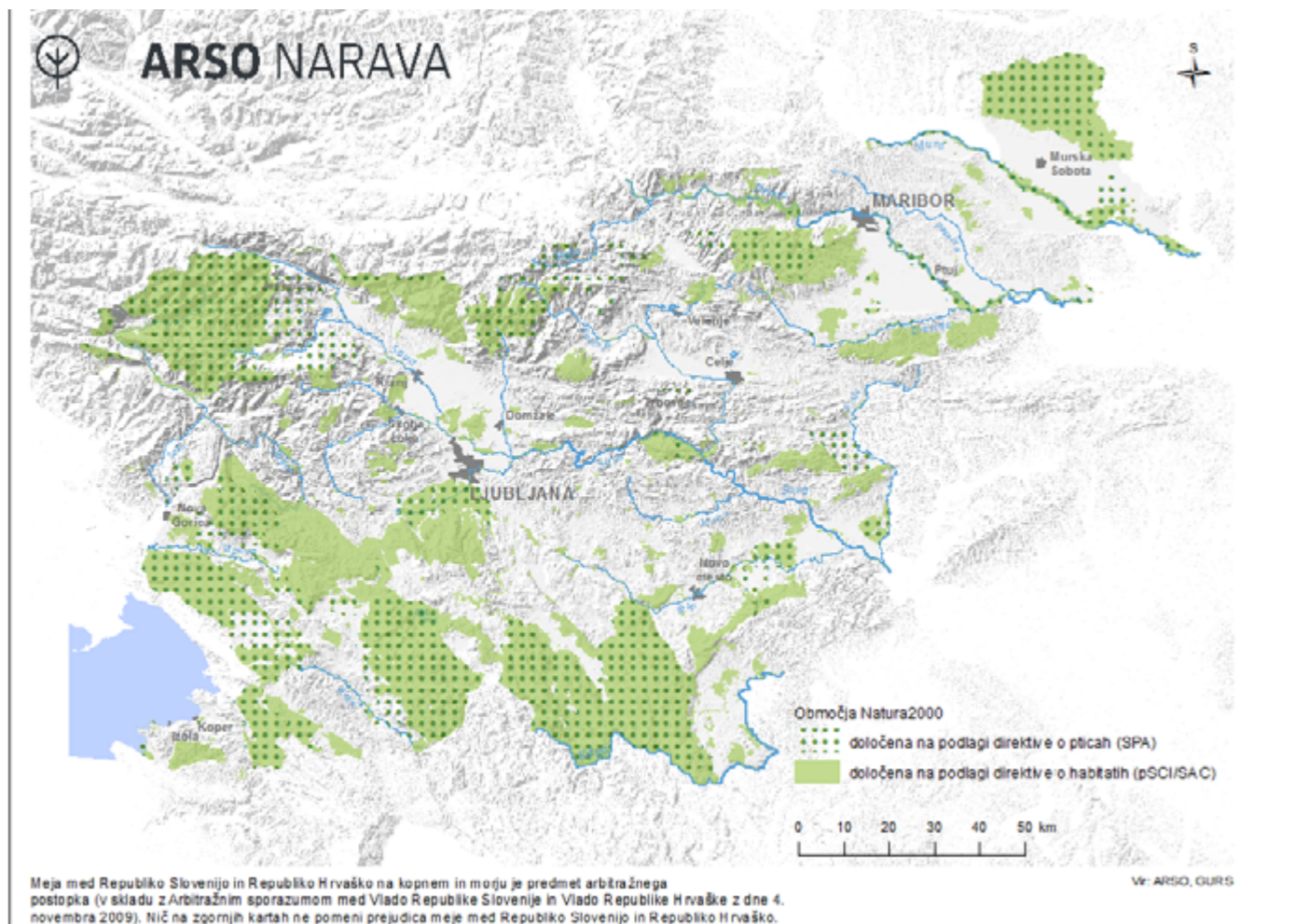
- 1 national park (the Triglav National Park with 83,982 hectares);
- 3 regional parks;
- 44 landscape parks;
- 1 strict natural reserve;
- 56 natural reserves and
- 1.164 natural monuments.

Slovenia has designated 355 Natura 2000 sites, 324 according to the Habitats Directive and 31 according to the Wild Birds Directive. These areas cover more than 37% of the national territory. Most of Natura 2000 sites are covered by forests (71%), only 5% of which are above the tree line. 29 % of the Natura 2000 sites consist of protected areas (the Triglav National Park, regional and landscape parks, reserves and natural monuments).

1.2 ROAD NETWORKS AND TRAFFIC

HISTORY OF ROADS IN SLOVENIA

Slovenian transport routes developed some thousands of years ago thanks to Slovenia's geographical formations (Alpine, Pannonian and Mediterranean) and its favorable location in the European region. People with their religious, social, economic and military ten-



NATURA 2000 (SOURCE: [HTTP://WWW.ARSGO.GOV.SI/NARAVA/NATURA%202000/KARTA/](http://www.arsgo.gov.si/narava/natura%202000/karta/))

dencies played an important role in their development. Moreover, historical changes have affected their expansion. The route linking the Mediterranean and the flatland Ptujsko polje - along the Eastern Alps, the Postojna pass and the moor Ljubljansko barje - has been developed already in the Stone Age.

The latter was the most convenient and direct route for west to east land transport, to which all transverse road routes have been connected. Later on, important long-distance trade routes passed through Slovenia (Amber Road, Iron Route, Noricum Route and Salt Route) and the road network was expanded along the routes in all directions.

The road network, developed in the Roman era was ahead of its time in terms of economic, commercial and military needs. Even though there weren't any major trade centers in Slovenia since routes served mostly for transit purposes, the road network was further expanded

in the Medieval period. In the 14th century, most of the territory of Slovenia was taken over by the Habsburgs who gained access to the Adriatic coast. Their rule influenced the development of the road network in the Karst area.

Contemporary roads

The public roads in Slovenia are managed by the state and municipalities. The total length of the road network (as of December 31, 2017) is:

CATEGORY OF ROAD	LENGTH (km)
Motorways	685
Expressways	96
Main roads	807
Regional roads	5.129
Total state roads	6,717

Local roads	13,361
Public paths	18,885
Total municipal roads	32,246
Total public roads	38,963

Besides the above-mentioned roads, the forestry service also manages 13,000 km of forest roads; these are, to a large extent, in public use.

TRAFFIC LOADS ON STATE ROADS

After years of financial crises, which had a significant impact on the negative trend of traffic, Slovenia is currently experiencing its increase. The annual average daily traffic in 2016 was 32.433 vehicles per day on motorways (12% of them were heavy-duty vehicles) and 7.434 vehicles per day on main roads (4% of them were heavy-duty vehicles).

The share of heavy-duty vehicles ranged from 10 to 20% on transit routes; however, the highest share (40%) was recorded on the routes in the direction to Hungary.

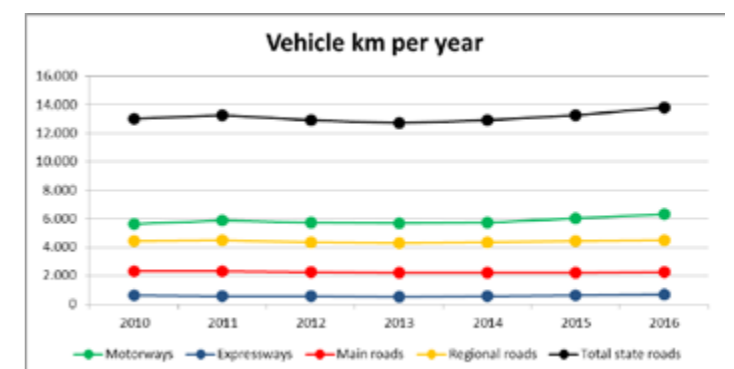
The motorization level has come to 1.3 cars/ household

REGISTERED MOTOR VEHICLES

YEAR	TOTAL	CARS
2010	1.375.556	1.068.932
2011	1.386.890	1.074.109
2012	1.393.645	1.073.967
2013	1.396.691	1.071.922
2014	1.412.316	1.076.962
2015	1.437.531	1.087.686
2016	1.469.501	1.106.116
2017	1.524.582	1.128.214

2 CLIMATE

Slovenia is situated on the verge of the Alps, which has a significant impact on the climate. Snowfalls can be frequent, especially in the Alps, as well as elsewhere throughout the region, except in the coastal strip. In order to provide acceptable level of service for daily migrations, road winter management needs to deal with adverse weather conditions on a large road network, regardless of time. The latter is the result of dispersed settlement.



Because of Slovenia's position at the intersection of the Mediterranean, Alpine and Pannonian areas, its climate conditions vary significantly across the country. This can lead to frequent daily and seasonal variations in temperatures and in precipitation. Consequently, these variable road conditions require frequent and prompt response by the road winter maintenance service.

There are substantial differences between western and eastern Slovenia, especially regarding the average annual snowfall covering the roads.

While there are only two days of snow cover per year in Primorje (the Slovenian Littoral), there are annually 45 snowy days in Postojna, which is located only 30 km away from the coast.

In the other parts of Slovenia there are 50 to 70 days of snow cover in the lowlands and more than 100 in the highlands. An important data for the winter service is the average annual number of days with more than 10 cm of new snow; there are 15 to 30 days of such snow in the areas of both mountain barriers and 10 to 15 such days in the lowland areas. Primorje has special characteristics because snowfall is very rare. Nevertheless, gale force winds, and sometimes also snow drifts, cause traffic problems.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Classification of the roads

The process of ensuring the passability of roads is carried out in accordance with six priority classes concerning:

- The category;
- The density and structure of traffic;
- Geographic /climatic conditions and

● Local characteristics.

Class 1: includes motorways and expressways, which must be passable 24 hours a day. When snowing, passability shall be ensured along the entire carriageway, as well as on important crossroads and access roads to larger car parks; however, emergency lanes also have to be passable. In the event of heavy snow, at least one carriage lane has to be passable, as well as access roads to larger car parks.

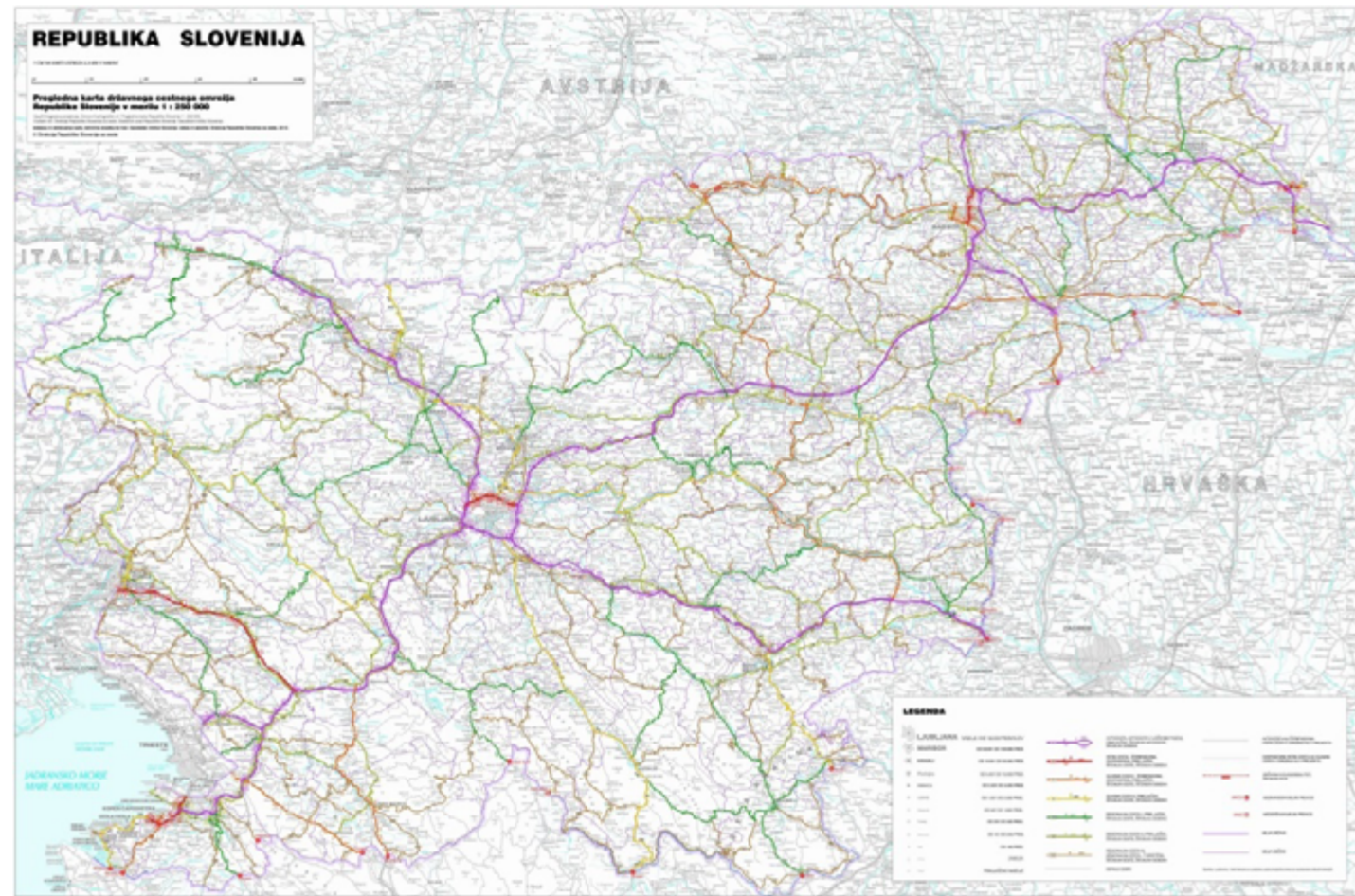
Class 2: includes roads with AADT > 4000 vehicles, main roads, main urban roads and important regional roads. These roads need to be passable between 5 am and 10pm; when snowing, two-hour traffic delays are acceptable between 10 pm and 5am. In the event of heavy snow, at least one lane has to be passable with a possibility of the up to two-hour delays between 10 pm and 5 am.

Class 3: includes the rest of regional roads, important local roads, urban feeder roads and local roads, which have to be passable between 5 am and 8pm; when snowing, two-hour traffic delays are acceptable between 8 pm and 5am. In the event of heavy snow, at least one lane has to be passable with a possibility of delays between 8 pm and 5am.

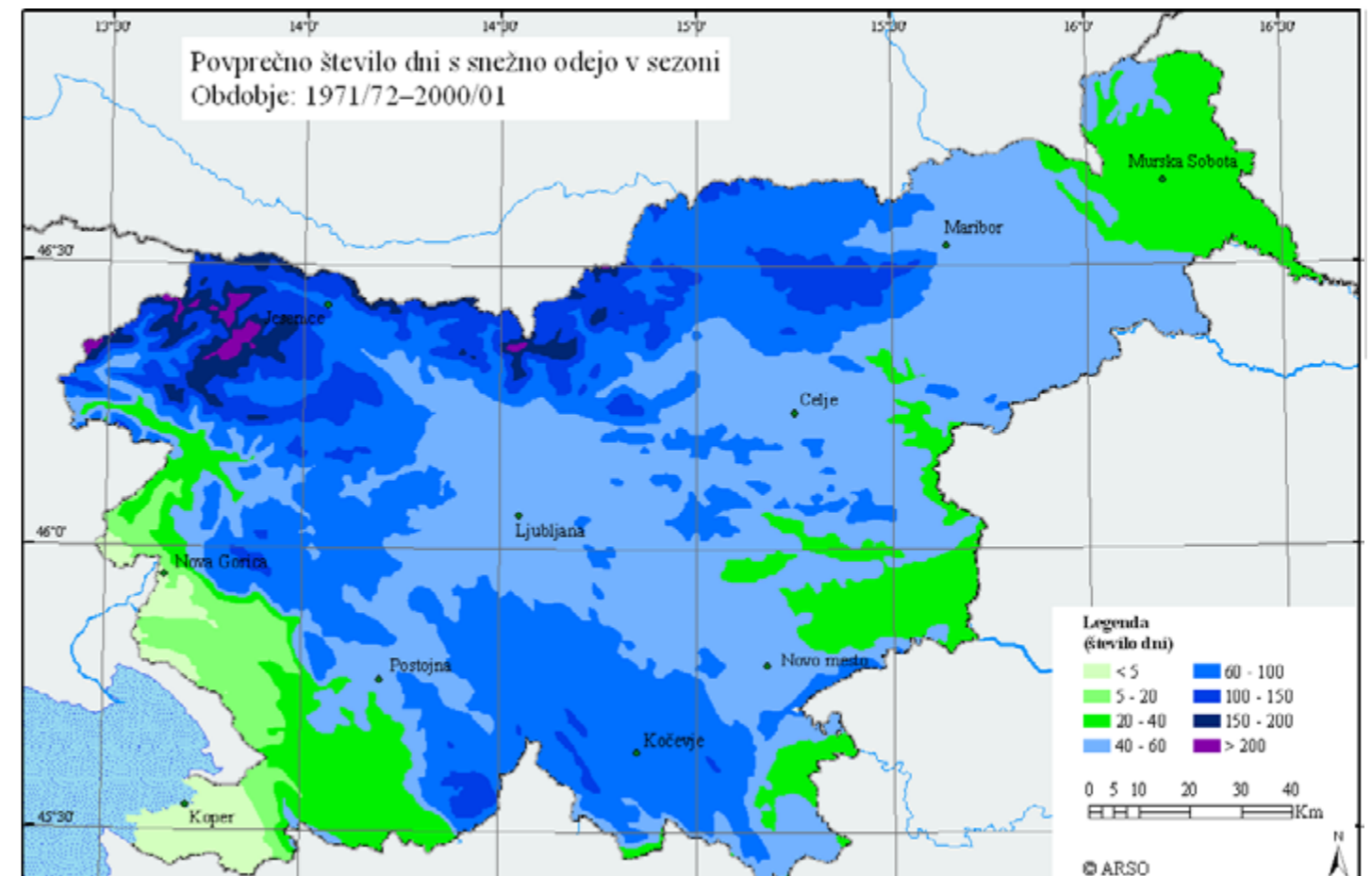
Class 4: includes the rest of the local roads, urban roads and suburban roads, as well as state roads with AADT < 100 vehicles. As a rule, these roads have to be passable between 7 am and 8 pm.; however, when snowing, shorter traffic delays are acceptable. In the case of heavy snow, one-day delays are possible as well.

Class 5: includes public paths, regional tourist roads, car parks and cycle tracks, for which the passability is ensured on the basis of local needs. When snowing, one-day holds-up are acceptable, and in the case of heavy snow, holds-up may last even longer.

Class 6: includes pedestrian surface, which needs to be passable between 7 am and 8 pm in relation to local needs. In the event of snow or heavy snow, access to public buildings must be ensured.



NATURA 2000 (SOURCE: [HTTP://WWW.ARSLGOV.SI/NARAVA/NATURA%202000/KARTA/](http://www.arslo.gov.si/narava/natura%202000/karta/))



AVERAGE NUMBER OF DAYS OF SNOW-COVER DAYS (SOURCE: [HTTP://METEO.ARSLGOV.SI/UPLOADS/PROBASE/WWW/CLIMATE/IMAGE/SL/BY_VARIABLE/SNOW/MEAN-SEASONAL-SNOW-COVER-DURATION_71-00.PNG](http://meteo.arslo.gov.si/uploads/probase/www/climate/image/sl/by_variable/snow/mean-seasonal-snow-cover-duration_71-00.png))

Class 7: includes roads and bicycle paths that are closed for traffic in winter conditions.

The exclusion of freight vehicles from traffic

In accordance with the provisions of the Order on Traffic Restrictions on Roads in the Republic of Slovenia, freight vehicles with trailers and vehicles transporting dangerous goods are prohibited from driving on all Slovenian roads, when snowing or blowing hard, and they shall be excluded from traffic. On motorways and expressways, 62 locations in total are envisaged (39 on the resting places and 23 on the routes), at which vehicles are excluded from traffic.

These locations have room for 7.473 freight vehicles (1.448 on the resting places and 6.025 on the routes), while on other state roads there are another 32 locations which can accept 850 freight vehicles. As a rule, these capacities are not sufficient, so occasionally, additional suitable areas are rented out.

Rules regarding materials

The road gritting material, used in Slovenia, is sea salt (NaCl), and to a smaller extent also calcium chloride (CaCl₂) and magnesium chloride (MgCl₂). The latter is mainly used for preventive gritting on motorways, expressways and major roads, and in the event of low temperatures (-8 °C). In the last few years, roads have been sprayed with a salt solution which prevents salt being blown off from dry roads under heavy traffic conditions. This way the response time for ice melting is shortened.

Use in kg/m²

	MIN	MAX	AVER.	CaCl ₂ portion
motorways	0.9	2.1	1.7	12%
other roads	0.6	1.85	1.34	0.6%

The average costs for winter maintenance in the last ten years (in millions of EUR):



	GRITTING MATERIAL	EQUIPMENT PERSONNEL
motorways	1.75	13.25
other roads	3.10	13.2

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

During the winter period, extending as a rule, from 15 November to 15 March, roads are maintained in accordance with the winter service implementation program, which is prepared by the routine maintenance contractor, who submits it for acceptance to the specialist service at the latest by October 15th of the current year.

The winter service implementation Program includes:

- the organizational scheme of management responsibilities and competences of winter service providers, with data of interactive communication (e.g. contact information, information about data centers);
- the coordination of different winter service providers on the same roads in settlements (e.g. maintenance of pedestrian and cycling areas, intersections, connections, bus stops and their access, removal of snow, disposal to landfills);
- locations of constant higher concentration of pedestrians origins or destinations, their use of public facilities or public areas in settlements (e.g. schools, shopping centers, railway and bus stations, health centers, hospitals, homes for the elderly, sports facilities, cultural institutions, public car parks);
- head of coordinated work of various operators;

- the list of contractors;
- the schedule of preparatory work;
- the road network plan with priority classes names and starting points for the implementation of the winter service (road database);
- the list of particularly difficult road sections at the occurrence of unfavorable weather conditions;
- the list with the location specification for the positioning of traffic signals during the winter service;
- the list of weather stations which data is taken into account when implementing the winter service;
- the arrangement of machinery, equipment, gritting materials and workers to carry out the planned works;
- the list of special machines;
- on-call and stand-by duties, attendance obligations and work groups schedules;
- paths sprayed with gritting material against snow and freezing rain (salted and cleared paths);
- the location and method of separating certain types of vehicles in the event of unfavorable road conditions;
- the method of data collection and the public information scheme on the condition and transportability of roads;
- the work after the winter service (e.g. removing residues of road gritting materials, temporarily installed traffic signs and traffic equipment, road devices and arrangements for road and traffic insurance in the winter period).

Preparatory work is carried out before the beginning of the winter period, in order to enable the winter service to work effectively.

The preparatory work includes, in particular, the following:

- the preparation of machinery, traffic signalization, traffic equipment and gritting materials;
- the preparation of the road and its surroundings (installation of additional traffic signalization in dangerous places, positioning of snow poles, installation of devices and other arrangements for protection against snowdrifts - palisades),
- cleaning and arrangement of drainage systems and carriageways,
- professional training and education for workers operating in the winter service.

After the end of the winter period, it is necessary to remove the remains of gritting materials (sand), as well as the temporary supplementary traffic signals, temporary traffic equipment, road devices and facilities for the protection of roads and traffic in winter.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

For some years now, the costs of winter maintenance for state roads have been rising; they come up already to approximately 50% of the total maintenance costs. At the same time, the use of salt is questionable with respect to the damage it causes to vehicles as well as to the environment, road facilities and groundwater.

It is not possible to stop salting completely; otherwise traffic safety would be impaired. Replacing salt with sand materials is uneconomical and inefficient in regard to contemporary traffic. The economic benefits of using salt are several times higher than the costs and damages it causes.

In order to protect the environment, the amount of necessary salt used for traffic safety has to be limited. Consequently, salt gritting of roads has been reduced to the minimum.

Up-to-date technical equipment and regular education of all participants in the winter road service are of great importance for maximizing impact. The attitude of technicians facing maintenance problems has had to be changed as well. Modern equipment is also critical

to ensuring quality maintenance. Clearing and salting have been optimized. Users are also obliged by law to use winter equipment on their vehicles.

What to do in the future

Analyses show that the fixed costs for road winter service, namely the costs for on-call and stand-by duty services, represent a large amount. To reduce these costs, a system is being introduced for monitoring road conditions at critical points and observing local weather conditions (road-weather station, video surveillance). It is being connected with the road-information system. Besides, up-to-date technical equipment is being introduced for calibrated dosing of gritting materials.

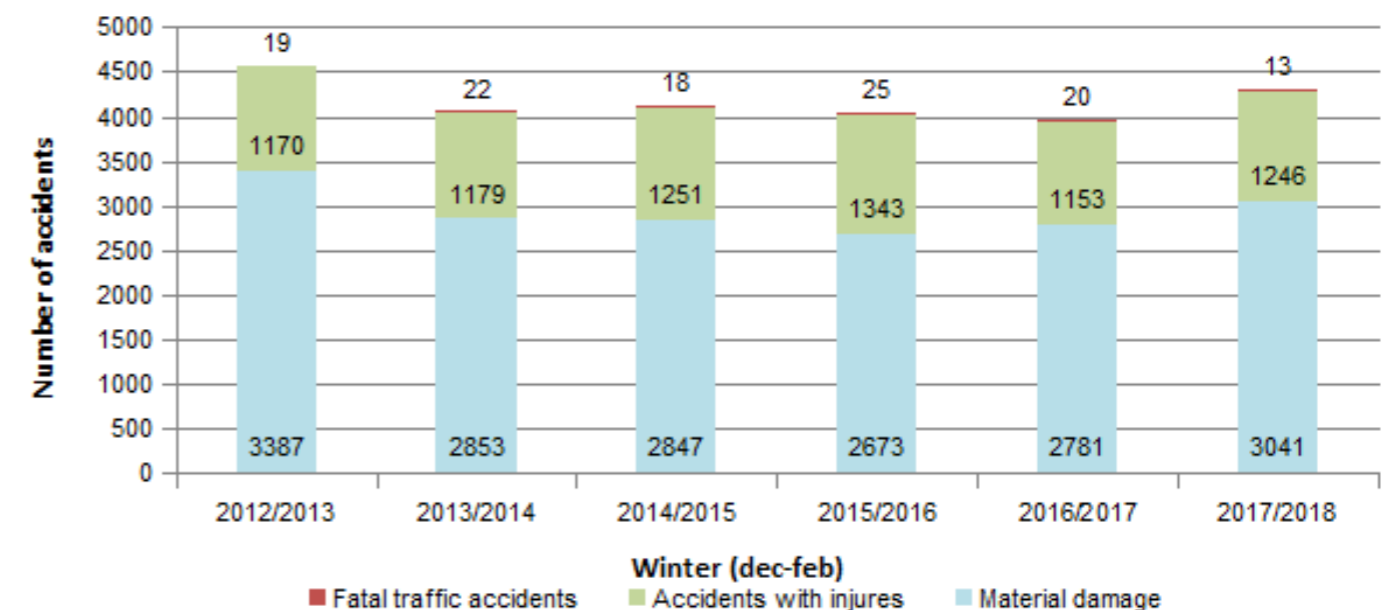
3.4 TRAFFIC SAFETY AND INFORMATION

Traffic safety

Traffic safety in Slovenia is still not satisfactory. An analysis of the situation made for the needs for Slovenian Traffic Safety Agency, showed that:

- 0.30% of fatal traffic accidents;
- 28.98% of traffic accidents with injures, and;
- 70.72% of traffic accidents with only material damage occurred during the 2017/2018 winter.

Road conditions and passability, as well as weather conditions and observing of regulations (e.g., winter equipment for vehicles) have a substantial impact on the occurrence of accidents and their increase in number.



SLOVENIA

Most of traffic accidents in winter occur in relatively good driving conditions but can end with severe consequences. These findings are based on the fact that most drivers are aware of the dangerous driving conditions in winter, but as soon as the conditions improve, they forget about the dangers and drive carelessly or with reduced attention.

The most frequent reason for traffic accidents in winter is speeding, which is especially connected with favorable conditions on roads. The milder and drier the winters are, the greater is the risk of speeding.

The Ministry of Infrastructure and, consequently road managers, are responsible for the goals of the National Program for Road Traffic Security, namely:

- Construction of the traffic infrastructure;
- Introducing measures to slow traffic down;
- Traffic education;
- Preventive measures and publicity actions;
- Surveillance.

Road users Information

During the winter time, several methods of informing the public on road conditions are used:

- Radio and TV stations - in live;
- Telephone call to a specific number, directly via mobile appliances;
- Web pages of road managers and of the information center of the Automobile Association of Slovenia;
- Smart phone Apps;
- Traffic data are communicated also to ERIC (European Road Information Center) at its registered office



A TRAFFIC CAMERA AT LOILBL PASS (LJUBELJ PASS)

- in Geneva;
- Through information portals on the roads;
- INFO-pillars at the rest areas along motorways;
- Personal advice at information centers.

In accordance with the provisions of the Public Roads Act and regulations on the maintenance of public roads, road maintenance companies have to report regularly and in special circumstances on the conditions and passability of roads.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

With the purpose of improving road winter maintenance and environment protection, several researches and studies have been made, such as:

- Quick and efficient methods to control the quality of ice-melting substances;
- Checking the possibilities of excluding freight vehicles from traffic in the event of strong wind conditions;
- The introduction of weather-road stations into winter road maintenance;
- Determining the basic hydro-geological criteria for increasing the active protection of groundwater in the case of pollution on the Slovene road network;
- Effects of road gritting on the environment;
- An analysis of the winter service organization and operation.

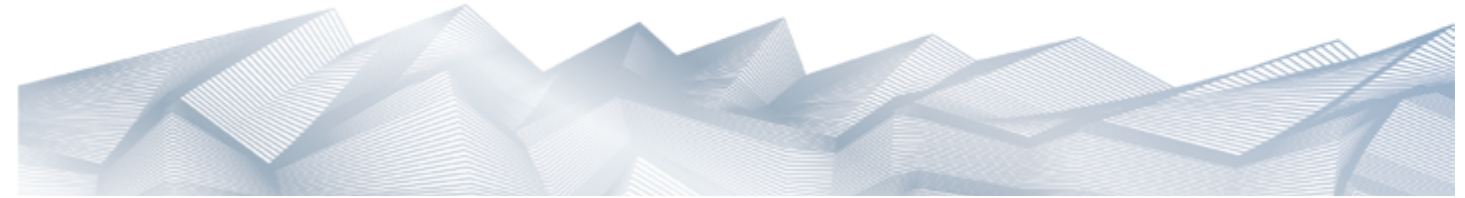
The conclusions of the studies could be summarized as follows:

- too many gritting materials are used which have negative impacts on road structures, vehicles, groundwater, vegetation and the health of people;
- the pollution (especially of waters) can be substantially reduced by introducing special facilities;
- damage to road structures and facilities can be reduced with appropriate maintenance.

Therefore, the Slovene road managers have employed wet salting, which results in a reduced use of salting materials; the materials used are purer and of higher quality with the least harmful agents possible. By using up-to-date machinery, by monitoring and timely informing road users on road conditions, we endeavor to foster winter road maintenance rationalization and environment protection.



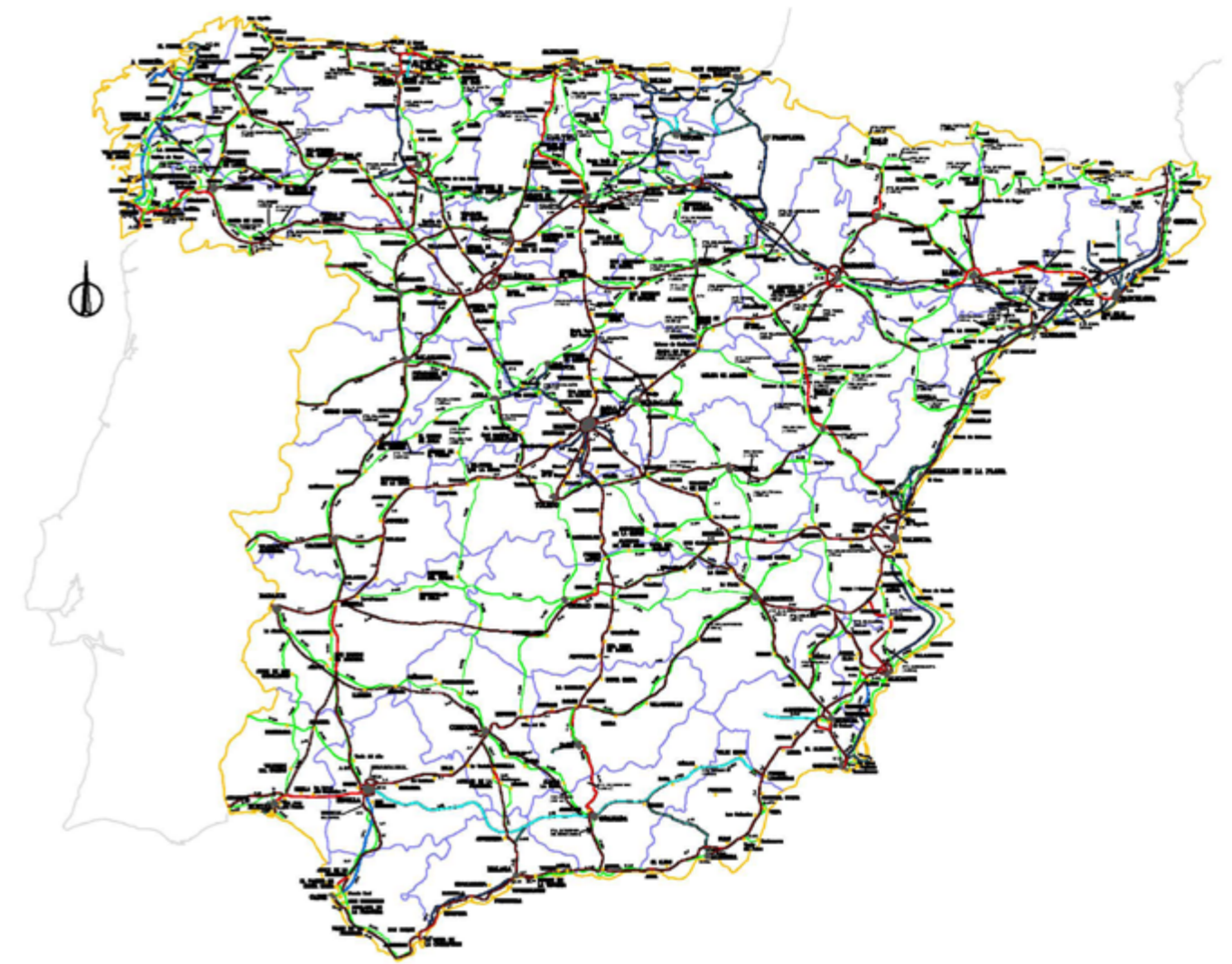
SPAIN



1. DEMOGRAPHICS AND ROADS

Spain is a southern European country located on the Iberian Peninsula. Its territory covers an area of 505,954 km², bounded to the north by the Cantabrian Sea and the Pyrenees (which cover the border

between Spain and France), to the east by the Mediterranean and to the west by Portugal and the Atlantic. The Strait of Gibraltar is the southernmost limit of Spain and is the closest point between the continents of Europe and Africa (14 km). The country's population was 46.8 million in 2011, representing a density of 92 inhabitants per square kilometre.



SPAIN'S ROAD NETWORK (MAIN ROADS)

An outstanding topographical feature of the Spanish peninsula is a large central massif, known as the Castilian Plateau, which covers almost 50% of the national territory and is at a considerable altitude. This plateau is not only one of the reasons why Spain has the second highest average altitude above sea level (660 m) in Europe, but also the reason why the country has a significant East-West slope. The waters of the Spanish Peninsula flow with different volumes to the three seas surrounding the country due to the fact that the climate and, above all, the orographic characteristics influence the distribution and importance of the hydrographic system, with the Atlantic receiving the largest inflow. The Meseta is divided into two sections by a central mountain range, whose surroundings are surrounded by several mountain ranges (except on the western side, where the plateau decreases gently towards Portugal).

Administratively, Spain is a parliamentary monarchy, composed of seventeen Autonomous Communities or regions:

Andalucía	8.3
Aragón	1.3
Asturias	1.0
Balearic Islands	1.1
Canary Islands	2.1
Cantabria	0.6
Castile-La Mancha	2.0
Castile-León	2.5
Catalonia	7.2
Valencian Community	5.0
Extremadura	1.1
Galicia	2.7
Madrid	6.4
Murcia	1.5
Navarre	0.6
Basque Country	2.1
La Rioja	0.3
Ceuta	0.077
Melilla	0.078
TOTAL	46.81

POPULATION FIGURES OF THE 19 AUTONOMOUS COMMUNITIES (IN MILLIONS OF INHABITANTS. 2011 DATA)

This political agreement is similar to an organization of federal states. The regions of Spain have a broad level of self-government including legislative, budgetary,

administrative and executive powers, guaranteed by the central State to each region through the corresponding Statute of Autonomy. Each autonomous community is in turn divided into one or more provinces, adding a total of 50, plus the autonomous cities of Ceuta and Melilla.

For administrative purposes, the Spanish road network is organised under three different levels of authority: firstly, the state road network under the Ministry of Development (Central Administration); secondly, the regional road network (run by the autonomous communities); and finally, the local road network run by provincial councils and town councils.

The State Highway Network includes the national highways that form the long-distance routes linking the different regions. The autonomous road networks are regional in scope, as their name indicates, while the road network run by the town councils and councils are local in scope.

The different networks have the following lengths of roads, divided between high-capacity (motorways, highways...) and normal to low-capacity (one-lane roads in each direction, smaller roads):

SPAIN: ROAD NETWORK (2016)

State run network	High capacity roads	11.957 km
	Normal to low capacity roads	14.438 km
	TOTAL	26.395 km (16%)
Local and regional management network	High capacity tracks	5.152 km
	Normal to low capacity roads	133.936 km
	TOTAL	139.088 km (84%)
Spanish Network	TOTAL	165.483 km

As can be seen in the table above, the state road network represents a small fraction of the total network, barely 16%. However, it bears a substantial part of the actual traffic in Spain, especially when looking at heavy vehicle traffic:

SPANISH NETWORK: TRAFFIC (2011)

Total traffic	State run network	123.823 vehicles/km (51.8%)
	Regional and locally run roads	115.530 vehicles/km (48.3%)
Total traffic	TOTAL	239.353 vehicles/km

HGV traffic	State run network	16,468 million vehicles/km (64.9%)
	Regional and locally run roads	8,903 million vehicles/km (35.1%)
	TOTAL	25.371 vehicles/km
Spanish Network	TOTAL	165.483 km

2. CLIMATE

Generally speaking, Spain has 4 different types of climate:

- Atlantic climate: Temperatures are mild throughout the year (annual average of 10 °C to 20 °C), precipitation is abundant due to the influence of humid air masses coming from the Atlantic. Galicia and the regions along the northern coasts belong to this zone.
- Continental climate: the characteristics of this climate are long, cold winters and a mild summer in the north and a hot summer in the south (temperatures range from 25°C to -13°C). Rainfall is scarce and occurs during summer storms. The plain and the depression of the Ebro belong to this climate.
- Mediterranean climate: Temperatures are high in summer and mild in winter. Rainfall is irregular (especially in Almeria and Murcia). The Mediterranean area, the Atlantic area of Andalusia, the Balearic Islands, Ceuta and Melilla are part of this climatic zone.



- Mountain climate: Low temperatures with long and very cold winters, and short and warm summers, these are its most remarkable features. Rainfall is abundant and increases with altitude. The Pyrenees, the Central and Penibetic Mountains, some areas of the Cantabrian Mountains, the Iberian Mountains and the Grazalema Mountains are included in this zone.

However, due to the complex geography and influence of different seas and oceans, the reality is substantially more complex, due to drastic variations in temperature and precipitation within the features of these general areas.

In fact, if we look at a more precise method of classifying climate types, such as the Köppen scale, we can distinguish nine climatic zones (see following map):

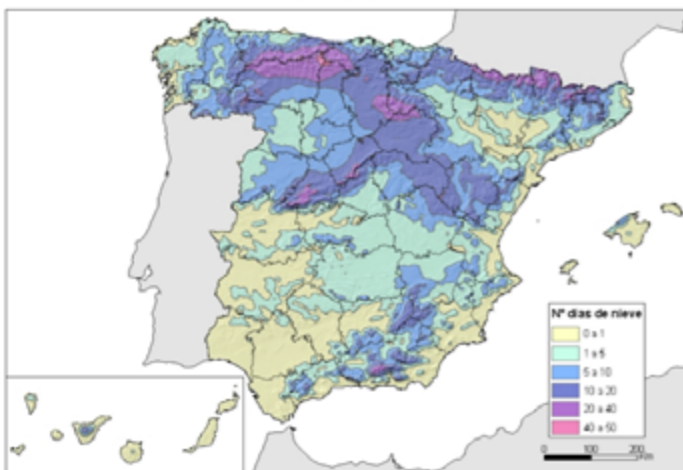
In the first place, we can distinguish two zones with an extreme continental winter climate (the coldest month has an average temperature below -3°C and the hottest 10°C): on the one hand we have the Pyrenean mountain areas, some points of the Iberian Mountain Range and the Cantabrian Mountain Range, which hardly have a dry season; and, on the other hand, we have the Penibetic Mountain Range (Sierra Nevada) and some small areas of the Central Mountain Range which have dry summers.

Four different zones have hot rainy climates (in which the coldest month has an average of between 18 °C and -3 °C and the hottest of 10 °C). Of this, an area that covers most of Galicia, Asturias, Cantabria, La Rioja, northern Castile and León, northern Aragón and Catalonia, areas north of Aragón and the lower Pyrenees in Catalonia, and most of the Iberian Cordillera is characterized by no dry season and a warm summer. The area between the northern and southern borders of the Ebro depression,

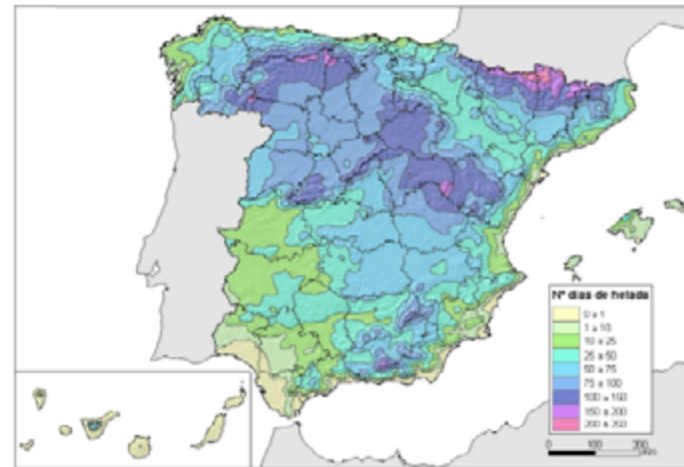
the interior of Girona and an area to the south of the Iberian Cordillera do not present a dry season but have hot summers. Some areas of Galicia, most of Castilla y León and the Cordillera Central, the southern border of the Cordillera Central, the rest of the mountainous areas of the Cordillera Penibética and some regions of Catalonia are dry and hot summers (apart from the mainland, the islands of La Palma, Gomera, Hierro, most of the island of Tenerife and the central area of Gran Canaria are also included in this category). Finally, the southwestern part of Castilla y León, Extremadura, most of Andalusia and Castilla-La Mancha, Levante, the coastal and lower mountainous area of Catalonia, the island of Menorca and most of Ibiza and Mallorca have dry and hot summers.

The climatic zones defined as dry and warm (with greater evaporation of precipitation and average annual temperature below 18 °C) are found along the depression of the river Ebro, Castilla-La Mancha, most of the southeast peninsular and the south of the islands of Mallorca and Ibiza. Areas of Almeria, Murcia, the interior of Gran Canaria, Fuerteventura and Lanzarote have a dry and hot climate (average annual temperature of 18 °C). And finally, areas of Almeria, Murcia and much of Fuerteventura and Lanzarote have a desert climate (evaporation greater than rainfall and a dry winter season).

Note: There are other climatic classifications that use a classification similar to that used by the French, but they are not the official classification of the Climatological Atlas. The material distributed by the Ministry of Education can be consulted, but it is not the system used by AEMET.



NUMBER OF DAYS WITH SNOWFALL



NUMBERS OF DAYS WITH TEMPERATURE $\leq 0^{\circ}C$
EDUCATION MINISTRY CAN BE CONSULTED, BUT THAT IT ISN'T THE SYSTEM USED BY THE AEMET.

WINTER WEATHER

Winter weather can be very hard in Spain, as many areas have a large number of days with freezing temperatures and snowfall. As can be seen in the following map, some areas of Spain have an average of 40 to 50 days of snowfall in the reference period (1971-2000): the areas of the Pyrenees, the Cantabrian Mountains, the Central System, the Iberian System and the Sierra Nevada. Around these areas there are extensive areas that have an average of 20 to 40 days of snow per year. Outstanding areas in this area are the cities and surrounding areas of Soria, Burgos and Ávila and some of the main motorways.

The highest elevations on the Peninsula have between 150 and 250 days per year of sub-zero temperatures in the reference period (1971-2000). We can include Soria, Burgos, Ávila, Teruel, Valladolid and Salamanca in areas that have between 75 and 150 days of sub-zero temperatures. The areas of León, Segovia, Cuenca, Albacete and some major roads have between 50 and 75 days of sub-zero temperatures. As a whole, the three areas described above cover a large part of the surface of the peninsula and an important part of the main road network has sections found in them.

3. Winter road management

3.1. STANDARDS AND PROVISIONS

The Directorate General of Roads, which belongs to the Ministry of Development, has power in the techni-

cal and operational management of the infrastructure of the state road network. This service is provided by the Subdirectorate General for Conservation and Exploitation.

The strategies for the execution of winter road maintenance works dedicated to maintenance services are indicated in the documents known as Operational Plans. These plans are drawn up for each maintenance section and cover any scenario likely to occur, as well as the means required to deal with each of them. The primary and desirable objective of these contingency plans is to limit the number of traffic interruptions to, at most, those assigned to the sector according to its assigned service level.

There are three levels of service in the management of the State Road Network, which contemplate two parameters - the maximum number of traffic interruptions per year, allowed and their maximum duration.

Service Level 1 (NS-1):

- all motorways and highways
- conventional roads with an IMD equal to or greater than 5,000 vehicles with the exception of mountain passes that have alternative routes on motorways or dual carriageways, which will have Service Level 2 (NS2).
- access routes to ski resorts
- all provincial capitals and cities with a population of more than 20,000 inhabitants where at least one national road passes must be connected to the main road network by a NS1 road.
- for both this level of service and the next NS2, an attempt will be made to provide the same level of service on all sections of the road along the same route so that the level of service does not vary from origin to destination.

This level of service does not allow road blockage or interruption of all vehicles due to snow or ice on the road. To this end, the actions to be taken will be to prohibit the circulation of heavy vehicles and restrict the passage to light vehicles with snow chains, minimizing the restriction time.

The maximum time for cutting heavy vehicle traffic or restricting traffic to light vehicles with snow chains shall be equal to the duration of the snowfall plus 2 hours.

The cleaning of the margins of the road should be done no later than 6 hours after the end of the snowfall.

Service Level 2 (NS2):

- conventional roads with an IMD of 1,000 to 5,000 vehicles
- All accesses to provincial capitals or localities with more than 20,000 inhabitants will have at least NS-2
- All towns with more than 4,000 inhabitants will link to level 1 roads with roads considered NS-2.

For this level of service, road blocking and/or traffic cut-off to all vehicles will be admitted only once a year. For this purpose, when necessary, traffic will be cut off to heavy vehicles and traffic will be restricted to lightweight vehicles with snow chains, minimizing restriction time.

The maximum time limit for cutting heavy vehicle traffic or restricting it to light vehicles with snow chains, will be the duration of the snowfall plus 4 hours.

The cleaning of roadsides should be done at the latest one day after the end of the snowfall.

Service Level 3 (NS3):

- The rest of conventional roads except mountain passes that communicate two provinces or that are the only link between populations of more than 2,000 inhabitants (these will have at least the NS-2).

In these roads the necessary restrictions caused by snow are allowed as long as it is as a consequence of dedicating efforts to clean the roads of superior level. Under no circumstances shall the presence of ice on the road be allowed to cause disturbance to the State Highway Network.

The quality of the service is based on the degree of compliance with the Operational Plan. Taking into account the conditions of service laid down in the maintenance contract, the performance of the contract is defective when the established service levels are not reached on the different roads covered by the contract.

No fixed rules have been established regarding the characteristics of the materials and equipment used as these characteristics are defined in each individual Operational Plan and adapted to the particular characteristics of each section of road.

In general, snow ploughs with front and, in some cases, lateral thrust shovels, solid or wet antifreeze sprinklers or brine are used to carry out maintenance work on the road network in winter. Dynamic snow ploughs are used in some mountain areas. The most commonly

used emulsifiers are sodium chloride (salt) and, in some cases, mixed with calcium chloride. Nowadays, the most commonly used treatments are fluxes such as brine.

3.2. ORGANISATION AND OPERATION OF WINTER MAINTENANCE ROADS

Winter road maintenance on Spanish roads is the responsibility of the Road Maintenance Service belonging to the corresponding road authority.

In a large part of the Spanish road network continuous interventions are needed for the maintenance of the road network during the winter, specifically it is necessary to carry out works for the maintenance of winter road maintenance in more than 80% of the roads of the State Network.

Public-Private Collaboration

Virtually all road authorities outsource part of their maintenance tasks to private companies that carry out maintenance work on most infrastructure, which generally includes winter road maintenance. The State road network is currently divided into 144 maintenance sectors. The maintenance of these sectors is contracted to private companies, which offer it publicly in accordance with a Technical Specification designed by the Ministry. The document specifies the human and material resources required to carry out the maintenance contract, including all operations related to winter road maintenance of the road network.

In the management of the State Highway Network, the management of resources used to carry out the tasks necessary to maintain service capacity in winter, are defined in so-called operational plans covering the procedures of action and the working system of all tasks related to winter road maintenance of each section. The plans are drawn up to comply with the instructions contained in the service note issued by the Directorate-General for Roads.

Private companies, in order to comply with service plans, are in charge of detours and also play a role in the decision-making process for interventions. On some toll roads, management is entirely in the hands of the private companies that have been granted the concession or franchise.

These operational plans are approved by the management team in charge of each contract and are reviewed

annually, adapted to new needs that may have arisen and are ready to be implemented in the following winter season.

An important part of this annual review concerns the inclusion of experiences that are considered important for improving the service, such as the application of new technologies or specific improvements to the working techniques used.

The operational plans of each section should cover at least the following information:

- Personnel and machines assigned to the section (snow ploughs, self-propelled snow ploughs and antifreeze spreaders, etc.);
- Melting agents (brine production plants, granaries, silos and other existing storage facilities in and around the concrete sector, etc.);
- Policy and procedures for data transmission (communication systems between databases and vehicles, as well as weather forecasting and other types of data transmission);
- Organization of preventive tasks (establishing itineraries, schedules and inspections, etc.);
- Organization of corrective tasks (location of equipment, itineraries, alternative routes, particular hot-spots and vehicle parking areas, etc.).

Cooperation with the Directorate General of Traffic and Civil Protection

There are parts of the operational plans that require collaboration with other government agencies involved in or affected by winter road maintenance, mainly the Directorate General of Traffic and the Directorate General of Civil Protection, both under the Ministry of the Interior.

The Directorate General of Traffic has a very important role in winter roads, as its powers include the regulation of traffic on roads and the application of existing regulations to drivers in the circulation of vehicles. When roads are affected by snow and ice, this body is responsible for enforcing traffic restrictions such as the mandatory use of chains on tyres or the driving ban on a certain class of vehicles (e.g. heavy vehicles in heavy snow).

The decision to impose traffic restrictions (cutting traffic or using snow chains) belongs to both the Directorate General of Roads and the Directorate General of Traffic. In the case of traffic interruptions, the attention

to affected users corresponds to the Civil Protection Services.

Provincial Protocols (based on and adapted from the National Protocols) are developed to organize coordination between the different governmental strata responsible for the tasks arising from the presence of snow on roads. They define the approach to be adopted for each situation with regard to the „Coordination of the General Administration of the State, in case of snowfall and after extreme weather conditions that may affect the national road network“.

Road weather information

Weather forecast information is provided by the State Meteorological Agency (AEMET) through the issuance of bulletins and a daily forecast of adverse weather when snowfall is expected to exceed certain thresholds.

The Directorate General of Traffic has installed an extensive network of weather stations in order to know the weather conditions on the roads. This weather information is transferred to drivers via variable message boards and is also available on the internet.

3.3 ROAD SAFETY AND INFORMATION

The Delegation or Sub-delegation of the Government of each province is responsible for providing information to motorists and media in case of snow conditions.

Providing information to drivers

The Directorate General of Traffic, under the Ministry of the Interior, is responsible for keeping drivers and road users informed about road conditions.

Motorists currently have different sources available to access information on the state of the roads:

Firstly, general information is broadcast on the different radio and TV stations, and is also published in the written press. Second, real-time data, specific to a particular road, is emitted by Traffic Management Centers on variable messaging panels located on the particular road. And finally, the information can be provided verbally on the spot by Civil Guard Traffic officials who, in addition to regulating vehicle traffic, establish controls to enforce the use of chains for tires in the event of bad weather conditions.

In addition, the Directorate General of Traffic has established 4 levels that determine the degree of dif-

iculty with which a driver can be found traveling on a particular stretch of road that is being affected by snow or ice.

- Green: It begins to snow. This colour identifies a stretch of road where it has started to snow and traffic is not affected. Speed recommendations are established (100 km/h on motorways and dual carriageways, and 80 km/h on other roads). Trucks must be in the right-hand lane and cannot overtake other vehicles.
- Yellow: A little snow on the road. The road begins to be covered with snow. Trucks may not circulate and light vehicles and buses may not exceed 60 km/h.
- Red: Snow-covered road. Traffic is only possible with snow chains and must not exceed 30 km/h. The movement of trucks and buses is prohibited.
- Black: thick snow or ice on the road. The road is impassable for any type of vehicle and there is a high risk of being immobilized for an indefinite period of time.

Systems to improve driving safety

Improving driving safety on Spanish roads is based on two main pillars managed by two different administrations. The first pillar is the maintenance and conservation of the infrastructure, managed by the Ministry of Development. The second is the Traffic Management Authority, under the Ministry of the Interior, which provides drivers with information on the state of roads affected by bad weather.

The information provided is based on obtaining and recording the parameters relating to weather conditions and the state of the roads, modelling them and, subsequently, issuing the corresponding information through the means indicated in the previous section.

Use of sensors and variable message panels

The knowledge of the state of a road affected by bad weather conditions is one of the activities controlled by the agents in charge of carrying out maintenance and conservation tasks and members of the Guardia Civil de Tráfico.

From the year 2000, which was the first year in which Sensors of Atmospheric Variables on the Road (SEVAC) were installed, their use has made it possible to know, record, evaluate and model the capacity of the different meteorological parameters recorded, which means that



4.2 NEW MANAGEMENT SYSTEMS

Winter maintenance management is reviewed after each season in order to correct defects found in the previous campaign and propose improvements designed to provide a better service to drivers and road users during the coming winter seasons. In recent seasons it has been shown that the effectiveness to avoid or reduce the number of sections with restrictions and delays in traffic and the duration of these, is the preventive cut of heavy vehicles before they can be stopped, making difficult the circulation of other vehicles and the work of snowploughs. These restrictions are made by trying to stop the trucks in the shortest possible time, intensifying the work of the snow ploughs and obtaining better performance during snow clearing.

Today, the State Highway Network continues to review the emergency parking plan for heavy vehicles, both in terms of its functionality and the need to build new parking lots. There are currently 33 car parks in which it will be possible to store these vehicles in the event of problems on the road, both during the winter season and during the rest of the year.

Another important issue aimed at improving the effectiveness and efficiency of road maintenance work in winter is the use of decision support systems. The latest technologies applied in surrounding countries such as Ireland, Slovenia, Finland, the United States, etc. for winter road management are the MDSS (Maintenance Decision Support System), which consists of a computerized decision support tool that integrates relevant weather forecast information, winter road maintenance operating procedures and data on available resources to provide conservation personnel with recommended treatment strategies.

Today, conservation personnel use the Internet, AEMET warnings, media forecasts, different types of weather stations, etc. to decide the work to be carried out for the maintenance of winter road maintenance, based on the Operational Plans established, being the decision making generally reactive.

In short, the use of MDSS is aimed at proactive and well-informed decision-making, so as to optimise the use of available resources while improving the degree of efficiency of the work carried out and reducing the consumption of fluxes and therefore the impact on the environment.

the actions carried out and their duration and purpose have been classified and confirmed.

In addition, information about the capacity, location and status of roads is made public in the form of messages on the variable message boards. Almost 600 km of motorways and highways on the general road network, plus a few other special kilometres on the regional network, are covered by variable message boards.

Technologies for informing drivers

All types of technology are used, whether it is based on audiovisual media, the Internet or personalised receipt of incidents through telephone calls and SMS text messages. On-site information points are also available for specific locations on exceptional stretches or routes.

4. RESEARCH AND ONGOING STUDIES TO IMPROVE WINTER ROAD MAINTENANCE

4.1 NEW TECHNOLOGIES

Since the year 2000, all machinery involved in winter maintenance work on the State Highway Network has been equipped with GPS tracking systems which are used as an aid to the management of snowplough fleets.

The data supplied by the GPS and the different sensors on board the vehicles are stored in a database, thus providing the possibility to create a wide range of reports on the tasks actually carried out.

With regard to infrastructure, fixed automatic spraying technology (FAST) has been installed as a system to prevent the formation of ice on some roads.

In Spain, on the State Road Network, a pilot experience was carried out between 2010 and 2012, and currently, as a challenge for the coming years, it is planned to implement this system, fine-tuning the system with the lessons learned in the previous pilot project, with a view to its possible widespread implementation.

4.3 TRANSNATIONAL COOPERATION

Spain participates in the SRTI Project which provides information services to drivers, cooperation for cross-

-border traffic management and equipment for data exchange and traffic management, etc. in order to improve safety and comfort on the roads linking Germany, France, Spain, Italy, Switzerland and Andorra.

5 REFERENCES

Climate data have been provided by the State Meteorological Agency (AEMET) of the Ministry of the Environment and Rural and Marine Affairs.



1 Demographics and Roads

Area	Total	410,929 km ² Mainly forest Fields 8%, Lakes and rivers 9%, Cities 3%
Population	Total	10 million
Road - Length - Vehicle km	Total trafficable by car	420,000 km
	Open to the public	210,000 km
	State Roads In- cluding Motorways	98,500 km, 58 billion vehicle km 2,050 km
	State Cycle ways	2,200 km (uncertain)
	Municipal Roads	41,600 km, 24 billion vehicle km
	Municipal Cycle ways	11,000 km (uncertain)
Number of vehicles	Private cars	4.3 million
	All road vehicles	4.8 million
Latitude (capital)	59° 20' North	Sweden covers almost 55–70° N



SWEDEN DIVIDED IN FOUR CLIMATIC ZONES

The average number of days with frost per year (1961-1990) differs between 240 in the North West and 75 at the coast in the South.

2 CLIMATE

All statistical data is calculated from a 30-year period at the Swedish Meteorological and Hydrological Institute (SMHI). The years 1990-2005 have all been warmer than in the table. Through the countries elongated form in the direction north-south differs the temperature considerably in the southern compared to the northern parts.

The Gulf Stream makes it much warmer than in other parts of the world on the same latitudes (between 55° and 70° North). In southern Sweden the winter period is about four months and in northern Sweden about seven months.

	Average Temperature 1961-1990		
	Dec	Jan	Feb
Kiruna	-13.9	-15.6	-13.7
Luleå	-9.0	-11.5	-10.7
Östersund	-6.1	-8.6	-7.3
Stockholm	-1.0	-2.8	-3.0
Göteborg	0.8	-1.1	-1.2
Jönköping	-2.1	-3.7	-3.9
Malmö	1.3	-0.7	-0.6

	Average Precipitation (mm) 1961-1990			
	Dec	Jan	Feb	Cumulative snow fall depth
Kiruna	32	29	24	243
Luleå	42	40	28	233
Östersund	31	27	21	251
Stock- holm	46	39	27	153
Göteborg	72	61	40	131
Jön- köping	69	63	41	225
Malmö	58	49	30	113

Temperatures could increase by as much as 8 °C during winter months according to IPCCs RCP8,5 climate change scenario. In the north coastal areas, the increase could be one or some degrees more and in the south coastal areas one or some degrees less. The predicted changes are shown in the following figure.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

LEGAL OBLIGATION

According to the Swedish constitution the Swedish Transport Administration (STA) is responsible for the road transports system and must work for attaining the objectives of the transport policy. The STA must especially work for securing that the road transport system is available, accessible and effective and that it contributes to the regional balance. The STA must also work for adapting and designing the road transport system according to high demands on environment and traffic safety. In one paragraph of the "Road Statute" it is stated that road operation includes the removal of snow and ice and taking actions against slipperiness to such a degree that the road is kept accessible

to existing traffic, both vehicles and pedestrians.

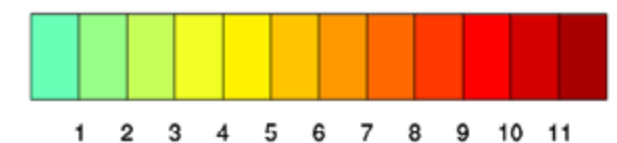
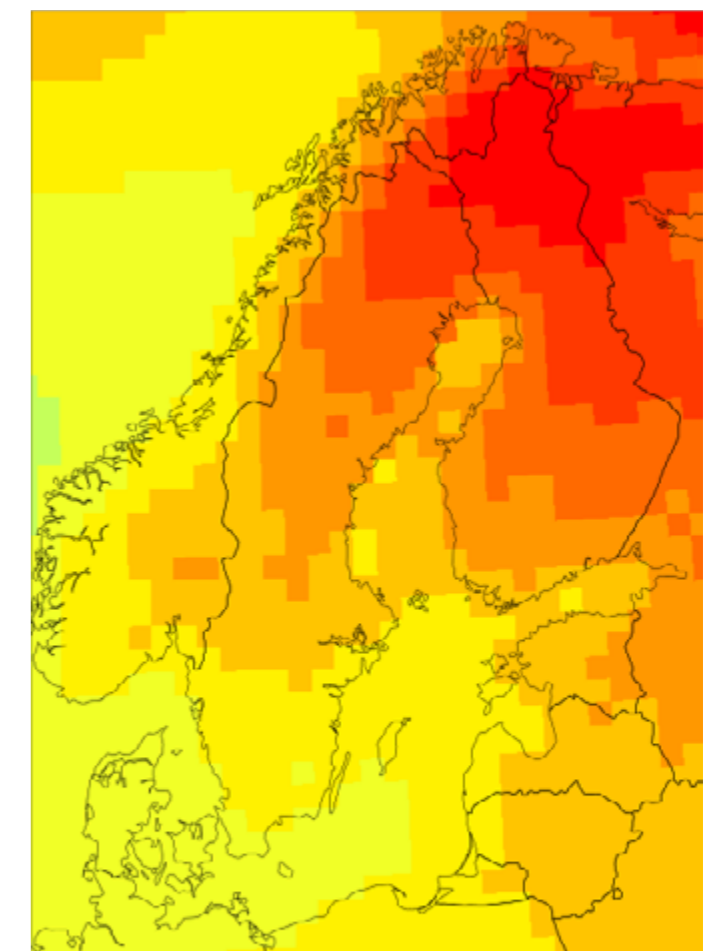
CLASSIFICATION OF ROADS ACCORDING TO LEVEL OF WINTER SERVICEABILITY

The winter maintenance on the state roads in Sweden is carried out according to the "General technical description of road operation service levels during winter. Winter 2003" (VV Publ 2002:147 and 148).

DEFINITIONS

ROADSIDE FACILITY

A roadside facility refers to an auxiliary surface where a vehicle can be parked outside the roadway.



PREDICTED CHANGE IN AVERAGE WINTER TEMPERATURES FOR THE PERIOD 2071-2100 WHEN COMPARED WITH 1971-2000 (SMHI.SE).

FRICTION

The friction coefficient shall be determined in accordance with the SNRA Methods Specifications 110:2000, Friction Measurement on Winter Road Surfaces. (Retardation measurements with Coralba or similar).

UNEVENNESS

The unevenness on thick ice or compacted snow roads shall be measured using a 60 cm long straightedge. This applies both in the longitudinal and transversal direction of the road as well as at an adjoining state road. The straightedge shall rest on two ridge points or between a ridge and the road surface, whereupon the measurement is taken at a right angle to the straightedge.

SNOW DEPTH

The snow depth shall be calculated as an average value on an area that is 1.0 x 1.0 meters. Every cm of slush is calculated as 2 cm of loose snow.

MATERIALS DE-ICING/ANTI-ICING

NaCl (rock or sea salt) is the only salt used for de-icing/anti-icing. The NaCl should be 97% pure and must not contain more than 100 g of Potassium or Sodium Ferro Cyanide per tonne NaCl.

Crushed stone aggregate, usually of 2-6 mm fraction,



STANDARD CLASSES

has been used for several years.

On roads with speed limit above 70 km/h the maximum allowed aggregate grain size is 4 mm.

Crushed stone aggregate, 2 – 4 mm, is used for pedestrian and cycle paths. No addition of salt is needed.

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

Traffic flow, AADT	Winter standard class
≥ 16,000	1
8,000 – 15,999	2
1,500 – 7,999	3
500 – 1,499	4
< 500	5

STANDARD CLASSES 1-3

Cross-sectional elements	Requirements during precipitation/Action time after precipitation				
	Trigger value		Action time in hours		
	Snowfall	Rain			
	Loose Snow depth (cm)	Friction (μ)	Standard class		
			1	2	3
Traffic lane	1	0.30	2	3	4
Side shoulder	1	0.25	4	6	8
Roadside facility	1	0.25	4	6	8

Cross-sectional elements	Dry weather requirements when action time after precipitation has expired			
	Road surface temperature			Evenness (cm)
	Warmer than -6 °C friction coefficient	-6 °C to -12 °C friction coefficient	colder than -12 °C friction coefficient	
Traffic lane	Snow and ice-free	0.35	0.25	1.5
Side shoulder	0.25	0.25	0.25	1.5
Roadside facility	0.25	0.25	0.25	1.5

STANDARD CLASSES 4-5

Cross-sectional element	Dry weather requirements when action time after precipitation has expired							
	Trigger value			Action Time				
	Loose Snow depth (cm)		Friction coeff. (μ)	Evenness (cm)	Snow depth/friction hours		Evenness hours	
	Standard class				Standard class		Standard class	
	4	5			4	5	4	5
Traffic lane	2	3	0.25	1.5	5	6	48	72
Roadside facility	2	3	0.25	1.5	8	8	48	72

Cross-sectional element	Requirements during precipitation/Action time after precipitation				
	Threshold value		Action time in hours		
	Snowfall		Rain		
	Loose Snow depth (cm)		Friction coeff. (μ)		
	Standard class		Standard class		
	4	5		4	5
Traffic lane	2	3	0.25	5	6
Roadside facility	2	4	0.25	8	8

“High” and “Normal” standard class for pedestrian and cycle paths and prioritized bus stops

Dry weather requirements when action time after precipitation has expired					
Trigger value		Action time/friction hours		Action time/evenness hours	
Friction	Evenness (cm)	Standard class		Standard class	
		High/P	Normal	High/P	Normal
0.30	1	1	2	2	4

Cross-sectional element	Requirements during precipitation/Action time after precipitation			
	Trigger value		Action time in hours	
	Snowfall	Rain		
	Loose Snow depth (cm)	Friction coeff. (μ)	Standard class	
		High/P	Normal	
Traffic lane	2	0.30	2	4

A NEW STRATEGY FOR REDUCED USE OF SALT IN WINTER ROAD MAINTENANCE SINCE 2004

Environmentally Adapted Winter Road Management shall ensure that the Swedish Transport Administration (STA) maintains high accessibility to the road network and traffic safety while minimizing the use of salt in winter road maintenance in a way that meets the demands of citizens and the business community. The

strategy shall be compatible with prevailing environmental standards and STA’s ambition to be an environmentally aware, efficient road manager that puts the customer first.

STA has worked actively for the last 30 years to limit the use of road salt in winter road maintenance. An investigative committee called “MINSALT” formed in the early 1990s a recommendation that:

- Roads with less than 1500 AADT should not be treated with salt, except during autumn and spring.
- Increased use of brine, especially for preventive actions.
- Improved weather forecasts.
- Improved equipment for snow removal and ice control.

Even if not all findings have been fully applied in all parts of the country the total salt consumption in Sweden may be considered low from an international perspective, but there is still reason to believe it can be further reduced. Examples of other actions taken over the years include physical protection of especially vulnerable water sources.

OBJECTIVES

Salt Consumption

The objective is to maintain high accessibility to the road network and traffic safety while minimizing the

use of salt. A salt index shall be used to measure accomplishment of the objective. During the 2006/2007 winter season and subsequent years, no operational area shall have an index greater than 1.0 (see 3.3).

Water

The objective is to reduce and eventually eliminate palpable negative impact from road salt on large water sources that supply more than 50 people.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

ORGANIZATION

In 1991, the Swedish Government passed a decision that the design and construction of new roads, as well as all road operation and maintenance work within the state road transportation network, were to be contracted through competitive bidding. This entailed major changes at the STA. 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 STA was to be divided into a client / contractor organization. In addition, it was stipulated that the contracting arm of the organization was to function like a private contractor, i.e., that it was to be subject to competitive terms on the open market and furthermore required to show a profit for its owner.

REQUIREMENTS

Co-ordination

The contractor shall plan and co-ordinate his undertakings with those performed in the adjoining areas to ensure continuity in road surface conditions. Contact shall be made with contractors in adjacent areas to co-ordinate snow clearance and skid control measures.

Level of service

The requirements must always be fulfilled, except when weather conditions are so severe that it becomes impossible to meet the action time limits. The client (STA) shall be notified when such severe weather conditions prevail.

Operative actions

Sweeping and sand collection shall be carried out so that neither road users nor the surroundings are subjected to dust.

FORMS OF PAYMENT

Form of payment used at present is unit-price payment based on weather data statistics. In order to reduce salt consumption there is a bonus and fine system.

FINANCE

Twenty-five percent of the STA appropriation for road maintenance and operations, a total of almost SEK 1.8 billion (US\$ 220 million), 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.

There are 110 maintenance contract areas, covering the state roads, in Sweden. The maintenance contract areas comprise between 600 and 1,650 kilometres of road, centreline. This size has proven sufficient to be financially viable for contractors. In total here is 2,600 plough trucks contracted, which gives an average of 37.7 km per plough truck. In addition, there are graders and agricultural (farming) tractors used. Agricultural tractors are used mainly in pedestrian and cycle paths.

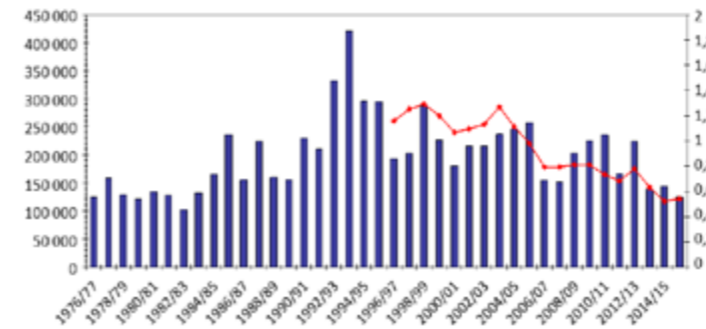
COMPETITIVE SITUATION

In 1992, the first competitive procurements of basic routine maintenance occurred. Since that year, the competitive procurement of maintenance and operation works has steadily increased and since 1999, 100% of the road network is under competitive bidding. There are basically four contractors that compete for road contracts in Sweden. In beginning of 2017, the division of contractors by km is; Svevia (state owned) 50%, Skanska 5%, NCC 18% and PEAB 22% and others 5%. In the most northerly and southerly parts of Sweden, a couple of smaller contractors have managed to enter the market, having been awarded four areas all in all.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES WINTER INDEXES

During recent years an experimental work has begun calculating a number of winter indices starting from weather situations. Mean values are calculated for each month and for each county. Representative RWIS stations and MESAN scaled weather data are chosen for each contract and values for STA region are given.

The weather index describes the number of occasions with slipperiness, snow and snowdrift, respectively.



SALT CONSUMPTION AND SALT INDEX ON NATIONAL ROADS

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, who make the decisions about winter maintenance actions, must show that they have a certain competence by passing the national examination SIK (Scandinavian infrastructure competence).

WEATHER INFORMATION PROVISION RWIS FIELD STATIONS

Sweden has nearly 800 RWIS field stations located all over the country. The stations are equipped with sensors for measuring air and road surface temperature, humidity, amount and type of precipitation, and wind. Dew point temperature is also calculated and delivered for every station. Most of the stations are also equipped with cameras.

METEOROLOGICAL INFORMATION

During the winter season (1st October – 30th April) a contracted weather information service delivers continuous radar and satellite information 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 every third hour during the season. All day and night special cloudiness forecasts are produced for a combined sta-

tistical and energy model that every hour predicts the road surface temperature for the next six hours.

INTERNET

The information from the field stations and from SMHI are collected and compiled at an information centre at the headquarters of STA and can then be obtained via the Internet. (See example from www.trafikverket.se)

MEASUREMENTS OF EFFICIENCY

INTERNAL

Both the STA and the municipalities follow up the consumption of salt and abrasives.

EXTERNAL

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

ROAD CONDITION

In the most southern region of Sweden the biggest roads have ice and snow condition about 5% of the wintertime (4 months) and the smallest roads 40%. Up in the northern region the corresponding figures are 20% and 70-80% when the winter is 7 month long.

ENVIRONMENTAL IMPACT

The main part of the de-icing salt used on the roads will leave the road as run-off or be deposited within some tens of meters but still some amount may be transported further away from the road. The deposition pattern depends on: amount of salt used, intensity, type and speed of traffic, type and amount of precipitation, direction and speed of wind.

The sodium ion participates in ion exchange reactions and is to some extent retarded in soil and groundwater, whereas the chloride ion is conservative and highly soluble. Since the chloride ion is not subjected to retardation or degradation it is a good tracer. If chloride from de-icing salt can be found in a well or in surface water, there is a substantial risk that other pollutants may also be present. Increased chloride concentrations have been observed in both municipal water supplies and in private wells close to roads. Furthermore, the chloride concentration has been observed to increase in lakes in Sweden with concentration peaks during spring. The roadside exposure to de-icing salt may

change the species composition of vegetation and also influence the growth conditions and aesthetically appearance of trees.

Other pollutants from the road and traffic related especially to winter-traffic are metals from corrosion of vehicles, wear of road surfaces and tyres. The fear about wear-particles has increased the last decade.

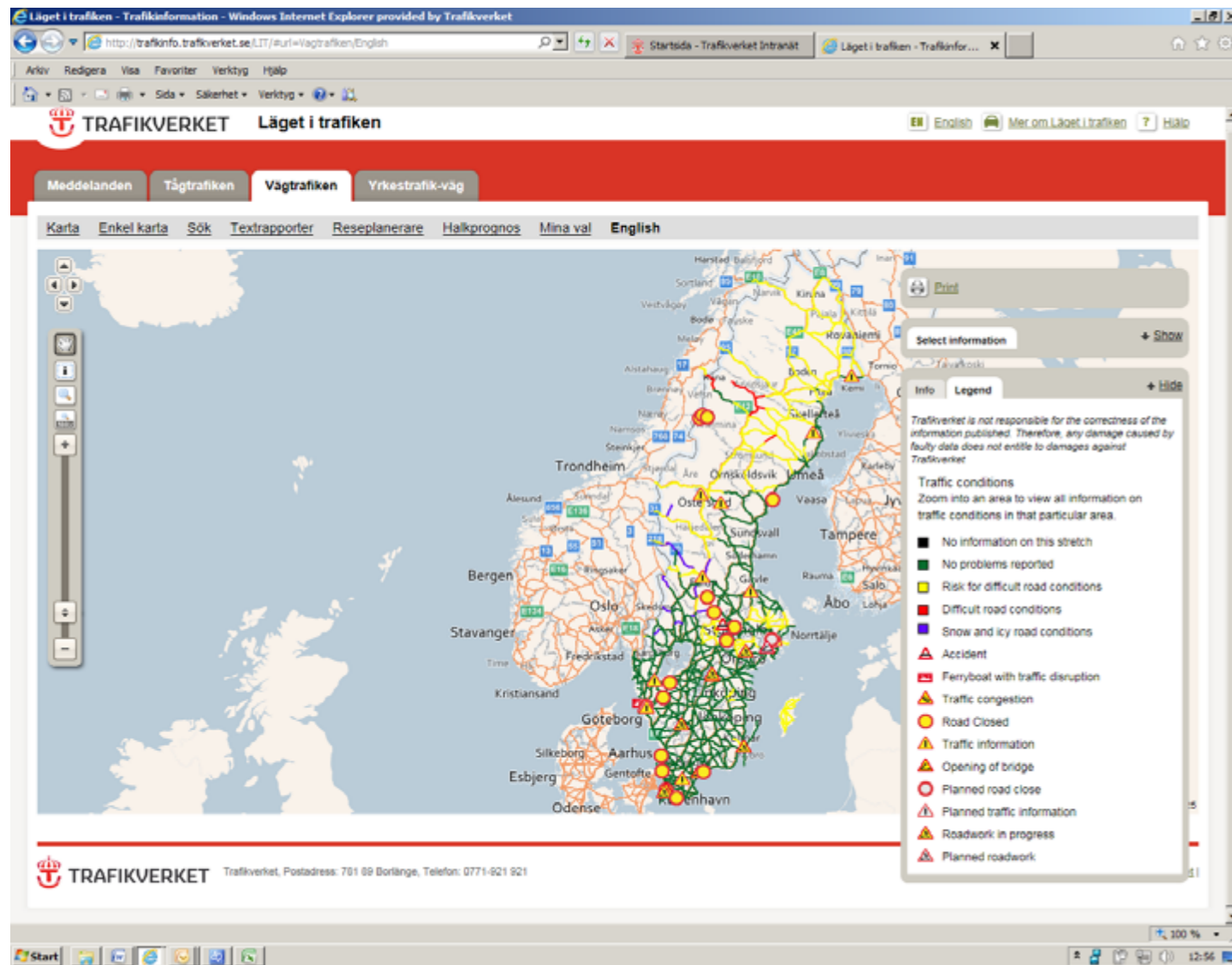
3.4 TRAFFIC SAFETY AND INFORMATION INFORMATION TO ROAD USERS

All operation centres have to report at least 3 times a day to the TC (Traffic Centre) and also every time there is a change in road condition (e.g., after a turnout). The information is then distributed from the TC in different ways:

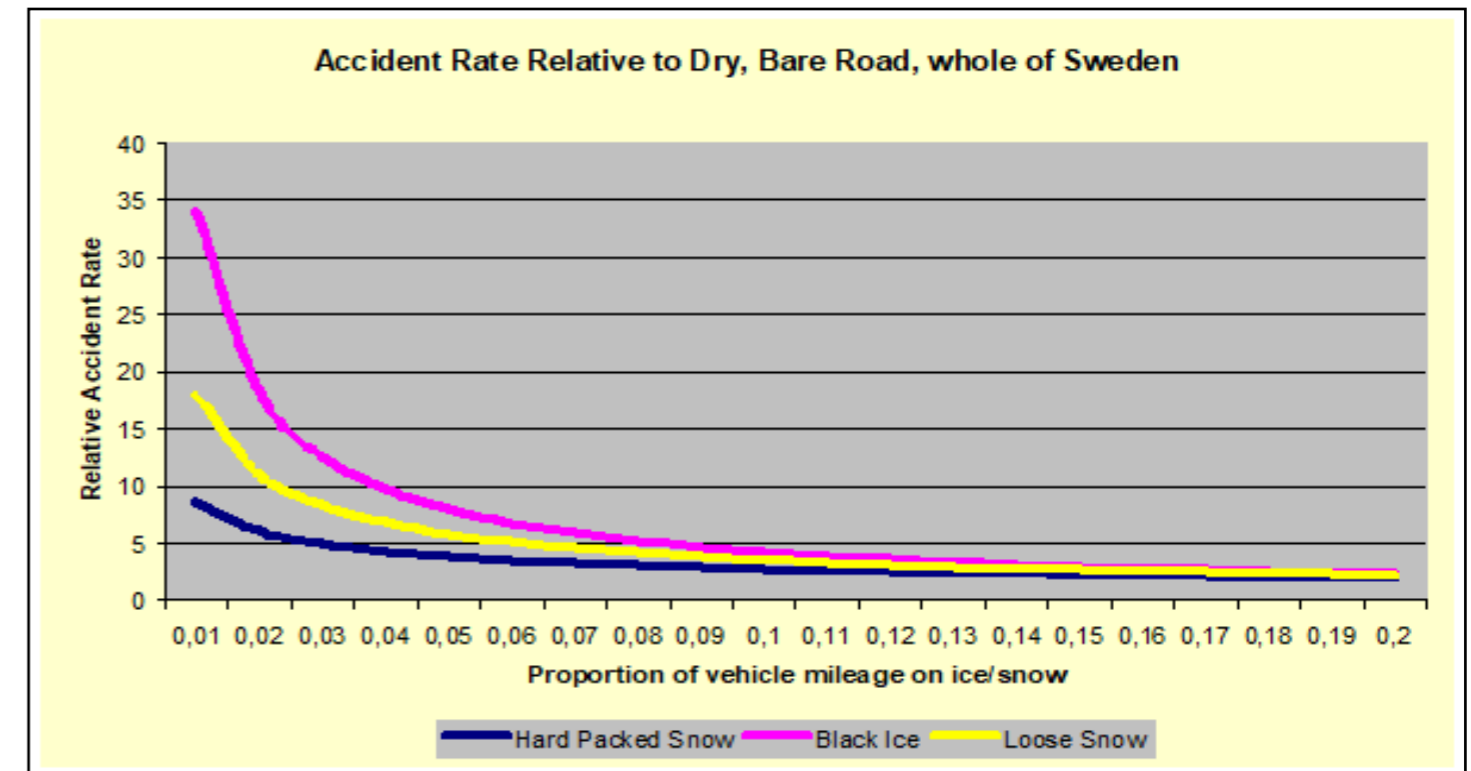
- Radio: Local radio stations get information from the TC
- Newspapers
- Internet: A map showing the present road conditions can be found at the home page of STA (see example from www.trafikverket.se)
- RDS-TMC for real time road condition data for in-car navigators etc.
- Road users can also use web based applications to get information.
In some places there are traffic signs showing road surface temperature and air temperature.

TRAFFIC SAFETY

Speed and speed adaptation play important roles in



EXAMPLE FROM WWW.TRAFIKVERKET.SE ON ACTUAL ROAD CONDITION



ACCIDENT RATE VERSUS A DRY, BARE SURFACE FOR VARIOUS PROPORTION OF VEHICLE MILEAGE ON ICE/SNOW DURING ONE WINTER

terms of the accidents that will occur with a particular road condition or friction. To stop a private car in more or less the same distance as on a bare road, the car needs to be travelling at half the speed on roads covered with ice or snow. The adaptation of Swedish drivers to ice and snow conditions is, however, significantly less. With a combination of poor road condition and poor visibility (falling snow) speed reductions are about 25%, but when only ice or snow, speed reduction is often between 10% and 20%.

People driving under various road conditions where friction is varied for the various road conditions have shown that it is the appearance of the road and not the road grip which determines the speed that is maintained. This has been observed both in a simulator and on the road. Driving simulator tests have been conducted to determine how best to inform drivers and get the best speed adaptation to the friction. Recommended speed display leads to lowest speed and largest headways.

The risk of accidents is estimated as the number of accidents reported by the police per million vehicle kilometres and is known as the accident rate. Accident rates can be calculated either as an absolute value or as a risk relative to a dry bare road in winter. In general, an icy or snowy road condition has about 3-30 times

higher accident rate for vehicular traffic than for a dry bare surface. The black ice road condition is the most dangerous. Accident rate can also be calculated as a function of the frequency of occurrence of a given road condition during the winter season.

Accident rates for various icy and snowy road conditions have an exponential relationship with the proportion of total vehicle mileage during the winter season carried out on the current road condition (see figure on previous page).

To study the effect of winter road condition frequency more closely, the winter period is divided into short pre-winter and post-winter periods, with a long mid-winter in between. The accident rate during pre-winter is not higher than during post-winter. This indicates that it is not the first skid phenomenon during a winter period that causes many accidents, but unusual with an icy or snowy road condition that surprise drivers.

VEHICLE EQUIPMENT

Since 1999 passenger cars, light trucks and buses with a total weight up to 3.5 tonnes shall have winter tyres or equal equipment during the period December 1 – March 31 when winter road conditions (slippery) appear. It is allowed to use studded tyres October 1 – April 30.

A follow-up study showed that this requirement led to an 11% – 14% drop in accidents involving seriously injured and fatalities in icy and snowy road conditions. The interval depends on whether it is assumed that the requirement also has an effect on bare surfaces. Over all road conditions during the whole winter period, the reduction was 8%. These reductions are not statistically significant at the 5% risk level.

ABS (anti-lock braking system) and ESC (Electronic Stability Control) systems proportion the acceleration and/or the braking force in such a way that the tyre is not blocked, and the tangential grip is always used completely to its limit. The accident reduction in Sweden of ESC is for serious and fatal loss-of-control type crashes on roads covered with ice or snow the effectiveness was $49.2 \pm 30.2\%$. It was estimated that for Sweden, with a total of 500 vehicle related deaths annually, that 80–100 fatalities could be saved annually if all cars had ESC.

PEDESTRIANS

The risk of injury is higher to pedestrians than to car drivers when slippery road conditions. When ice/snow is on footways the injury risk is about 8 times higher than when the foot way has bare conditions.

ROAD FURNITURE

In Sweden it has been quite common with roads with a width of 13 m. When they were built it was with 2 lanes 3.5 m in width and broad shoulders. Those roads had a quite high accident risk and some of them were changed to 2 lanes 5 m in width. But much better results come from the new standard with a guardrail on the road. Often it is 1 lane in one direction and 2 in the other (non-meeting roads with cables). The number of lanes in one direction changes at intersections. This standard resulted in a significant decrease in severe accidents. The fatalities have been reduced to 9 instead of estimated 60 with no cables and severe injuries have had a 50% decrease.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

THE WINTER MODEL

The project “Winter Model” started at the beginning of the 2000s. The idea was to try and predict the consequences of different winter maintenance strategies

and to calculate the associated socio-economic costs. It is now possible to calculate and validate the impact that different winter maintenance measures have on road users, road authorities and local communities. This model will continue to be developed in the coming year. For instance, the accident model will get updated.

At the heart of the winter model is the Road Condition Model. This model provides the foundation for the other sub-models, because it is here road conditions are calculated. The models input values are weather conditions from a RWIS-station, together with annual average daily traffic (AADT) and information about the climate zone and road standard class.

SWEEP-SALTING

In order to be able to cycle safely, a high winter maintenance service level is required. Although the method has certain drawbacks and difficulties, using salt for skid control on bicycle paths could be one solution. In recent years, a method using a front-mounted power brush for snow clearance and salt for de-icing – commonly called “sweep-salting” – has become more and more popular for maintaining bicycle paths in Swedish municipalities. One challenge is to develop and optimise equipment, methods and maintenance strategies associated with “sweep-salting”. This is necessary when striving to achieve a maintenance service level that is as high as possible under different conditions and circumstances

RSI

Road Status Information (RSI) is a new type of service where a number of different sources of information work together to make current road maintenance practices more efficient. In order to assess future road surface conditions and to plan relevant maintenance measures, the Swedish Transport Administration and its subcontractors now use forecasts, satellite information and radar pictures from weather prediction services in conjunction with RWIS.

Ongoing RSI projects contain a number of new information sources that can help to improve forecast accuracy and the follow-up of any measures taken. RSI can be described as an advanced decision making and follow-up system that can be used to improve road climate conditions and save resources.

5 REFERENCES

Berglund C.M. Tema Vintermodell. Nytt och kostnader för vinterväghållning. VTI notat 55-2005. Summary in English.

Bergström, A. Tema Vintermodell. Olycksrisker under för-, hög och senvinter. VTI notat 19-2003.

Carlsson, A & Brüde, U: Utvärdering av mötesfri väg: halvårsrapport 2003:1 VTI notat 36-2004

Friction Measurement on Winter Road Surface. SNRA Methods Specifications 110:2000

Ihs, A. Winter maintenance in Sweden. Compiled for COST 344. VTI särtryck 351, 2002.

Kircher, Katja. INTRO - Intelligent roads. Deliverable D2.3: Simulator study. Final report. VTI, EU-project report, 2007

Lie, A et al. The Effectiveness of Electronic Stability Control (ESC) in Reducing Real Life Crashes and Injuries. Traffic Injury Prevention, 7:38–43, 2006

Möller, S & Wretling, P. Estimate of the distribution of road surface conditions during the 1993/94 to 1996/97 winters. VTI meddelande 848, 1998. Summary in English.

Möller, Staffan. Tema Vintermodell.Väglagsmodellen. VTI rapport 529, 2006. Summary in English.

National Environmental Programme 2002-2005. SNRA Publ nr 2001:57

Niska, Anna. Tema Vintermodell. Olycksrisker och konsekvenser för olika olyckstyper på is- och snöväg. VTI rapport 556, 2006. Summary in English.

TRB. 7th International Symposium on Snow Removal and Ice Control Technology. Transportation Research Board/Circular E-C126. June 16-19, 2008. Indianapolis, USA.

Page 159: Blomqvist, Göran & Gustafsson, Mats. Winter Model: Roadside Salt Exposure Under Different Weather Conditions.

Page 512: Möller, Staffan. Winter Model: Road Condition Submodel.

Wallman, Carl-Gustaf. Driver behaviour on winter roads: A driving simulator study. VTI rapport 419A, 1997.

Wallman, Carl-Gustaf. Tema Vintermodell – Olycksriskmodellen. VTI notat 60-2001, 2001.

Wallman, Carl-Gustaf. Hastighet/flöde – väglag. VTI meddelande 953, 2003. Summary in English.

Wallman, Carl-Gustaf et al. Tema Vintermodell: Etapp 1. VTI meddelande 958, 2004. Summary in English.

Wallman, Carl-Gustaf et al. Tema Vintermodell, etapp 2. Huvudrapport. VTI rapport 531, 2006. Summary in English.

Wiklund, Mats. Tema Vintermodell. Anpassning av vinterväglagsmodell till empiriska data med censurerade observationer. VTI notat 25-2006. Summary in English.

Winter 2000 General Technical Specifications. Swedish National Road Administration. Unpublished.

Winter 2000 In-house instructions. Head office to regional road administrations. Swedish National Road Administration. Unpublished.

VINTER 2003. Val av vinterväghållningsstandard. Swedish National Road Administration VV Publ 2002: 147

VINTER 2003. Allmän teknisk beskrivning. Swedish National Road Administration VV Publ 2002: 148

Öberg, G. Effect of sanding. Traffic and friction studies. VTI Rapport 164, 1978. Summary in English.

Öberg, G. Friction and journey speed on roads with various winter road maintenance. VTI rapport 218, 1981. Summary in English.

Öberg, G; Gustafson, K & Axelson, L. More effective de-icing with less salt. Final report of the MINSALT-project. VTI rapport 369 SA, 1991.

Öberg, G et al. Single accidents among pedestrians and cyclists. VTI meddelande 799A, 1996.

Öberg, G; Wiklund, M & Velin, H. The effect of the winter tyre law on the use of tires and on accidents. VTI rapport 479, 2002. Summary in English.

Öberg, Gudrun (editor). PIARC 2006. XII Winter Road Congress 27–30 March 2006, Torino, Italy. VTI notat 19A-2006.

Öberg, Gudrun. Tema Vintermodell. Fordonskorrosion beroende på vintervägsaltning. Kunskapssammanställning. VTI notat 24-2006. Summary in English.

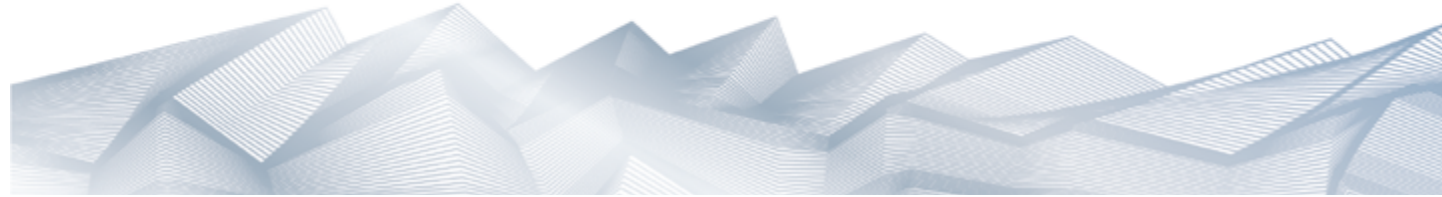
Öberg, Gudrun & Möller, Staffan. Hur påverkas trafiksäkerheten om restriktioner av dubbdäcksanvändning införs? Kan en förbättrad vinterväghållning medföra att trafiksäkerhetsnivån bibehålls? VTI rapport 648, 2009. Summary in English.

From the homepages below most of the reports can be downloaded.

www.vti.se Swedish Road and Transport Research Institute (VTI)

www.trafikverket.se Swedish Transport Administration (STA and in Swedish VV)

www.smhi.se Swedish Meteorological and Hydrological Institute (SMHI)



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Switzerland is a small (41,285 km²), landlocked country in the heart of Europe. Roughly two-thirds of its surface is mountainous. The Midlands between the Alps and the Jura mountain chain is densely populated.

Switzerland is a federal state with 26 cantons. The capital is Berne. Zurich and Geneva are international financial centers. Geneva accommodates the headquarters of several UN organizations as well as other international organizations. Basel is the seat of major pharmaceutical multinationals.

Four cultures or linguistic regions coexist in Switzerland: German: 64% of the population, French: 20%, Italian: 7%, and Romansch (in some alpine valleys): < 1%.

The economy is based on services (71%), industry (25%) and agriculture (4%). Export commodities are: machinery, chemicals, metals, watches, agricultural products.

1.2 ROAD NETWORK AND TRAFFIC

Roads	National roads	1,855 km
	Cantonal roads	18,000 km
	Communal roads	51,000 km
Vehicles	Utility vehicles	416,501
	Passenger cars	4,570,823

The Confederation owns the national roads and has full authority over the latter. The network of Swiss national roads, comprising a total length of 1,907 km, was defined as a whole in 1960. Close to 90% built, it will theoretically be completed by 2020. Construction has now made way for adaptation and review of the network.



NINE PERCENT (9%) OF THE POPULATION SPEAKS OTHER LANGUAGES.

The cantons and communes respectively own the cantonal and communal roads.

The average Swiss travels 13,400 km a year in private cars and 2,703 km by train. The average daily traffic on motorways reaches 130,000 vehicles on certain stretches (3+3 lanes). Road transport accounts for 85% of the total freight tonnage. The economic importance of roads is therefore very high. The federal, cantonal and communal road authorities are responsible for keeping the roads serviceable at all times.

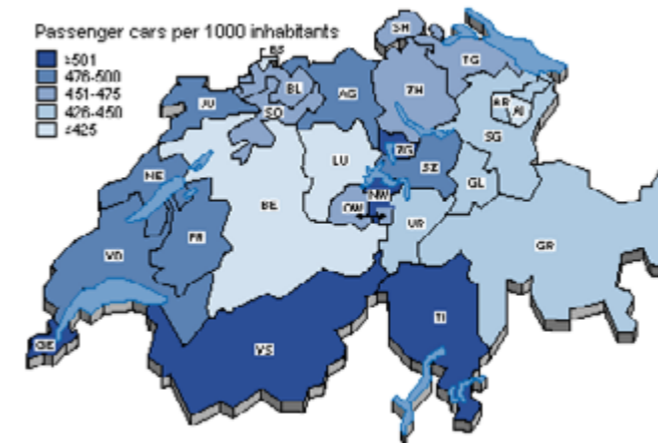
Winter maintenance is in operation between October and April and accounts for 20-25% of the yearly operational cost.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

About a hundred of Switzerland's mountain peaks are close to or higher than 4,000 meters and there are more than 3,000 square kilometers of glaciers. Forests occupy about a quarter of the country.

The climate varies according to altitude. Four characteristic climate regions can be distinguished:



characteristic climate regions can be distinguished:

JURA

The Jura is a mountain chain in the northwestern part of the country. The highest peak reaches 1,300 meters.

High precipitation, accompanied by frequent strong winds, prevails. The winter climate is harsh. Precipitation averages between 120 and 180 cm over 140 to 160 precipitation-days a year. Strong winds reach peak speeds up to 140 km/h and 210 km/h at the mountaintops. In winter, blowing snow is frequent.

MIDLANDS

More than two-thirds of the population lives in the region between the Jura and the Alps. All the major cities lie in this region. The altitude varies from 300 to 700 meters.

A well-balanced distribution of precipitation prevails. The quantity of snow varies from winter to winter and fog is a frequent phenomenon.

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



ALPS

The Alps and Pre-Alps cover almost two-thirds of Switzerland's surface. The highest peak stands at 4,500 m. The Alps and Pre-Alps are generally rich in precipitation. Precipitation averages between 140 and 200 cm for 140 to 160 precipitation-days a year. Strong winds with peak speeds of up to 270 km/h are possible in the valleys. Foehn winds (hot and dry) are frequent in north-south oriented valleys.

SOUTHERN ALPS

Ticino, the sunny part of Switzerland, lies south of the Alps, where palm trees grow. The altitude descends to 200 meters.

High yearly precipitation of up to 220 cm prevails as a result of the rain accumulation on the southern face of the Alps in the spring and autumn. Wind speeds go up to 120 km/h.





3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legislation differs for national, cantonal and communal roads. A legal obligation to ensure winter maintenance exists for the national roads.

The official codes of practice for roads comprise 18 documents on winter maintenance.

SN 640 750b	Bases;
SN 640 751	Avalanche Protection;
SN 640 752b	Manpower Training and Requirements;
SN 640 754a	Weather Information, Record of Road Conditions;
SN 640 756a	Priority, Winter Service Levels, Route Planning and Register and Response Plan;
SN 640 757a	Intervention Equipment;
SN 640 760b	Snow Characteristics;
SN 640 761a	Snow Removal;
SN 640 763	Engines for Snow Removal;
SN 640 764b	Attachment for Snowplows;
SN 640 765a	Snowplow characteristics;
SN 640 772b	Ice Control;
SN 640 774a	Requirements for Spreaders;
SN 640 775a	Snow Fences;
SN 640 776b	Structures for Snow Stabilization;
SN 640 778a	Signage, Facilities.

ROAD CLASSES

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

- Motorways, highways;
- Main arteries, steep roads;
- Roads used by public transportation;

2.2 STATISTICS ON TEMPERATURES

The table shows the winter characteristics of the various climatic regions.

2.2 COMPENSATION OF WINTER MAINTENANCE COSTS

For the compensation of the winter maintenance costs three parameters are taken into account. The weather parameter contains days with temperature under zero degrees (ice days) or days where the temperature is only once under zero degrees (frost days) as well as the number of times of snowfall within a period of time of 12 hours. The other two parameters are the salt consumption and the effective costs.

Climate	Air temp		Precipitation					
	Days where T < 0° C	Frost days	Days with rain	Rain in cm/year	Days with snow fall	Days with snow cover	Max. snow cm/day	Amount of snow cm/year
Jura	121	30	157	140.6	64	123	55	317
Midl	96	22	126	104.2	30	51	22	53
Alps	140	42	138	148.7	59	128	50-90	433
SoA	45	4	107	184.8	14	19	63	43

- Roads leading to railway stations, hospitals, etc.;
- Public transportation stations;
- Major pedestrian and bicycle paths, stairs.

SERVICE LEVELS

- Level A: bare roads, complete snow removal and ice control;
- Level B: prevention of slipperiness, bare roads in the medium term;
- Level C: roads practicable without the use of de-icers, white roads;
- Level D: no winter maintenance.

PRIORITY LEVELS

Level 1: First snow removal pass completed 3 hrs after mobilization (2 hrs on motorways). First spreading pass completed 2 hrs after mobilization.

Level 2: First snow removal pass completed 4 hrs after mobilization. First spreading pass completed 3 hrs after mobilization.

Level 3: First snow removal pass completed 5 hrs after mobilization. First spreading pass completed 4 hrs after mobilization.

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

Regulations for manpower

Maximum driving time is stipulated in a national ordinance. It must not exceed 9 hrs (10 hrs allowed twice a week). Weekly working time is 46 hrs. Maximum weekly overtime is 5 hrs (10 hrs in special cases).

Exceptions are, however, allowed for maintenance services. Conditions vary slightly from canton to canton.

Regulations for equipment and material

The regulations for equipment describe the types, test methods and operational areas of vehicles, snowplows, snow blowers, and spreaders. The main objectives are:

- Highest possible speed for plows/spreaders;
- Complete snow removal through mechanical means (plows, rotary brooms);
- Minimal use of thawing agents.

The codes of practice describe the types and operational areas of de-icing agents (NaCl, CaCl₂, MgCl₂,

Urea, salt solutions, methanol, and glycol) and abrasives.

The dosages prescribed are:

Spreading	Temperatures °C	
	0°C to -8°C	-8°C to -20°C
	g/m ²	g/m ²
Dry salt	7 - 15	10 - 20
Wet salt	7 - 15	10 - 20
Brine [in ASI]	5 - 10	5 - 10
Abrasives	≤ 200	≤ 200
Mixing ratio	only NaCl	2/3 NaCl 1/3 CaCl ₂

Certain surface conditions may require a higher salt dosage.

The wet salt technique (salt and brine mixed on the spinner) is actually the standard on the highways as well as the pure brine spreading technique. On the main roads and the municipality streets the dry salt is still widely used.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Confederation is responsible for winter maintenance on the national roads. It awards service contracts to 11 territorial units across Switzerland who perform the winter maintenance.

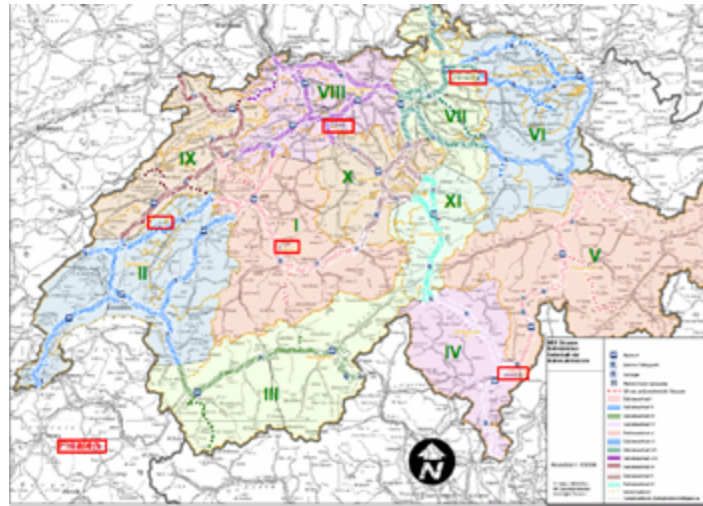
Winter maintenance on cantonal roads is performed by the cantons, and winter maintenance on communal roads is performed by the communes.

In general, the maintenance centers are responsible for winter maintenance. However private companies are frequently given contracts to do part or, in some cases, all of the winter maintenance. The contracts are established between the cantonal or communal road authorities and the contractor.

Types of contract:

A: The contractor is in charge of a stretch of road for snow plowing and ice control. He works with his own equipment, except plows and spreaders, which are provided by the maintenance center. The call for intervention is in most cases given by the maintenance center.

B: The contractor provides vehicles and drivers, who



ters have a silo for loading within a short time (2-3 minutes), which can be done by the driver alone. With an appropriate arrangement of the silos, 2-3 spreaders can be loaded at the same time. The silos are filled over the barns or directly by the Rheinsaline, which is the single supplier in Switzerland.

Automatic de-icer spraying facilities are in operation on specific stretches with a particular microclimate or which are particularly exposed. Two facilities are on high bridges, one facility (6 km length) on a segment with heavy traffic (80,000 vehicles per day) and a particular microclimate.

Manpower

The maintenance center staff usually consists of:

- One road master responsible for winter maintenance;
- One administrator, responsible for accounting and administration;
- Two to three group leaders;
- Crews, drivers and other professions;
- Two to three mechanics;
- One to four electricians, depending on the number of electromechanical facilities along the highway.

Either the territorial unit has a central RWIS operation center or the group leaders of the maintenance center are in charge of the operational tasks based on a RWIS. Each maintenance center has a standby organization during the whole year. Each employee is obligated to provide temporary standby availability.

The work schedule is set by the head of maintenance operations in each canton. As a rule, the work week is of 42 hrs. Overtime during winter is generally compensated in summer.

Shift working is becoming more common in the maintenance centers as the intensity of the workload increases. Maintenance work in tunnels is mainly done at night and more and more this also applies to other work likely to hinder the flow of traffic.

There are strict safety rules for every type of maintenance work (clothing, tool-handling, equipment, behavior on the road etc.). Every center has a designated safety supervisor.

Training and education

The head of the maintenance center is responsible for crew training.

Training includes:

- Winter maintenance tasks;
- General organization;
- Vehicles and heavy equipment;
- Response organization;
- Personnel and standby organization;
- Supply of information;
- Instruction on tools;
- Preparation of group leaders;
- Instruction on route planning, service levels and priority levels;
- Application of salt according to RWIS forecasts and residual salt;
- Plowing in teams;
- What should be done in the event of an accident, „risk management“;
- Reporting.

At the beginning of winter, courses are given to road operators on basic meteorology, forecasting technology and work on the RWIS and the weather radar.

Other courses cover the handling of ice detection systems.

Methods, equipment and materials for special problems

Special problems are caused by snow drifts, avalanches and porous asphalt. To reduce the amount of snow blown on the road, snow fences are put up where the phenomenon regularly occurs.

In some winters, avalanches cause severe problems for road authorities. In all mountain regions, a special avalanche task force has been organized. Their duty is to observe the characteristics and the amount of snow and to issue warnings, and in some cases to close the road. A special avalanche bulletin and warnings are issued daily by MeteoSwiss and the Swiss Avalanche Research Institute. Automatic warning devices have been installed in certain locations.

Meteorological information

Since 2016 MeteoSwiss provides general road weather information for winter maintenance. All the other winter prognoses which are special and specific are furnished by private weather services based on contracts.

MeteoSwiss:

General road weather forecasts and warnings, available to the general public on the Internet and the radio. Free of charge.

work together with the maintenance center's crews. C: The contractor provides vehicles for the winter season.

Payments are based on the number of work hours with a flat rate for providing the vehicles.

National roads

Equipment: The national roads have 45 maintenance centers. The average length of highways serviced by each center is defined by the obligation to do the first round of winter maintenance within 2 hours.

The equipment includes: 2-3 trucks per direction, equipped with plows, 3.5-6.0 m width, detachable spreaders, 4-6 m³ for salt and 2 m³ brine. One person per truck. On mountainous stretches and on stretches where the snow cannot be pushed to the side, snow blowers are required to load the snow onto trucks.

Salt is always stored under shelter, either in barns (up to 4,000 tonnes) or in silos (200 tonnes per silo). All cen-



ROAD HEATING IS NOT USED



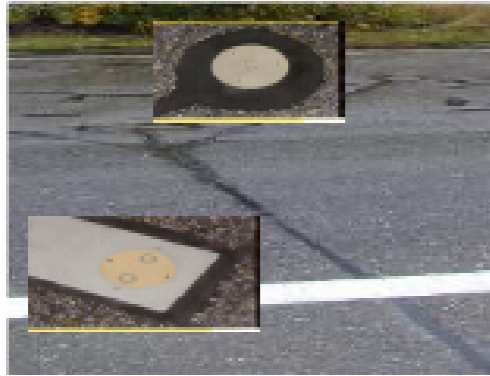
Information from 150 national road weather stations. New "Streets Weather Scenarios" based on 150 national road sensors, MeteoSwiss weather station network (ANETZ) and different meteorological prognoses (cosmo, Inca...).

Private weather services

24-hour road weather forecast specifically designed for maintenance centers and street sections.

Weather forecast delivered directly to the maintenance center's RWIS computer and trigger a warning signal.





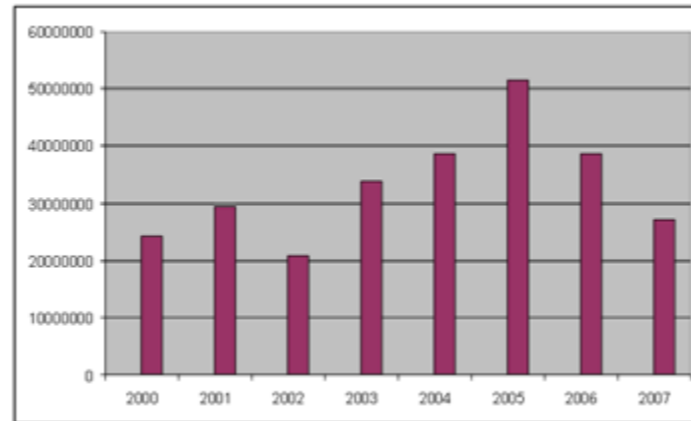
RWIS

All maintenance centers for the national roads have a RWIS. The system combines measurements and warnings from road sensors, road weather stations and local weather forecasts.

Road sensors and road weather stations generally provide the following parameters:

- Air temperature 2 m aboveground, surface temperature, humidity, dew point, freezing temperature, precipitation
- Wind: direction and intensity, road conditions: dry or wet, residual salt.

The national road network is equipped with more than 500 road weather stations. The road sensors measure the surface temperature and the freezing point, depending on the technology either by electrically cooling down the sensor surface or by infrared measurement. The average distance between road sensors is approximately 6 km. The location of the sensors was de-



termined by experience or through thermal mapping.

There are a various amount of management systems available. Those systems combine the actual weather information with prognoses up to the visualization of the spreading vehicle positions and the billing of the performed work.

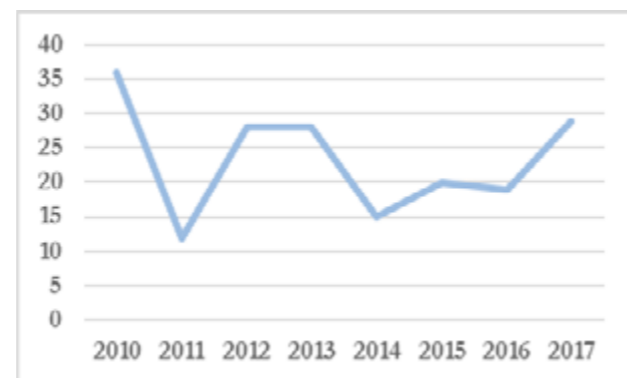
3.3 ASSESSMENT OF WINTER MAINTENANCE MEASURES

Operating costs on national motorways

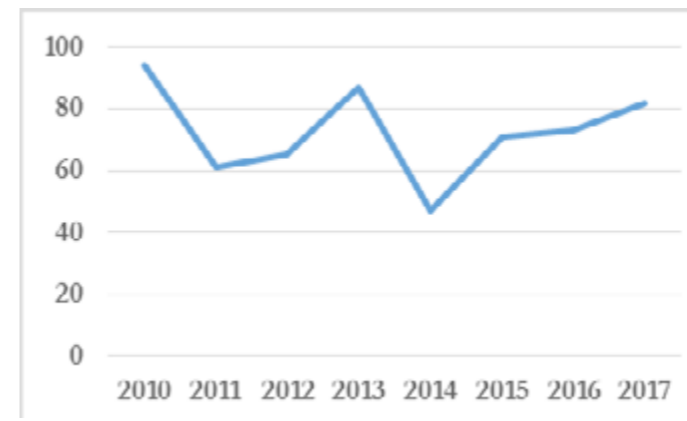
Winter maintenance costs can vary between 15% and 20% of total annual operating costs. The following diagram shows the winter maintenance costs.

Salt consumption on national motorways

Salt consumption is directly related to the harshness of the winter. Several measures have been introduced in the past years to minimize the use of deicers systems. The annual consumption is shown in tons/km.



HISTORY - ANNUAL CONSUMPTION (T/KM)



HISTORY - DAYS UNDER ZERO DEGREES AND FROST DAYS

Measurements of efficiency

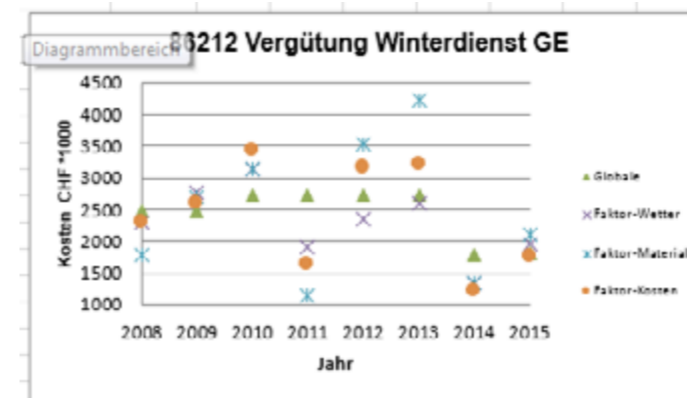
Internal

All the maintenance centers for national roads and some for communal roads have a cost accounting system. Therefore the total cost of winter maintenance, as well as the personnel, vehicles/engines, material etc. cost factors are exactly known. Based on this cost accounting, efficiency assessments are made after every winter.

Measures aimed at reducing the salt consumption

Besides the approved methods like the wet salt technique, dosage prescriptions according to surface conditions and annual staff education, new procedures and devices are systematically tested for their efficiency.

Very good results have been obtained by the introduction of the automatic salt dosage system based on „ThermoMat“ infrared thermometers or the introduction of the pure brine spreading technique. The salt consumption on a motorway can be reduced by 20%



to 30% without any reduction of the road safety, providing both environmental and economic benefits in ice control.

3.4 TRAFFIC SAFETY AND INFORMATION

Safety measures

In a large national project called Via Sicura aiming to reduce the number of victims on the road, a number of measures indirectly related to winter maintenance have been defined.

Weather-related information for road users

This kind of information is mainly available by radio. The road administration does not provide any on-site information on road weather or road surface conditions.

However, fixed and variable road signs provide information on closed roads and recommended detours.

International exchange of road information

International information exchanges regard road closures and difficult driving situations. This exchange is ensured by the traffic control center of the national road in Lucerne.

Traffic management on national roads

There are supraregional offices for traffic management. These traffic guidance centers are responsible for such operations as the collection of data on traffic flow and density, active traffic guidance, the coordination of road maintenance, and information on traffic, the weather, and road conditions. The main center is in Lucerne.

4 ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW MANAGEMENT APPROACHES

Compensation of winter maintenance costs

For the compensation of the winter maintenance costs three parameters are taken into account:

- the weather parameter
- the salt consumption
- the effective costs

Those three measurands give an indication of the efficiency of winter maintenance.

SWITZERLAND



Use of modern communication technology in road maintenance to optimize traffic safety

The study will provide the technical and financial criteria for implementing such communications as satellite-based positioning, online data transfers between the base and vehicles, remote-controlled salt dosage, etc.

4.2 TRANS-NATIONAL COOPERATION

In the area of winter road maintenance, Switzerland collaborates with the following organizations:

PIARC World Road Association, Technical Committee B5 B.2 „Winter Maintenance“;

COST European Cooperation in Science and Technology, Project 353 „Winter Service Strategies for Increased European Road Safety“;

SIRWEC Standing International Road Weather Commission, Executive Committee;

CEN European Committee for Standardization, TC 337 „Winter Maintenance and Road Service Area Maintenance“;

D-A-CH Annual seminars organized by the road research associations of Germany, Austria and Switzerland;

F-CH Regular seminars on technical and organizational issues organized by the road research associations of France and Switzerland.

In the past, Switzerland has hosted the following international conferences on winter issues:

PIARC VI International Winter Road Congress, Davos, 1982;

SIRWEC 10th International Road Weather Conference, Davos, 2000.

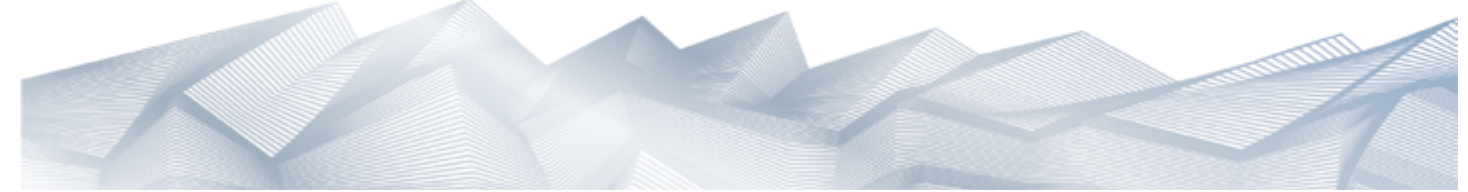
5 REFERENCES

Swiss Federal Roads Authority
www.astra.admin.ch

Other references
www.swissroads.ch
www.vss.ch



UNITED KINGDOM



1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

The United Kingdom is made up of four countries, namely England, Northern Ireland, Scotland and Wales. The total area of the United Kingdom is 243,800 km², split up as follows:

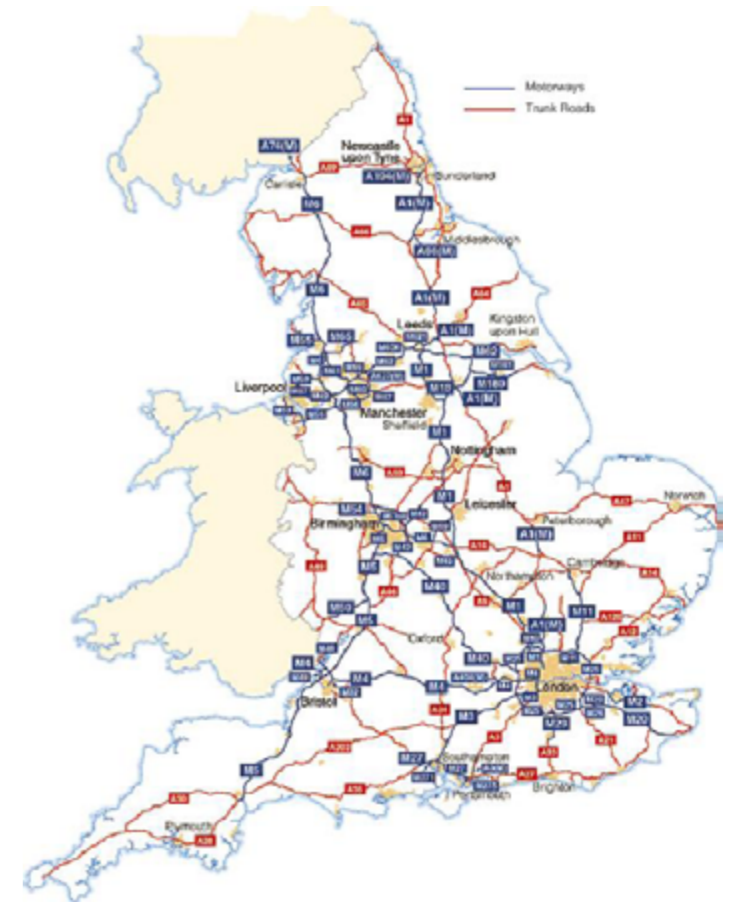
England – 130,400 km²

Northern Ireland – 13,800 km²

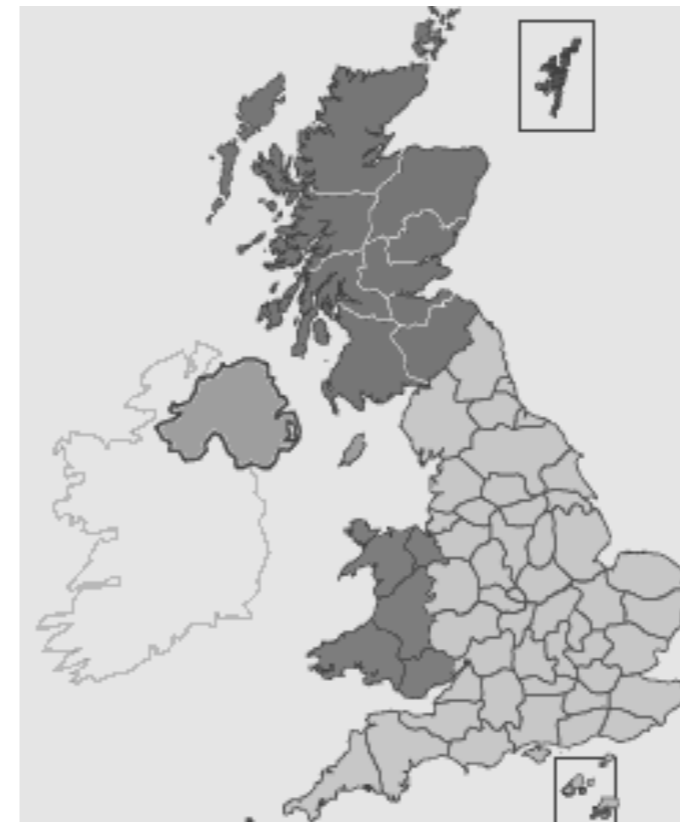
Scotland – 78,800 km²

Wales – 20,800 km²

The physical geography of the UK varies greatly. It includes the chalk cliffs of the south coast, the rolling hills and fields of southeast England, the granite cliffs of the southwest peninsula, the mountains of Wales, the lakes and mountains of northern England, the Scottish lowlands, highlands and islands, and the fields, lakes and mountains of Northern Ireland. The 61 million population in the UK is rather unequally distributed among the four countries: 51 million in England, 2 million in Northern Ireland, 5 million in Scotland, and 3 million in Wales.



HIGHWAYS ENGLAND'S STRATEGIC ROAD NETWORK
(SOURCE: HIGHWAYS ENGLAND)



1.2. ROAD NETWORK AND TRAFFIC

The road network in the United Kingdom comprises 14,568 km of motorway and trunk roads and 405,473 km local roads.ⁱ Road traffic on this network is 488.9 billion vehicle kilometres per year (excluding Northern Ireland).ⁱⁱ Each country within the United Kingdom uses a different approach to network management.

England – The English network consists 7,300 km of motorway and trunk roads and 294,000 km of local roads. The Department of Transport delivers transport through a number of executive agencies and government owned companies with responsibility for the various modes of transport. Previously known as the Highways Agency, Highways England was established in 2015 as a government owned company with responsibility for managing most of the motorway and trunk road network. Local authorities, usually County Councils, have the responsibility for managing local roads. Transport for London is responsible for all forms of public transport in London, including all roads.

Northern Ireland Road Network - There are 25,591 kilometres of public road in Northern Ireland. Unclassified roads account for the largest proportion of all roads (61%) followed by C roads (18%), B roads (11%), A roads (9%) and Motorways (<1%)

The Department for Infrastructure, Roads Winter Service Policy provides for precautionary salting on approximately 7200kms of this network. This service is



MAIN SALTING ROUTES IN NORTHERN IRELAND
(SOURCE: THE DEPARTMENT FOR INFRASTRUCTURE, ROADS)



SCOTTISH TRUNK ROAD NETWORK
(SOURCE: TRANSPORT SCOTLAND)

carried out at the most effective times to try and prevent ice from forming therefore helping to facilitate the free and safe movement of traffic. This salted network equates to some 28% of the total Northern Ireland road network

The Department for Infrastructure, Roads maintains a fleet of approximately 130 winter service spreaders and 12 Snow blowers to manage this network.

The Northern Ireland Salting Network is fairly extensive and the scale of the map only allows for the main routes to be shown.

Scotland – The Scottish road network comprises

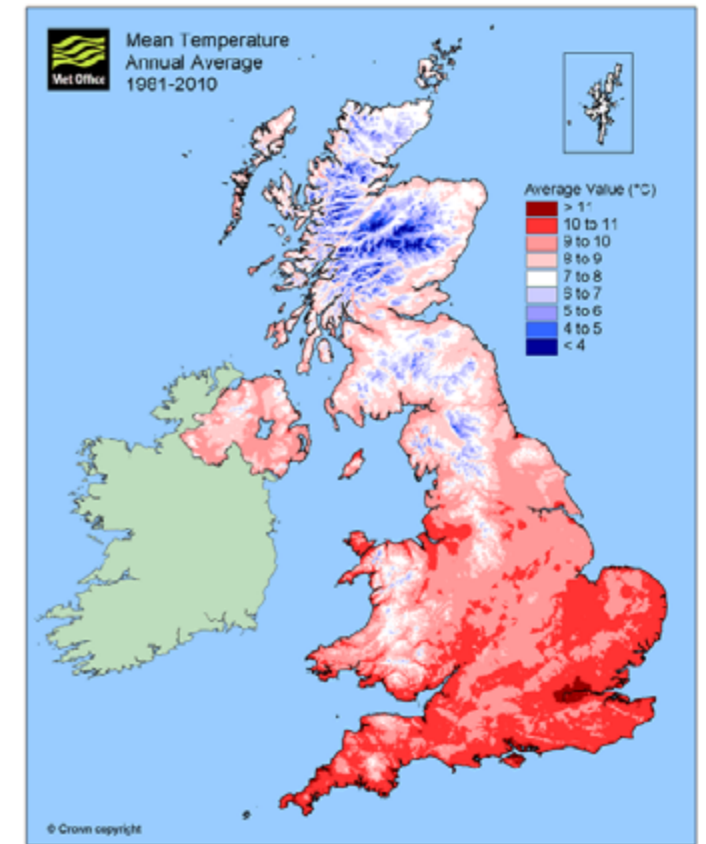
3,400 km of trunk roads and 56,000 km of local roads. Transport Scotland is responsible for managing and maintaining Scotland’s motorways and trunk roads. Winter service is delivered by five operating company units and five DBFO company contracts. The 32 local authorities have the responsibility for managing local roads.

Wales – The Welsh road network comprises 1710 km of trunk roads and 32,933 km of local roads. Welsh Government has the responsibility for managing major roads, which is comprised of trunk roads, including motorways. Local unitary authorities have statutory powers and obligations for all public highways, which are not trunk roads or motorways.

In England and Scotland management and maintenance of trunk and motorways are procured on the basis of competitively tendered contracts. Service providers are appointed to operate specific geographical areas for a period of five to ten years, and up to 30 years on DBFO contracts. In Wales this service is predominantly managed and delivered through two local authority partnership based Trunk Road Agents. The Department for Infrastructure, Roads is responsible for all roads in Northern Ireland with the exception of motorways which are maintained through a Public, Private Part-



WELSH STRATEGIC HIGHWAY NETWORK
(SOURCE: WELSH GOVERNMENT)



nership contract. The length of motorway in Northern Ireland is 115 km (exc slips).

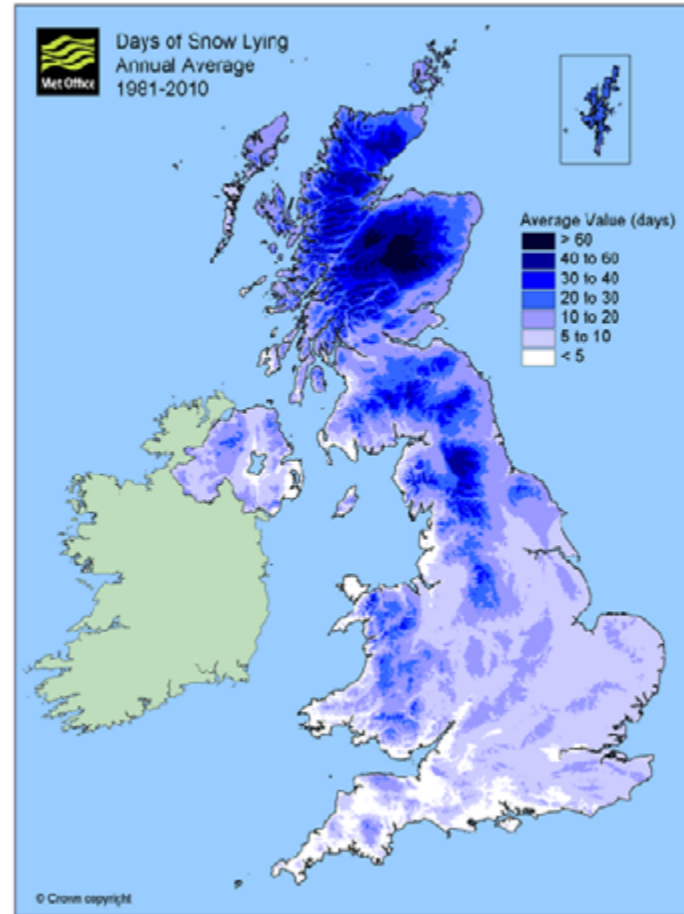
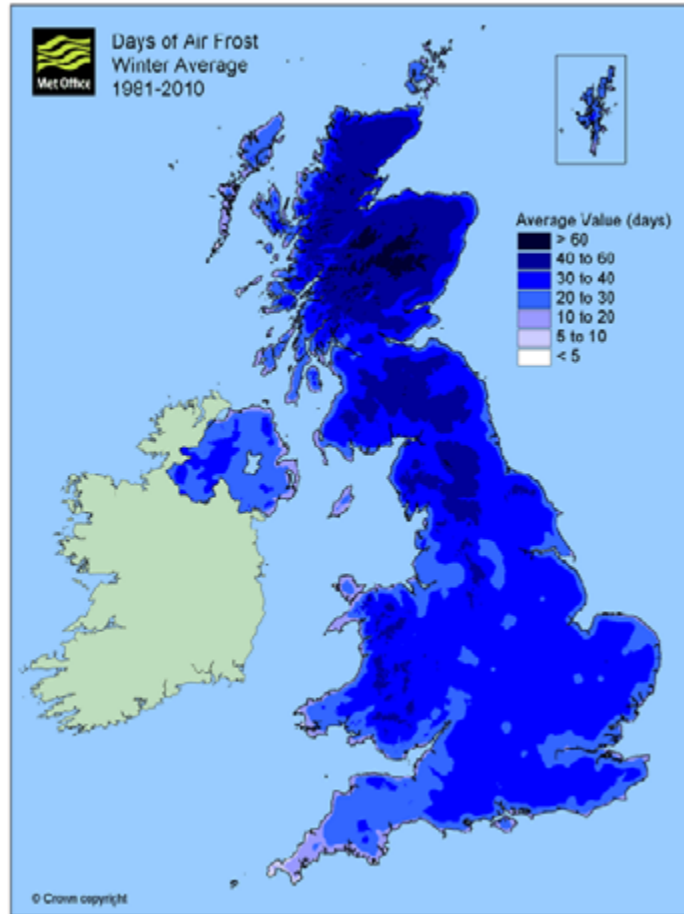
2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS

The climate of the United Kingdom is classified as temperate, with warm summers, cool winters and plentiful precipitation throughout the year. The principle factors of influence on the climate include the UK’s northerly latitude (which ranges from 50° to 60° N), its close proximity to the Atlantic Ocean and, especially, the warming of the waters around the British Isles by the North Atlantic Drift together with the effects of the Gulf Stream. The weather can be notoriously changeable from one day to the next but temperature variations throughout the year are relatively small.

2.2. STATISTICS ON TEMPERATURE, ICING AND PRECIPITATION DAYS

The UK is at the boundary of convergence between the warm tropical air to the south and the cold polar



air to the north. In this area, the large temperature variation creates instability and this is a major factor that influences the changeable and often unsettled weather the UK experiences, where many types of weather can be experienced in a single day.

	MaxTemp [deg C]	MinTemp [deg C]	Days of Frost [days]	Rainfall [mm]
England	13.5	5.9	49.1	855
N. Ireland	12.4	5.4	42.8	1136
Scotland	10.7	4.2	67.4	1570
Wales	12.6	5.7	49.3	1460

1981-2010 AVERAGES (SOURCE: MET OFFICE)

Winter in the UK is generally a cool, wet and windy season. Temperatures at night rarely drop below -10 °C and in the day rarely rise above 15 °C. In the period from 2005-2010, snowfall had become more frequent. However, in the last few years heavy rainfall and high winds have presented the UK with the most significant challenges.

Towards the end of the winter season the weather usually stabilises with less wind, precipitation and lower temperatures. This change is particularly pronounced near the coasts mainly due to the fact that the Atlantic Ocean is often at its coldest during this time after being cooled throughout the autumn and the winter.

2.3. WINTER INDEXES USED IN THE COUNTRY

In England, Northern Ireland and Scotland, the Met Office makes use of the Meteorological Office Open Road Index (MOORI). This index reports weather conditions and is typically presented in (i) long term averages of the nights of salting actions, (ii) month-by-month differences from the average, and (iii) whole winter differences from the averages, for each weather station. In addition, graphs are produced to illustrate long-term trends.

Typically in the UK there are three winter maintenance periods for normal operational purposes: (i) High Risk Period (typically December, January and February), when severe conditions might reasonably be expected;

(ii) Low Risk Period (November and March), when severe conditions may occur; and (iii) Marginal Risk Period (mid-September, October and April), when severe conditions are generally not expected.

Local highways/roads authorities throughout the UK make use of similar classifications. These periods have an impact on the winter service delivery requirements in service providers contracts.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

Highways/roads authorities in the UK have a statutory duty to maintain highways/roads with effective winter service being one element of that responsibility. The statutory basis for winter maintenance differs throughout the countries.

Highways Authorities in England and Wales have a statutory duty to “ensure, so far as is reasonably practicable, that safe passage along a highway is not endangered by snow or ice”.iii In addition, the Highways Act 1980 also imposes a duty upon authorities to remove obstructions of the highway resulting from “accumulation of snow or from falling down of banks on the side of the highway, or from any other cause”.iv

In Northern Ireland, the Roads (Northern Ireland) Order 1993 requires The Department for Infrastructure, Roads the highway authority to remove snow and take such action, as it considers reasonable to prevent snow or ice interfering with the safe passage of persons and vehicles using the road.

In Scotland roads authoritiesv have a statutory obligation to take “such steps as it considers reasonable to prevent snow and ice endangering the safe passage over public roads.”vi

Highways England aims to provide a winter service, which, as far as possible, allows the safe movement of traffic on motorways and all-purpose trunk roads in England, and keeps delays and accidents caused by adverse weather to a minimum. The winter service delivery requirements for the strategic road network in England are set out in the Severe Weather Plan template which forms part of each service provider’s contract.

The Welsh Government Trunk Road Maintenance Manual; Part 5: Adverse Weather Service sets out the requirements and the advice of the Welsh Government

[–Department for Economy and Infrastructure] for adverse weather and winter service activities on motorways and all-purpose trunk roads which are within the responsibility of the Welsh Government, whereby top priority is given to the motorways and the more important all-purpose trunk roads.

3.2. ORGANISATION AND OPERATION OF WINTER MAINTENANCE

The budget for winter service on roads in the United Kingdom is an estimated £150 million per annum. England and Wales spends approximately £20 million and £5 million on motorways and trunk roads winter service during an average winter respectively. Scotland spends up to £14 million on winter service. In Northern Ireland, the average winter service operation costs between £5 and £7 million.

Both the English and Welsh trunk road maintenance manuals outline roles, responsibilities, operational purpose and techniques, application of salt and alternative de-icers, use of maintenance plant and equipment, liaison and communication.

Roles and Responsibilities – Highways England, The Department for Infrastructure, RoadsNorthern Ireland, Transport Scotland and the Welsh Government [Department for Economy and Infrastructure] are responsible for setting the overall policy on the provision of winter services on the motorway and trunk road network. The service providers and maintenance agents normally undertake the operational management of the service and provide the necessary labour materials and in most cases the plant. In England on the strategic road network Highways England provides the full fleet of dedicated pre-wet spreaders and snow blowers for the service providers to operate and about 75% of the depots to operate out of.

Service providers and highways/roads authorities throughout the UK typically prepare a severe weather/winter service plan updated annually, which describes the policy, objectives, procedures and operational arrangements. This document is often made widely available so that local residents, transport firms and local industries may be informed of the level of service to be expected. In addition, the document details unique local conditions and how a satisfactory level of service will be provided, while at the same time complying



with local, regional or national specific legislation.

Operational Purpose and Techniques – The operational arrangements within the severe weather/winter service plan define the precautionary pre-treatment network, the preparation, the dedicated spreading and snow-clearance plant, strategically sited stocks of de-icing agents, ice/snow prediction and monitoring, action/operational procedures for the treatment of ice and snow, defined procedures for public information/media coverage, and monitoring the effectiveness of action.

Pre-treatment is undertaken on all the major routes of the network and provides the most effective way of ensuring the safety of these routes where the majority of vehicle movements take place. The definitions and criteria applied to determine the precautionary pre-treatment network vary considerably between countries and highways/roads authorities.

The guide used by many is Appendix H of the Well-Maintained Highways Code of Practice which sets out the general national standard. The precautionary pre-treatment network will typically comprise a maintenance category priority order as indicated in the following table.

Maintenance category	Road type	Function
1	Motorways	Major road
2	Primary national trunk	Major road
3	National primary	Major road
4	Primary county	Interurban and through routes
5	Secondary county	

In addition to defining the network on a maintenance category basis, consideration is given to the criteria such as traffic flows, settlement population, emergency premises, adjoining highway authority salting networks with respect to lower road categories and important facilities for cycling and walking.

Treatment route optimisation exercises are carried out to maximise efficiency and ensure coordination with other routes. This exercise improves the targeting of pre-treatment operations and minimises inappropriate treatment on marginal weather forecasts by determining action on a route-by-route basis. The precautionary pre-treatment network is typically denoted on a map. In addition, route cards and maps are produced for each precautionary spreading route and copies retained in the assigned spreading vehicles at all times. The precautionary spreading network is reviewed annually to reflect developments, improvements and changes in traffic patterns.

Highways/roads authorities and service providers define the planned winter service operations by late summer. The issues typically discussed at the winter preparation operations and pre-winter meetings are preparation of winter service plant and equipment, calibration of road weather sensors, plant and equipment, certification of plant operatives, preparation of winter service cover, de-icing agents stocks, contact/stand-by systems and rotas.

In addition to precautionary treatments in Scotland, winter patrols operate on all motorways and selected major routes. Winter patrols are deployed to monitor conditions, provide salt treatments and plough as required.

Winter patrols operate on the busiest roads and those trunk roads that experience the severest winter weather when temperatures are forecast to be low and there is a risk of ice forming. Patrols operate from early morning through to the end of the morning peak period and at other times of the day when severe wintry weather is forecast, at the discretion of the Operating Company winter managers.

Patrol vehicles are fitted with surface temperature sensors which allow winter decision makers to monitor, in real-time, the road temperature at the location of each patrol vehicle. All motorways have a maximum 30 minute response time to winter incidents when the patrols are deployed.

The Application of Salt – The management of the salt stock and its replenishment is an essential element of effective winter service. Minimum holdings are specified for each depot, which can be varied over the winter period. The salt stock levels are generally based on historical information and are sufficient to cope with an average winter and are topped up should extreme weather conditions occur.

The use of salt barns, which is becoming more widespread across the UK, ensures that salt is maintained with low moisture content, preventing leaching and allowing easier handling of the salt.

The quality, chemical composition and uniformity of salt are important to ensure control of the rate of spread. Rock salt is used by most organisations in preference to vacuum and marine salt, mainly on the basis of cost. Generally, a fine grading of rock salt is used for precautionary salting due to reduced vehicle damage and a more uniform spread on the carriageway together with minimising overspread and contamination of adjacent vegetation.

Type and grade		BS410 test sieve	% passing
Rock salt	Coarse	10 mm	100
		6.3 mm	75-95
		2.36 mm	30-70
	Fine	300 µm	0-20
		6.3 mm	100
		2.36 mm	30-80
Vacuum salt and marine salt	Coarse	300µm	0-20
		10 mm	100
		1.18 mm	0-80
	Fine	150 µm	0-10
		1.18 mm	100
		150 µm	0-30

GRADING OF SALT (BS3247)

Highways England's fleet of winter spread pre-wetted salt. Tanks fitted to the sides of the bodies on the new vehicles carry brine, which during treatments, is mixed with dry salt in measured proportions, to create the optimum blend (typically a 70:30 ratio, dry salt to brine). This pre-wetted salt is spread onto the surface of the road in a similar manner as if carrying out purely dry treatments. In Scotland all front-line vehicles use

pre-wetted salt and pre-treatment routes are designed to allow a maximum 40g salt treatment to be delivered in a single pass.

During season 2016-17 transport Scotland introduced full brine precautionary treatments. This followed trials during the previous winter period in conjunction with TRL to assess the effectiveness and suitability for use. Brine treatments are now carried out on two individual routes on separate Operating Company units and Transport Scotland will look to roll out further treatments following a full review at the end of the current season.

For treatments in extreme cold, Transport Scotland has developed guidance for the Operating Companies on the use of alternative de-icers that work at temperatures below which road salt (sodium chloride) becomes less effective. The guidance advises the trunk road operating companies on the storage, management and application of a range of alternative de-icers. Transport Scotland has obtained stocks of EcoThaw, Safecote and Magnesium Chloride. Experience of using alternative de-icers is being built by trialling enhanced performance specifications for treatments on high altitude sections of the A9.

In Wales a combination of pre-wetted, pre-coated (addition of agricultural by products) liquid and dry salting using either 10mm or 6.3mm salt grading depending on the treatment requirement is used. Welsh Government has been using pre-wetted / pre-coated treatment for over 20 years.

The Use of Maintenance Plant and Equipment – The serviceability of the winter service plant is crucial to the effectiveness of operations. It is therefore essential to operate a well-maintained fleet of spreading vehicles.

There is a vast selection of plant and transport available for highways/roads authorities with which to discharge their winter service responsibilities. The topography and needs of each country and area is unique and it follows that this will create the need for a particular range of equipment in order to fulfil its function and the requirements. The choice in size and type of vehicle used depends on the character of the road network and length of salting route.

The current fleet of Highways England vehicles was procured through two companies: Romaquip and Aebi-Schmidt. The Romaquip spreader body is constructed almost entirely from stainless steel. The benefits



of this construction include reduced maintenance and increased operational life. The Aebi-Schmidt vehicle is equipped with a Stratos modular hopper with a powder-coated finish (electrostatic spraying and baking) which is an advantage for work in the harsh winter environment.. A vehicle with stainless steel spreader body is shown below.

Transport Scotland's South West Unit Operating Company Scotland TranServ have implemented further improvements utilising technology to improve winter service decision making and in controlling the application of anti-icing materials using the Schmidt Autologic system to run treatment routes and electronically record the route widths using GPS.

Each route is then programmed into the spreader control box for each permutation of spread rate. The spreader driver selects the combination of route number and spread rate, and spread is controlled by GPS, preventing overspreading by automatically changing spread width at each change on carriageway cross-section, and leaving the driver free to concentrate fully on driving.

Careful consideration is given in regard to resource requirements to react to heavy snowfalls. Purpose built four or six- wheel drive spreading plant is assigned to high ground or routes with significant gradients where increased traction and pushing power are essential in the event of heavy snowfall. Provisions are made for reserve snowploughs to be available to provide additional support and give cover in the event of damage to front-line equipment.

'Vulnerable locations' are identified where the road gradient can make it difficult for HGVs and other vehi-

cles to make progress in wintry conditions. Service providers evaluate the most vulnerable locations within their area and develop various measures, documented within their Winter Service Plans, which they will employ when severe weather is forecast. The measures include additional salt applications during precautionary treatments, special attention during winter patrols, pre-positioning snow ploughs vehicles in advance of snow storms. In addition, enhanced arrangements are put in place with recovery vehicle operators to aid quicker recovery of vehicles in difficulty or clearing incidents.

Where precautionary treatment shall be insufficient to prevent ice or snow remaining on the trunk road, further treatment including salting, ploughing and/or snow blowing is carried out to restore all roads to a

5.1.2 Treatment Matrix Guide

Weather Conditions Road Surface Conditions Road Surface Temperature (RST)	Air Temp	Treatment	
		Dry Salting (g/m ²)	Pre-wetted Salting (g/m ²) (see Note 1)
Frost or forecast frost RST at or above -2°C (irrespective of dry, damp or wet conditions)		8	8
Frost or forecast frost RST below -2°C and above -5°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked)		10	9
Frost or forecast frost RST below -2°C and above -5°C and wet road conditions (see Note 3 if lightly trafficked)		16	15
Frost or forecast frost RST at or below -5°C and above -10°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked and Note 5)		18	18
Frost or forecast frost RST at or below -5°C and above -10°C and wet road conditions (existing or anticipated) (see Note 3 if lightly trafficked and Note 5)		2 x 15	2 x 15
Light snow forecast <10 mm		20	18
Medium/heavy snow or freezing rain forecast		2 x 20	See Note 2 and Note 4 below
Freezing rain falling		20 (successive)	See Note 2 below
After freezing rain		20	See Note 2 below
Ice formed (minor accumulations)	above -5°C	20	See Note 2 below
Ice formed	at or below -5°C	2 x 20	See Note 2 below
Hard packed snow/ice	above -8°C	20 (successive)	See Note 2 below
Hard packed snow/ice	at or below -8°C	salt/abrasive (successive)	See Note 2 below

The rate of spread for precautionary treatments may, if appropriate, be adjusted to take account of residual salt or surface moisture.
It has been assumed that two treatments are required to achieve spread rates at or exceeding 30g/m².

Notes:

- 1) Spread rates for pre-wetted salt is the combined weight of dry rock salt and brine combined at 70:30 proportions by weight respectively with a maximum brine concentration of 23% salt.
- 2) When ice has formed or snow is lying dry salting is the preferred treatment unless the road is closed to traffic when pre-wetted salting may be used. Pre-wetted salting is the preferred treatment in advance of such conditions.
- 3) Treatments should be carried out, whenever possible, after traffic has dispersed standing water. Successive half rate treatments (for both pre-wet and dry salt operations) should be considered for lightly trafficked roads at the lower end of temperature bands indicated.
- 4) For snow covering forecast to exceed 30mm ploughing should be conducted early enough to ensure snow accumulations do not exceed 10mm. The rates in the table are for precautionary salt treatment.

ICE AND SNOW CLEARANCE TREATMENT RATES

(SOURCE: HIGHWAYS ENGLAND)



TRANSPORT SCOTLAND ICEBREAKER

safe condition and expose the original surface as soon as reasonably practicable. Snow is ploughed when the snow depth exceeds 30 mm. Each pass of the plough is supplemented by the spread of salt in accordance with a treatment matrix such as the one opposite.

Procurement of the Highways England fleet has led to savings in salt usage. This is due to the fact that the fleet has the ability to alter spread rates in 1g/m² increments. This has allowed the Highways England to adopt a new treatment matrix that works at reduced spread rates to those previously applicable. The treatment rates for ice and snow conditions currently used by Highways England can be seen in the table below.

In severe snow situations highways/roads authorities also make use of snow blowers, which are either self-propelled or de-mountable units. In Scotland where heavy snowfalls are a regular occurrence each year the self-propelled units are essential. The modern blower is powerful and capable of moving a high volume of snow. Transport Scotland recently introduced innovative new equipment including icebreakers, inverted V-ploughs and footway snow blowers.

Calibration of salt spreaders is essential to providing an efficient winter service operation and attention is given to the tests ensuring that each vehicle is achieving the correct spread rate and width of spread within defined parameters. The calibration of equipment is carried out in advance of the expected first frost by Highways England. Transport Scotland vehicles are calibrated twice each winter, in September and again in January. In Wales the vehicles are calibrated once the salt stocks have been replenished and vehicle salt use monitored and where identified vehicles recalibrated through the

winter season or where there is a change in anti-icing material being used.

Mutual Aid – Whilst each organisation must prioritise the treatment of their own networks, there are often arrangements between organisations to provide mutual aid. This includes the sharing of plant, labour and salt. One example of this mutual aid in action can be found in Scotland where salt procured by the trunk road service provider is stored by the local authority with good flexible work arrangements. The mutual aid arrangements facilitated the sharing of snow blowers to each other in order to respond quickly to varying weather patterns. In Wales, additional salt stocks are stored by Welsh Government at strategic locations to ensure high levels of resilience are maintained.

Road Weather Information Systems - Accurate prediction of ice and snow is a key factor in facilitating efficient winter service operations, minimising abortive salting works while keeping the network as safe as possible.

Highways/roads authorities make considerable investment in the very latest technology to provide the means for accurate prediction so that appropriate winter action is taken. In England, there are currently 254 weather stations active on Highways England's road network gathering weather data. In Scotland, there are 153 weather stations across Transport Scotland's road network. Transport Scotland also has 50 patrol vehicles equipped with remote accessible mobile temperature sensors and CCTV cameras in spreader vehicles to show real time conditions. The Department for Infrastructure, Roads also has a network of 21 Weather stations and a further 160 CCTV cameras which can be used to monitor the weather. Road weather information systems allow remote monitoring of weather conditions that impact upon the safe operation of road networks in real time. They feed into the production of weather forecasts and provide support to maintenance and operations personnel enabling them to make informed and timely decisions.

A road weather information system typically consists of Environmental Sensor Stations (ESS), commonly referred to as weather stations, and a web based service for the dissemination of information generated by the ESS to its users.

All highways/roads authorities throughout the United Kingdom make use of road weather information systems.



SNOW BLOWER IN USE IN SOUTH WALES

Within Wales the highways/roads authorities share this information between them to ensure the most accurate weather forecast is provided and validated by local weather stations together with the road conditions.

LATEST ADVANCES IN UK ROAD WEATHER INFORMATION SYSTEMS – HIGHWAYS ENGLAND’S WEATHER INFORMATION SERVICE

In 2016, Highways England introduced its new Severe Weather Information Service (SWIS). Building on previous system developments that improved the overall provision and frequency of the weather forecasts and weather observations, SWIS combines critical elements for weather information, decision making and treatment activities, and winter fleet activities into a single system. The amalgamation of these services helps Highways England and its partners to manage the risk of severe weather more effectively through improved access to dynamic real-time information, together with delivering technology-based efficiencies.

SWIS delivers an enhanced, consolidated view of information to approximately 2,000 operational users actively working to manage and improve the performance of the road network in advance of and during severe weather conditions, including winter service providers, maintainers and control room staff, and external parties. The system supports better planning, execution and recording of winter treatment actions, improved identification of weather events with a potential impact on the road network, and enhanced rectification of weather and winter treatment equipment faults

The service is supported by a fleet data logging specialist, providing real-time vehicle tracking and route

navigation for drivers, to enable Highways England to monitor all treatment activity carried out by the winter maintenance fleet. The solution enables the monitoring of all activity once a vehicle has left a depot and this data is recorded in SWIS to ensure compliance and to inform future planning.

3.3. ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

Snow & ice control measures are typically included within the winter service plan. Local highways/roads authorities within the United Kingdom work to a ‘best value’ business principle. A range of performance indicators (PI) are used to monitor winter maintenance.

Examples of performance indicators are:

Objective:	Compliance with response time for leaving the depot
PI:	Number of late departures; 100% compliance expected.
Objective:	Compliance with response times for completing the routes.
PI:	Number of late arrivals; 100% compliance expected.
Objective:	Receipt of the service provider’s diary.
PI:	Number of diary entries received after the agreed time limit as a percentage of total winter service diary entries.
Objective:	Receipt of the winter service order.
PI:	Number of orders received after the agreed time limit as a percentage of total winter service orders.
Objective:	Average cost to salt per kilometre.
PI:	Cost per winter service season.

Auditing the service can be undertaken in two different and separate forms. The first is by desktop, through analysing written records such as tachographs, computer printouts (possibly involving GPS), salt diaries, confirmation of call-out, driver training records, quality assurance operating procedure/winter service manual, and salt management records for the individual salting routes. The second is on-site, by carrying out random inspections to check that salt is being placed on the network at the correct time and in the right manner. A comprehensive record must be kept for each audit.

An important part of road weather information systems is to record base data in order to be able to assess the value of the forecasts. In general, it can be said that a road weather forecast has value if a correct decision is



NEW WELSH GOVERNMENT COMBI (SOLID / LIQUID) SPREADER WITH VIEW OF SPRAY BAR AND SPINNER ASSEMBLY

taken which prevents the formation of ice or snow accumulation on roads and/or a correct decision is taken which prevents the use of unnecessary de-icer applications. However, assessing value is complicated by external factors such as the residual de-icing chemical on the road and political considerations, which can bring about unnecessary treatments.

In order to judge the value in a forecast it is best to look at forecasts of road frost. This is usually done using a 2x2 contingency table, which compares the forecast against the actual.

By assigning financial values to these contingencies it is possible to derive a measure of value from the forecast. Using the contingency table there are a number of derived variables which can be produced:

- Percentage correct;
- Probability of detection;
- False alarm rate;
- Frost frequency

TWO BY TWO CONTINGENCY TABLE

	Frost forecast	No frost forecast
Frost occurred	Protection cost: (F/F)s	Damage cost: (NF/F)s
No frost occurred	Protection costs: (F/NF)	Correct rejection: (NF/NF)

Transport Scotland has introduced an extended trial of the ITD Storm Performance Index which analyses data coming back from each of its Road Weather Information Systems (RWIS). It utilises readings from non-invasive road surface state sensors using three lasers to determine the layer thickness of ice, water and frost/snow independently. These values are then combined into an index called Grip which shows how the friction level of the road surface has deteriorated due to the weather affecting the road surface.

Following upgrade of eight road weather stations on the Transport Scotland trunk road network in 2014, data suitable for analysis of treatment effectiveness utilising the Idaho Storm Performance Index has been possible over the past three winter seasons. The eight sites were chosen to represent two clear climatic areas.

The information provides a clearer indication of the saving made through current levels of investment in winter maintenance activities and provided an understanding of both individual event performance as well as macro level network details.

3.4. TRAFFIC SAFETY AND INFORMATION

Contact through the traditional and more modern media is important as a means of keeping the road user informed of adverse conditions and promoting safety on the highway.

Through this contact with the community and road users, the operations are more effective, better understood and promote a positive interchange of views with the public. Highway/roads authorities therefore make use of several means of communication which include:

- Leaflets on ways motorists can help to improve road safety;
- A plan of the spreading network;
- vPress releases relating to winter service and particular highway incidents;
- Press articles;
- Press/radio/television interviews;
- Information passed through motoring organisations and local radio stations;
- Information and advice on highway/road authority websites;
- Information on variable message signs both in advance of and during severe weather;
- Information passed through social media networks



HIGHWAY/ROADS AUTHORITIES' USE OF SOCIAL MEDIA

such as Facebook and Twitter; and

- YouTube videos to explain how winter service is delivered.

Many highway/road authorities provide information and advice to the road user through their websites, which includes details of priority treatment routes and advice on preparing for the winter. In recent years, the use of social media networks for the dissemination of information to the road user has grown. In terms of adverse weather, Highway/roads authorities are making use of their Twitter and Facebook pages to inform road users of spreaders on the road and also to warn of forecast adverse weather conditions.

For the English Trunk Road Network, weather and road condition information is distributed to the media and Highways England customers from Highways England's National Traffic Operations Centre (NTOC) in Birmingham. During the winter months, weather forecasters are stationed in the NTOC to ensure that Highways England can provide early warning of severe weather and give targeted advice about safe driving and road conditions regionally or nationally as appropriate.

Highways England provides the management team, Ministers ministers and the Press Office with information on the state of the network and weather-related incidents. SWIS also ensures that adjacent service providers, local authorities, police, and Highways England area teams are aware of winter service decisions. The service providers have a minimum requirement to report on the state of the network and treatment decisions at 10:00 and 16:00 each day. In addition, the service providers are to give an assessment of the weather forecast and their intended winter service action for the weekend before 16:00 on Friday.

Snow blower in use in South Wales

Following the successful introduction of a salt management facility in previous versions of Highways England's web based system, these functions have been delivered within SWIS all highways authorities in England use this so that a national overview of salt stocks can be derived. This live, reliable and accurate stock reporting is an aid to both the authority and the salt supplier.

In Northern Ireland, summary information on winter service salting activities is relayed electronically to the broadcast media for public distribution. Information is also relayed through the public facing traffic information website TrafficWatch to ensure that the latest news on road conditions is available to motorists prior to peak travel periods.

Transport Scotland's winter response is co-ordinated from the control centre for Traffic Scotland, the national ITS (Intelligent Transport System). It is controlled and operated from a purpose-built control centre, ope-



SNOW BLOWER IN USE IN SOUTH WALES

ned in 2013, at the existing Forth Road Bridge, ideally located for optimal management of the existing bridge and the new Forth Replacement Crossing, which will be opened in 2017.

In Scotland, the daily winter action plans are being made publicly available on the Traffic Scotland website. The information goes live at 3pm each day following receipt of the forecast. The action plan information tells people where the salt spreaders will be at what time and how much salt they will be spreading.

In 2016 Transport Scotland further enhanced the information available to the public when it launched the Gritter Tracker service on the Traffic Scotland providing live tracking of the Trunk road Winter fleet across Scotland.

Transport Scotland working in partnership with the Scottish Police has developed a severe weather information strategy to warn and inform road users when significant disruption to the road network is expected during extreme weather. The advice and information service is instigated when severe weather is forecast within Scotland. Forecast information will be provided in advance of, and during, any severe weather event.

Travel advice issued is aligned to four specific risk categories, with the appropriate warning issued based upon the anticipated severity of conditions described within the weather forecast. The four levels of advice are:

- Stage 1 Normal operations - No severe weather
- Stage 2 Travel with caution - Police are advising travellers that conditions for road travel are hazardous and drivers should exercise extra caution
- Stage 3 High risk of disruption for road journeys - Police are advising that conditions for travel are extremely poor and there is a high risk of disruption for road journeys. Travellers are likely to experience significant delays
- Stage 4 Avoid travelling on the roads - Police advise drivers to avoid travelling on the roads. Travellers will experience severe delays of several hours or more.

This advice is provided to road users through Transport Scotland's network of Variable Message Signs, the Traffic Scotland website, radio travel information broadcasts and the Traffic Scotland Customer Careline to help them play their part during extreme weather events.

The Scottish Multi Agency Response Team (MART), a group of partners that work together to improve the quality and timing of transport information, co-ordinates the flow of information between agencies and the public. A Met Office representative works in MART to ensure that any changes to the severity or areas affected by severe weather can be updated and provided to the public. The MART consists of Traffic Scotland, Transport Scotland, the Met Office, the operating companies, Network Rail, First Scotrail, Confederation of Passenger Transport, Police Scotland, and the Society of Chief Officers of Transportation in Scotland. Other ways in which Transport Scotland makes information available to the public include:

- The provision of CCTV camera images on its website, enabling road users to check current conditions on the network before setting out on their journey.
- The Traveline app for smart phones.

In Wales, the Welsh Government promotes the service providers to develop effective liaison and communications with Police, media, emergency services, public transport operators, freight transport, and haulage and automobile associations directly in order to avoid extended chains of information. A Traffic Management Centre is located in North and South Wales, and through "Traffic Wales" the public is informed of traffic and road conditions and can access live CCTV images. Where there is an impact on the operation of the motorway or trunk road network as a result of weather or incidents the most up to date information is available.

During severe weather conditions the Traffic Management Centre facilities are utilised to coordinate and manage winter service activities and liaise with other highway authorities.

3.5. LOCAL COMMUNITY COLLABORATION

Many local authorities have taken steps to collaborate with local communities in the delivery of certain aspects of winter service. Examples of this collaboration include the provision of salt/grit bins in locations that are not on treatment routes or where a particular hazard has been identified. The public are able to access these bins for use in the community on public roads and pavements. This can be particularly useful for 'joining up' treatments from the main road carried out by cCo-

County Council spreader vehicles to smaller access roads. Norfolk County Council can be used as one example of this scheme in action. They first implemented the sponsorship and provision of salt/grit bins through Parish, Town, District and Borough Councils in 2010. By 2012, Norfolk had a total of 1500 salt/grit bins available around the county for public use.

Some local authorities have commenced Snow Champion schemes. Champions are provided with the correct equipment and guidance on how and when to clear footways. There is no contractual relationship with the Snow Champions and this is on a purely voluntary basis. An example of this scheme can be found in Cumbria County Council, who during the 2012/13 winter season, were aiming to recruit up to 300 volunteers (around 50 in each district) to help clear snow and ice from footways and pavements near their homes.

A similar scheme used by other County Councils involves the recruitment of town and parish councils to help keep paths and pavements clear during the winter. Town and parish councils are provided with salt free of charge, and free training courses for the safe operation of clearance of snow and ice from footways. In return the town/parish council are asked to provide details of footways treated using the free salt provided, identify a 'Snow Warden' to co-ordinate activities locally and provide information to the County Council about local conditions, and someone who has the authority to order the refilling of bins on behalf of the parish/town council.

Other local authorities have contracted out snow clearing work in isolated villages, industrial areas and schools not on treatment routes to farmers and other large vehicle drivers as part of a tendering process to



SNOW CLEARANCE BY A FARMER ON A MINOR ROAD

provide added capabilities during instances of severe weather. One of the benefits of using those from local communities to assist with treatment is the local knowledge they have of the roads that need treating the most in their communities.

Suffolk County Council has contracts with over 200 farmers (and other contractors) and Kent County Council has arrangements with approximately 180 farmers across the county, who assist in snow clearance when needed. Many other County Councils have similar numbers of arrangements with farmers. An example of how this works in practice can be seen at Norfolk County Council. A mixture of modified ploughs supplied by the County Council and farmer owned ploughs are used to enable the clearance of snow on minor roads that are not on priority routes. Farmers receive start of season training/briefings on how to undertake the activities and all equipment is inspected by the county council prior to the start of the winter season to ensure it is in a safe and working order.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1. THE NATIONAL WINTER SERVICE RESEARCH GROUP

The NWSRG is a members group dedicated to advancing understanding of best practice for winter service delivery, taking the best from currently available knowledge and supplementing any gaps with new knowledge and research. It is supported by experts from the winter service industry and government bodies. The NWSRG Steering Group is a Technical Sub-Group of the



COUNTY COUNCIL SUPPLIED SALT/GRIT BIN

UK Roads Board. In turn, this is part of the UK Roads Liaison Group family of organisations.

The NWSRG provides oversight and liaison for the development of guidance and new knowledge for the UK public roads sector, with the NWSRG Practical Guide for Winter Service now providing the national guidance on winter service in the UK and promoting its use amongst highway authorities. It has also developed a syllabus for training winter service decision makers, based on the Practical Guide.

Improvement is an ongoing process and there has been a process of review and updating of the guidance to take on board feedback and comments from practitioners and to ensure consistency with the new risk based approach advocated in the UK Code of Practice 'Well-managed Highway Infrastructure. Some key changes include new, and simpler, spread rates tables. The guidance relating to factors such as traffic levels and wind speed is also being updated and revised. As part of the update, additional supporting information is also being introduced. For example, it may be useful for an authority to be able to demonstrate that the spread rates they utilise have 'safety factors' built in to account for expected losses over time, and that the actual amount of salt required on a road surface to prevent ice from forming at any particular time is not that great. A working group have also been reviewing the calibration guidance, including new photographs and guidance videos being added to help practitioners readily understand and undertake the calibration and monitoring process, including crucially an assessment of the salt distribution. The new national code Well-managed Highway Infrastructure places more emphasis on using a risk-based approach and the Practical Guide will incorporate how this approach should be applied to winter service

The group are considering the key areas for future research, with potential topics under consideration including research and advice on residual salt, both how to measure and its longevity. This will inform guidance for practitioners when retreatment is necessary. Another area for development is how risk based decision making can be applied to winter operations, including guidance that will clearly link to information presented by weather forecasters.

The group are also considering if its remit should be extended to cover other severe weather events apart

from snow and ice. Many winter practitioners are already involved in responding to these emergencies in addition to their winter service responsibilities and the NWSRG has strong links with the Environment Agency and Met Office, whose expertise would be essential to delivering the guidance.

4.2. ADVANCES IN SPREADER TECHNOLOGY

Since the mid-1990s organisations throughout the United Kingdom have been seeking to reduce salt usage through the integration of new technologies, such as global positioning system (GPS), geographical information systems (GIS), digital radio communications and forecast thermal mapping. Experimentation through recent research and development projects in the United Kingdom has demonstrated that selective salting is both possible and desirable. The possibility to start and stop spreading also provides the possibility of varying the spread rate along the route in accordance with the forecast thermal map temperatures. The next logical step would be to provide real-time weather data captured by the vehicle as it travels along the route and this is now possible through the spreaders reading and recording road surface temperatures whilst carrying out their route.

Highways England's winter fleet in England is equipped with a data logging capability which provides a facility for real time data capture. The amount of salt spread, spread width, material type, time taken to complete the route, and, fuel usage are examples of some of the elements that data logging can capture. The latest GPS technology also help drivers to accurately execute winter service activities through provision of in-vehicle software, meaning turn by turn guidance is readily available to ensure efficient treatments.

The use of data logging further aids Highways England and its Service Providers to monitor salt usage and spreader driver behaviour, thus improving the sustainability of the winter service provided.

Another benefit of the data logging technology comes in the form of protection against claims from third party motorists. This is a key issue for Highways England and data logging provides robust evidence to strengthen the defence against claims as data logging can pinpoint a vehicle's location at any moment in time.

4.3. ALTERNATIVE MATERIALS

As part of the drive to reduce salt usage Highways England is looking at the suitability of brine only treatments. Brine is particularly suitable for precautionary treatments on marginal nights which can be typical due to the weather patterns in much of the United Kingdom. The economical and social impact of winter treatments is being assessed by trials to measure the corrosive effect of various de-icers on highway assets. In addition, work into the environmental effects of winter treatments also continues.

Much of the ongoing work on the use of alternative materials in the UK is based around the need for intelligent application of treatment materials to best fit the environmental conditions of the location it is applied.



This also extends to the geopolitical environment. For example, Norfolk County Council undertook trials using alternative liquid de-icers on priority footways using a drop sprayer mounted on a small grounds maintenance vehicle. The purpose of the trials was to reduce the number of complaints about tracking rock salt into shops and to provide a more effective treatment on footways at lower temperatures. Trials proved effective preventing the formation of ice in low temperatures experienced during the 2010/11 winter season, and also resulted in fewer complaints from shopkeepers.

4.4. RESIDUAL SALT MEASUREMENT

Within the United Kingdom research is ongoing into measuring residual salt on the road surface. Currently road inspections confirm whether there is sufficient residual salt on the road to deal with the current conditions. There is a great possibility in the future that the measurement of residual salt on road surfaces might take place through intelligent systems.

4.5. MOBILE CONDITION SENSORS

In Scotland, four winter spreader vehicles used to patrol the M8 utilise a mobile condition sensor that monitors pavement condition - grip and pavement temperature in real time. The data is displayed on a smart phone on the dashboard of the vehicle or transmitted via the phone's mobile network to road weather management software for viewing by others at a central control room.

It provides information that can be used to complement existing fixed weather stations allowing the patrol driver and winter duty personnel to make better informed decisions on the need to carry out ad-hoc treatments on the network.

5 REFERENCES

- ¹ Transport Statistics for Great Britain (TSGB) 2012;
- ² Northern Ireland Transport Statistics 2003-2004; Transport Statistics Scotland 2003
- ³ Section 41 (1A) of the Highways Act, 1980; Section 111 of the Railways and Transport Act 2003; Section 150 of the Highways Act 1980
- ⁴ Section 150 of the Highways Act 1980
- ⁵ In Scotland, the terminology used is 'road' instead of 'highway'.
- ⁶ Section 34 of the Roads (Scotland) Act 1984



1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The United States of America is a federal system composed of 50 states, the District of Columbia (a federal district), five major self-governing territories, and several island possessions. Each state is composed of numerous local governments. The Federal Highway Administration (FHWA), within the national executive branch, neither operates nor builds highways, but administers over \$41 billion (1) since 2016 of federal-aid highway funds to states and localities, primarily for capital expenditures. State and local governments spent \$291.2 billion on transportation (including expenditures paid with federal grants). (2).

Area	Total	9,161,979 km ²
	Snowy regions	7,447,614 km ²
Population	Total	304.06 million
	Snowy regions	215.79 million
Road Length	National Highway System	262,809 km
	Snowy regions	195,626 km
	Other Federal-Aid Hwys	1,320,998 km
	Snowy regions	958,957 km
	Non Federal-Aid Hwys	4,900,125 km
	Snowy regions	3,678,426 km
	Total	6,483,932 km
Snowy regions	4,833,010 km	
Latitude (capital)		39°N

The total area of the United States is over 9.1 million square km. More than 81% of this land (or 7.4 million square km) is in snowy regions. Across the entire United States, the average snowfall is more than 67.9 cm per year with the highest average in Vermont at 226.7

cm and the lowest average in Hawaii at 0 cm. The population of the United States exceeds 325 million people (3). Nearly 71% of Americans (or more than 229 million people) live in snowy regions.

1.2 ROAD NETWORK AND TRAFFIC

The road network consists of more than 6,7 million km of highways. Over 364,000 km of the road network are part of the National Highway System, which is comprised of interstate expressways and primary roads. There are over 1,2 million km of other federal-aid highways and more than 5 million km of non-federal-aid highways. On average, each vehicle travels more than 21,243 km each year. Nearly 235 million passenger vehicles (cars and light trucks) use U.S. highways to commute to work, for personal business, or for recreational travel. More than 3 million commercial vehicles use the highways, with about 1,1 million being long-distance freight haulers (4).

	Private & Commercial	Publicly Owned	Total
Automobiles	111.490.611	1.470.655	112.961.266
Buses	567.573	408.588	976.161
Trucks	143.913.338	2.268.938	146.182.276
Motorcycles	8.649.613	29.767	8.679.380
All Vehicles	264.621.135	4.177.948	268.766.083

Winter weather has a significant effect on traffic flow, road safety, and agency productivity. It has been estimated that 23% of the non-recurrent delay on highways across the nation is due to snow, ice, and fog. This amounts to an estimated 544 million vehicle-hours of delay per year. Snow-covered and icy pavement also caused significant delay. Each year, approxima-

is related to performance measures for snow and ice control strategies. When the winter road maintenance budget is exceeded, the DOT plans to use the frost index to help justify requests for additional funding.

The Wisconsin DOT uses a winter index with five weather factors including snow events (SE), freezing rain events (FR), snow amount (AMT), storm duration (DUR), and incidents (INC) such as drifting, cleanup, and frost runs. The Wisconsin winter index is used to classify the type of winter and to evaluate expenditures and performance.

$$WI = 10 * \frac{SE}{63} + 5.9 * \frac{FR}{21} + 8.5 * \frac{AMT}{314} + 9.4 * \frac{DUR}{1125} + 9.2 * \frac{INC}{50}$$

The Kansas DOT and the Minnesota DOT have adopted a winter index developed by the Strategic Highway Research Program (SHRP). Weather factors in the SHRP index include mean daily snowfall (S), proportion of days with air frosts (N) (that is, days with maximum air temperature at or below 0 °C), temperature range (R), and an average daily temperature index (TI). The temperature index is 0 if minimum air temperature is above 0 °C, 1 if maximum air temperature is above 0 °C while minimum air temperature is at or below 0 °C, and 2 if the maximum air temperature is at or below 0 °C.

$$WI = a(TI)^{0.5} + b \ln\left(\frac{S}{10} + 1\right) + c \frac{(N)^{0.5}}{R + 10} + d$$

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Because of the allocation of maintenance to state and local governments, there is no national policy for winter road maintenance in the U.S. State and local governments may operate their own maintenance equipment, hire contract services, and establish their own Level of Service (LOS) goals. Level of Service may be based on pavement condition goals, traffic levels, or customer satisfaction. Winter road maintenance efforts vary based on climatic conditions, agency resources, and roadway characteristics. Higher classes of highways generally receive more attention. Routes on the National Highway System are typically cleared

more completely and quickly. Critical areas like mountain passes may have snow-chain requirements for vehicle tires, and many local streets are designated “snow emergency routes” that must be cleared of parked cars during snow events.

In the United States, winter road maintenance involves controlling snow and ice through mobile techniques or fixed systems. Mobile snow and ice treatment strategies include plowing snow, spreading abrasives (such as sand, ash, and crushed stone) to improve vehicle traction, and dispensing anti-icing/deicing chemicals to lower the precipitation’s freezing point and minimize the bonding of snow and ice to the pavement surface. These strategies are often used in combination. In regions with heavy snowfall, maintenance managers may also erect snow fences adjacent to roads to reduce blowing and drifting snow. (6)

Surveys by the American Association of State Highway and Transportation Officials (AASHTO) Lead States Program have found that nearly 40 states use anti-icing strategies. In addition to mobile anti-icing/deicing operations, 23 states have deployed fixed anti-icing/deicing systems on bridges, sharp curves, and other locations prone to icing (7). These fixed systems typically consist of a controller, tanks, pumps, conduits, and nozzles that dispense anti-icing chemicals on a predetermined area of pavement. Chemical applications can be activated manually or automatically based on Environmental Sensor Station (ESS) data.



FIXED ANTI-ICING SPRAY SYSTEM
(PHOTO COURTESY OF CRYOTECH DEICING)

Several types of snow and ice control materials are used in the U.S. including solid chemicals (dry and pre-wetted), liquid chemicals, abrasives, as well as abrasive and chemical mixtures. Chemicals used include sodium chloride, calcium chloride, magnesium chloride, calcium magnesium acetate, potassium acetate, calcium acetate, and magnesium acetate; with sodium chloride being the most prevalent. Snow and ice control material application rates depend on conditions (such as weather, pavement, and traffic) at the time of treatment and on how conditions are expected to change prior to the next treatment (7). Abrasive application rates range from roughly 140 kg to 419 kg per lane km with the average being approximately 224 kg per lane km. Application rates for solid and liquid chemicals vary based on pavement temperature ranges, dilution potential, and ice-pavement bonding. The American Association of State Highways and Transportation Officials (AASHTO) has created a guide for snow and ice control (8).

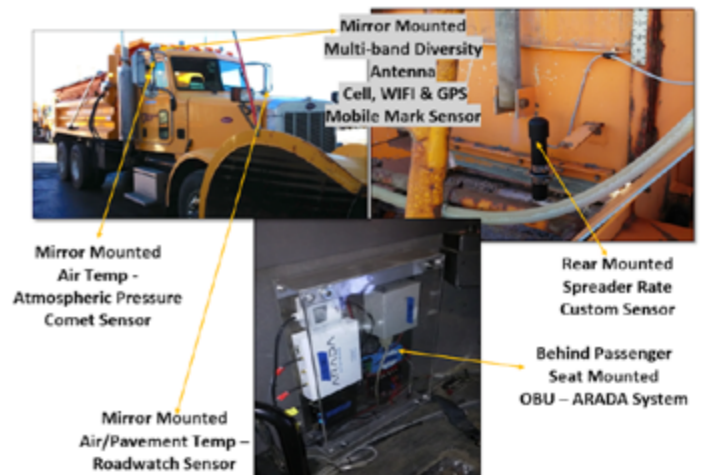
Solid treatment materials are often applied to roads by maintenance vehicles equipped with spreaders, which typically dispense free-flowing granular materials across a width ranging from one to twelve meters, but more often concentrating on the crown (high point) of the road. In many cases spreader operation is automatically adjusted based on vehicle speed. Liquid treatment chemicals are usually applied with vehicle-mounted spinners or spray nozzles. Different types of hydraulic snowplows are used including one-way front plows, reversible plows, deformable mouldboard plows, underbody plows, side wings, and plows designed specifically for slush removal (squeegee-type blades). (7)

Several states have demonstrated and tested advanced winter maintenance vehicles and new maintenance vehicle management systems (7). Snowplows equipped with environmental sensors, as well as Automated Vehicle Location (AVL) and Global Positioning System (GPS) technologies are being used to monitor air and pavement temperatures, observe pavement conditions, track vehicle locations, monitor vehicle systems (such as plow position, material application rate), and monitor road treatment activities. Central computers provide map-based displays for managers who can plan treatment strategies, monitor winter maintenance operations, or

conduct post-event analyses. Central managers can also communicate with plow drivers via in-vehicle devices with integrated display and communications capabilities.

In 2017, the FHWA promoted adoption of mobile data collection through a project named “Integrating Mobile Observations (IMO)”. IMO involves collecting atmospheric weather, road conditions, and native data from government fleet vehicles’ ancillary weather sensors and vehicle-based controllers. The data provides maintenance and operations managers with a more detailed view of the weather and road conditions as well as asset locations along the highway network. This information supports a host of road weather management strategies, including maintenance, traffic, and performance management decision making. IMO is being deployed through the Every Day Counts-4 Initiative “Weather-Savvy Roads”. For additional information on IMO, go to <https://collaboration.fhwa.dot.gov/dot/fhwa/RWMX/default.aspx> – click on Weather-Savvy Roads Resource Toolkits then click on Integrating Mobile Observations..

Other advanced snowplow technologies include heads-up displays that delineate the roadway when visibility is reduced by fog or blowing snow (virtual route guidance systems). These technologies can help snowplow drivers determine their lane position, warn of objects and obstacles in front of and behind the vehicle, and increase safety by reducing the frequency of snowplow-related crashes. (7)



NEVADA DOT IMO VEHICLE

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

In the United States, winter maintenance is decentralized since roads are owned and operated by state and local agencies. State and local governments fund and perform snow removal and ice control activities or contract with private entities for these services.

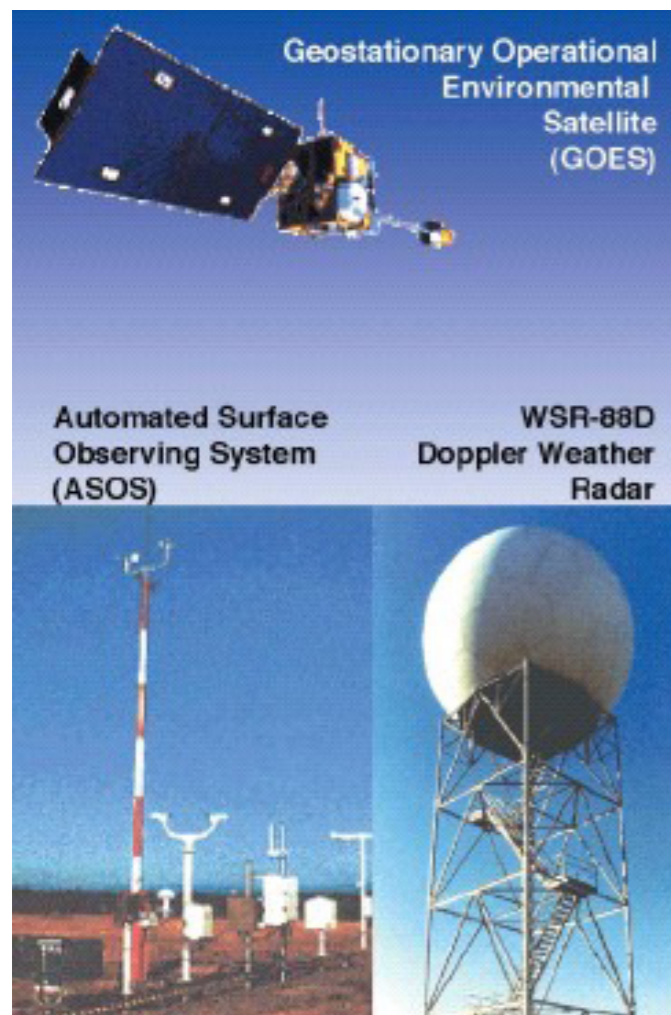
Regional differences between average and extreme snowfall create differences in how road maintenance agencies respond to winter weather, from continual and routine treatment to occasional and emergency response for infrequent events. In some states, maintenance agencies coordinate with traffic management agencies to close roads during snow and ice control operations, impose lower speed limits during inclement weather, or restrict travel to vehicles with snow tires or chains (13).

The 50 states coordinate through AASHTO's Snow and Ice Cooperative Program (SICOP) for implementation of advancements and training. SICOP has developed a Computer-Based for Road Weather Information System (RWIS)/Anti-Icing training. The national training program is being used by 90% of Snow Belt states, the Association of Public Works Association (APWA) and the National Association of County Engineers (NACE).

Maintenance personnel use road weather information to assess the nature and magnitude of environmental threats, make decisions about road treatment strategies, and manage resources (that is, staff, equipment, and materials) (8). State and local agencies use various sources to obtain road weather observations and forecasts including the National Weather Service (NWS), private sector meteorological service providers, RWIS, and thermal mapping. The NWS is a federal agency operated under the National Oceanographic and Atmospheric Administration (NOAA). The NWS is chartered with weather forecasting; issuing storm warnings; disseminating weather and flood warnings for the benefit of agriculture, commerce and navigation; and taking meteorological observations to record the climatic conditions of the United States. In practice, the NWS provides general weather information and warnings for public safety. NWS products include observations from surface sensors (such as ASOS), Doppler radars, geostationary and polar satellites; national forecasts and numerical model guidance from the National Centers for Environmental Prediction (NCEP); as well as regional forecasts and warnings from 122 Weather Forecast Offices and 13 River Forecast Centers.

Generally, the observations provided by the NWS are inadequate for characterizing details of the road environment such as pavement conditions and localized visibility conditions. Because it is not the mission of the NWS to provide customized forecasts to support operational decision making, tailored road weather information is typically provided by private value-added meteorological service (VAMS) providers, who are contracted for route-specific "nowcasting" and forecasting services.

Pathfinder: Heavy rain, snow, and other storms can have significant impacts on the safety, mobility, and productivity of road users. The Federal Highway Administration (FHWA) Weather-Savvy Roads effort, in coordination with the National Weather Service (NWS),



ENVIRONMENTAL OBSERVING TECHNOLOGIES

and through round four of Every Day Counts, is encouraging the implementation of Pathfinder to minimize these impacts. Pathfinder, a collaborative strategy for proactive transportation system management ahead of and during adverse weather events, encourages State departments of transportation (DOTs), NWS, and weather service contractors to share and translate weather forecasts and road conditions into consistent transportation impact messages for the public.

Pathfinder Benefits

- **Enhanced collaboration.** Working together to implement Pathfinder strengthens the relationships between the NWS and DOTs.
- **Informed travelers.** Impact-based road weather statements and decision support enables drivers to make better decisions regarding where, when, and whether to travel.
- **Improved safety, mobility, and economy.** With the ultimate goal of saving lives and property, and minimizing the impact of weather events, consistent impact messages can reduce traffic demand. (16)

State DOTs reported high levels of subscription to weather and road-weather products and services that support the DOTs' advisory, control, and treatment strategies. In addition to mass media, various weather data are available to agencies from both public and private sources, including information from the National Weather Service (NWS), the Federal Aviation Administration, sensors deployed by Federal and State

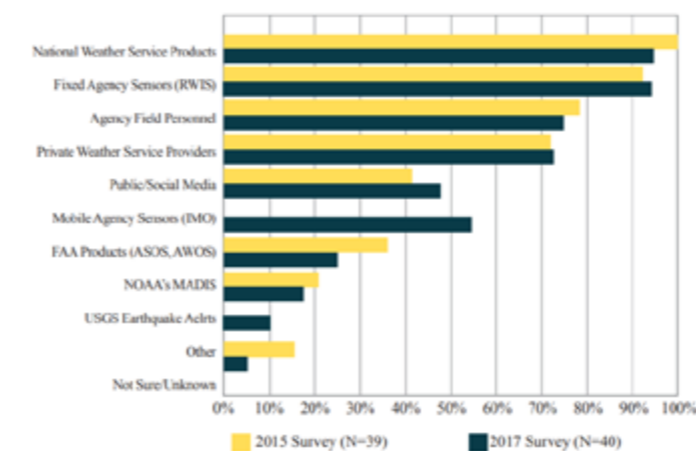
agencies, and private sector value-added services. Since 2015, the number of subscribers of these services has remained relatively constant, with some products and services seeing increases in popularity while other have seen declines as shown in the following table. (9)

The FHWA has been active in trying to integrate observations from state-owned Environmental Sensor Stations (ESS) with NWS surface observations. ESS are deployed along roadways and other transportation facilities to provide their agencies with observations of surface weather and pavement conditions. Most ESS are deployed as the field components of RWIS (16). RWIS has been widely used in the United States since the late 1980s. Currently, there are nearly 2,500 ESS in the U.S. Over 2,000 of these are part of state-owned RWIS. Central RWIS hardware and software collect field data from numerous ESS, process data to support various operational applications, and display or disseminate road weather data in a format that can be easily interpreted by a decision-maker. (10)

Maintenance personnel can also use thermal mapping to obtain information on pavement temperatures. Thermal mapping involves use of infrared sensors (hand-held, vehicle-mounted or satellite-based) to create thermal profiles of road surfaces. Measurements are taken under various environmental conditions. Several states, including Washington, Nevada, and Minnesota, have created thermal maps of highway segments. Thermal mapping data have been used to optimize siting of ESS, predict pavement temperatures in locations without ESS, and plan winter road treatment strategies. (4)

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Some states have embraced the concept of performance standards to assess winter maintenance activities (12). Some agencies conduct post-storm evaluations of treatment effectiveness (such as pavement friction measurements) to identify modifications or improvements in treatment strategies (4). Post-season assessments can be used to modify routing and determine changes in personnel and training procedures or equipment and material needs. The Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) Report 526: Snow and Ice



PERCENTAGE OF STATES THAT SUBSCRIBE TO WEATHER AND ROAD WEATHER PRODUCTS AND SERVICES.

Control: Guidelines for Materials and Methods provides guidance for selecting roadway snow and ice control strategies, and tactics for a wide range of winter maintenance operating conditions. This guidance applies to highways, roads, streets, and other paved surfaces that carry motor vehicles—under state or local jurisdictions. (11)

Some benefits of snow and ice control operations have been quantified. Winter maintenance activities have improved safety by reducing crash frequency and minimizing risks to field personnel and motorists. Roadway mobility is improved when accumulated snow and ice are removed and the number of road closures is minimized. U.S. maintenance managers indicate that effective anti-icing and pre-wetting strategies reduce sanding applications by 20% to 30%, decrease chemical applications by 10%, and reduce chloride and sediment runoff in local waterways. Evaluation data shows that anti-icing programs can lower snow and ice control costs by 10% to 50% and reduce crash rates by 7% to 83%. Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found crash reductions from 25% to 100%. With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety; benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1 (7).

3.4 TRAFFIC SAFETY AND INFORMATION

In addition to supporting winter maintenance decisions, ESS data is used by traffic managers to modify traffic signal timing, activate automated motorist warning systems, vary speed limits, close roads, and disseminate traveler information (7). Almost half of all states (i.e., 24) use ITS technologies to manage traffic diversions in response to road closures due to weather events. The same number of states use ESS to determine the need to implement temporary restrictions on vehicles. Many states use variable speed limits to respond to weather conditions (12) in addition to congestion and work zones. Traffic managers provide travelers with road weather information through dynamic message signs, highway advisory radio, Web sites, and 511—the national traveler information telephone number. The Internet is the medium most commonly used by state agencies to disseminate roadway conditions and we-

Answer Options	Deployed Statewide (or in all applicable locations)	Limited or Partial Deployment	Not Yet Deployed	Not Sure/Unknown	Total
Atmospheric Weather Information on Dynamic Message Signs	42.1%	21.1%	36.8%	0.0%	100.0%
Road Condition Information on Dynamic Message Signs	50.0%	35.0%	12.5%	2.5%	100.0%
Road Condition Information on Highway Advisory Radio	27.0%	27.0%	32.4%	13.5%	100.0%
Road Condition Information on Agency-Hosted Social Media (Twitter, Facebook, etc.) or Mobile Applications	60.5%	26.3%	13.2%	0.0%	100.0%
Road Condition Information on Agency-Hosted Websites or 511 Phone Systems	77.5%	15.0%	7.5%	0.0%	100.0%

Answered Question 40

ather forecasts on a statewide basis; 60.5% distribute weather information via Web sites and 77.5% distribute it via 511. Over 80% distribute weather information on dynamic message signs and over 50% use highway advisory radio. (9)

The Washington State DOT has an advanced web site that includes integrated displays of weather and pavement conditions.

Road weather information is more important to travelers than construction information, traffic conditions, travel times, public transit information, or incident information. A public opinion survey found that weather-related and road surface conditions were most frequently identified as important elements for a 511 service.

4 ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGIES

Since 2000, the FHWA Road Weather Management Program (<https://ops.fhwa.dot.gov/weather/>) has sponsored the development many guidance tools for road weather maintenance and operations decision makers.

Maintenance Decision Support System (MDSS):

The MDSS prototype was created by a consortium of U.S. national laboratories with significant input and feedback from numerous state DOTs and commercial weather information providers. The MDSS prototype capitalizes on existing road weather data sources, fuses data to present integrated road weather observations and predictions and generates recommendations on road treatment strategies with anticipated consequen-

ces of action or inaction. Treatment recommendations are based on standard practices for effective winter road maintenance (such as anti-icing, de-icing, plowing, sanding), which are tailored to the procedures of the local agency. The MDSS prototype was field tested during the winters of 2003 and 2004 in the state of Iowa. The FHWA has cultivated relationships with private vendors to foster integration of prototype modules into their product lines and development of applications tailored to the needs of state DOTs. Currently, MDSS technologies are being incorporated into the product generation routines of several private sector companies. (6)

By 2004, MDSS technologies were mature enough for private sector companies to incorporate MDSS capabilities into their product lines for State DOT clients. By 2007, 21 state transportation agencies were using or developing MDSS tools. Thirteen states have joined the MDSS Pooled Fund Study led by the South Dakota DOT to develop an enhanced version based on the federal MDSS prototype, while others are in the process of procuring the software or have contracted with private vendors for maintenance decision support capabilities. In 2008, the FHWA released an MDSS Deployment Guide (https://rosap.ntl.bts.gov/view/dot/3254/dot_3254_DS1.pdf?). From 2007 to 2009, the FHWA conducted evaluations of operational MDSS applications being used by the pooled fund states, the Maine DOT, and the City and County of Denver, Colorado (2).

4.2 NEW MANAGEMENT AND ORGANIZATION APPROACHES

The FHWA Road Weather Management Program was formed in 1999, for coordination of snow and ice programs, among federal agencies and with the state and local constituencies. The program seeks to better understand the impacts of weather on roadways and promote strategies and tools to mitigate those impacts. Envisioned is a system that provides “Anytime, Anywhere Road Weather Information” for road operating agencies and road users, as well as a robust, competitive market for road weather services. Program goals are to enhance observing capabilities, facilitate training and information dissemination, advance the state-of-the-practice, and promote coordinated research.

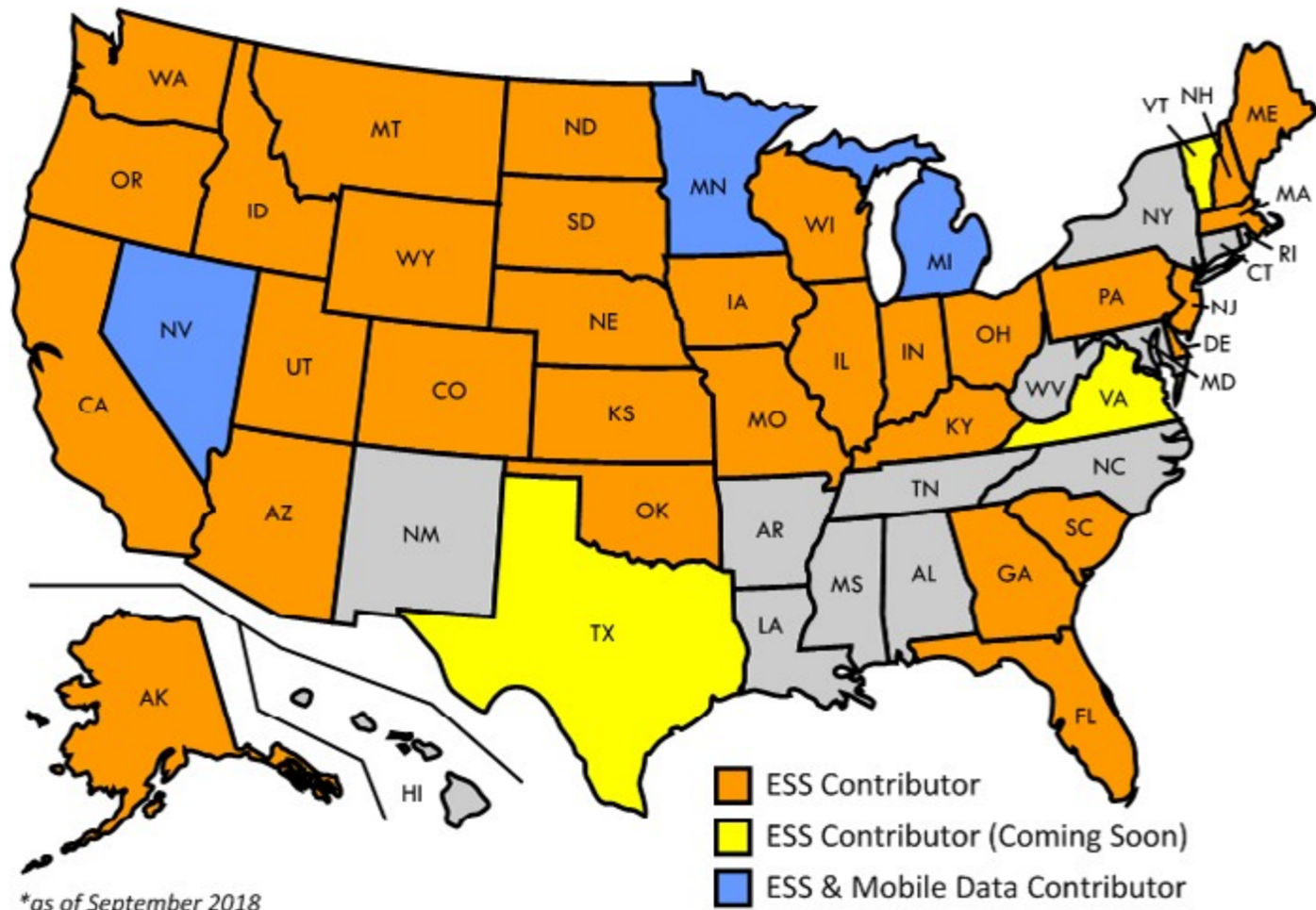
In late 2004, the Road Weather Management Program began a multi-year initiative called Clarus. The

Clarus Initiative developed and demonstrated an integrated surface transportation weather observation data management system that collected, quality checked, and disseminated atmospheric and road weather observations across the United States and Canada primarily from RWIS systems owned by State, Provinces, and Local DOTs. After Clarus was sunset in 2014, the Weather Data Environment was created that build upon the core capabilities of the Clarus System. The Weather Data Environment (WxDE) system (<https://wxde.fhwa.dot.gov/>) provides tools for getting quality-checked road weather data and forecasts. It collects both RWIS and mobile data and quality checks the data before sharing it. The system also allows users to view forecasts of road conditions and archived road condition data. Road weather data can be viewed through browsing the map, generating reports, and subscribing to data

The WxDE provides weather data for Connected Vehicle research, application development and pilot demonstrations. The system also demonstrates and provides tools for agency road weather data management.

The 2018 version of WxDE includes data from fixed and mobile sources from 40 state, local and other contributors. The map interface has been updated to improve performance. Pikalert and Vehicle Data Translator (VDT) modules have been integrated into the updated system and VDT quality checks for mobile data are now included in quality checking. Users also have online access to complete archives as well as forecasts and alerts. Subscriptions support Connected and Automated Vehicle (CV/AV) applications.

The U.S. DOT has also initiated the Connected Vehicle program (https://www.its.dot.gov/cv_basics/index.htm) to develop an enabling communication infrastructure to support both vehicle-to-vehicle and vehicle-to-infrastructure communications in support of both safety and mobility applications. Safety applications will have an emphasis on crash avoidance. Mobility applications will allow access to better information for roadway system management and operations. This includes the potential to observe and infer both driver-level weather and pavement conditions. Several studies are planned to determine how best to process the potentially large amounts of data for the benefit of the surface transportation weather community. A prime example of this is the connected vehicle pilot



*as of September 2018

STATUS OF STATE, LOCAL, AND PROVINCIAL AGENCIES CONNECTED TO THE WEATHER DATA ENVIRONMENT

project with the Wyoming DOT (WYDOT). This WYDOT CV Pilot is expected to reduce the number of blowover incidents and adverse weather-related incidents (including secondary incidents) in the corridor in order to improve safety and reduce incident-related delays. The types of alerts are shown in the figure below.

WHAT DOES CONNECTIVITY MEAN?

EN-ROUTE HAZARD AWARENESS
Using Dedicated Short Range Communication (DSRC) capability between vehicles and roadside infrastructure to provide new applications to support driver awareness.

VEHICLE TO VEHICLE

- Forward collision warning
- Distress notification

VEHICLE TO INFRASTRUCTURE

- Alerts and advisories
- Road weather warnings
- Work zone warnings

WYDOT'S DEPICTION OF EN-ROUTE HAZARD AWARENESS IN THE PILOT PROJECT

The FHWA Road Weather Management Program continues to support research and deployment of using vehicles as meteorological sensor platforms through the Integrating Mobile Observations projects through the Every Day Counts program described above. As part of this effort, the Road Weather Management Program delivered the Pikalert® System. As connected vehicle observations become more and more prevalent with the advent of autonomous vehicles, Pikalert has been designed to utilize these observations effectively. In particular, a number of quality check algorithms have been incorporated to guarantee that erroneous observations are flagged and set aside. Pikalert then assembles the observations that have passed the quality checks, associates them with the appropriate road segments, and then uses them to assess the road segment weather conditions. Detailed reports can then be generated, characterizing the status of the various road segments even when there is inadequate connected vehicle coverage.



- Pikalert focuses on the following three conditions:
- Precipitation conditions (such as rain, snow, ice)
 - Road surface conditions (such as snow packed, icy, clear)
 - Visibility conditions (such as foggy, clear)

Pikalert advises users of the presence of these three conditions and will make pavement treatment recommendations for snow and ice removal. Pikalert information is made available through web-based technology that supports browser-based displays and smartphones.

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program partnered with the Aurora Pooled Fund Program, and the AASHTO Snow and Ice Cooperative Program to develop siting guidelines for ESS in the roadway environment. The RWIS ESS Siting Guidelines, version 2, released in November 2008, provide a set of recommendations to support uniform siting of sensor stations that collect road and weather observations for RWIS (13).

The Road Weather Management Program aims to promote a systematic approach to the significant challenge of managing traffic during adverse weather. Weather-responsive traffic management strategies view weather events and their impacts as predictable, non-recurring incidents that contribute to roadway congestion. In 2004, the program identified research needs to advance weather-responsive traffic management

and began a study to examine use of weather information in Traffic Management Centers. In 2005 and 2006, the program quantified the impacts of various weather events on arterial and freeway traffic. Results from these empirical studies on traffic flow in inclement weather will support the development of guidance for state agencies and the incorporation of weather effects into traffic simulation models. Update In 2007, the program initiated a project to conduct a microscopic analysis of traffic flow in inclement weather. This project focuses on how weather events and associated road conditions affect driver behavior. The results will be a methodology for identifying and modeling microscopic traffic parameters that are influenced by poor road weather conditions and recommended procedures for incorporating findings into existing traffic microsimulation models.

Weather-Responsive Management Strategies (WRMS): Maintenance managers are challenged to implement strategies during all types of weather events with limited staff and budgets. Similarly, traffic managers are expected to provide safe and reliable travel options during weather events especially when the traffic volumes are high. (17)

The Weather-Responsive Traffic Management (WRTM) and Weather-Responsive Maintenance Management (WRMM) strategies currently used by transportation agencies include:

Traffic Management Strategies

- Motorist Advisory and Warning Systems (through various channels such as 511, Highway Advisory Radios, Variable/Dynamic Message Signs, Websites, Kiosks, in-vehicle applications, and Smartphone Applications)
- Adaptive or Weather Responsive Signal Timing
- Adaptive Ramp Metering
- Variable Speed Limits
- Road/Lane Closures
- Traffic Diversions
- Vehicle Restrictions

Maintenance Management Strategies

- Anti-icing and De-icing
- Plowing and Snow Removal
- Automatic Vehicle Tracking and Route Optimization
- Debris Removal

- Water Drainage Maintenance
- Vegetation Control

The Road Weather Management Program also sponsored a research project to study how weather information is integrated into operations at 38 Traffic Management Centers (TMCs). In general, very limited integration and application of weather information for TMC operations were observed. Clearly there was a need to advance the state of the practice and help agencies overcome the challenges associated with weather integration in TMCs. To address these challenges, the Road Weather Management Program initiated a project to develop a self-assessment guide to help TMCs evaluate their weather information integration needs and assist them in creating a plan to meet those needs. The FHWA is working with two TMCs to conduct a self-assessment using the guide and develop a weather integration plan.

Road Weather Management Capability Maturity Framework (Workshop and Tool): Transportation agencies can avail of a facilitated workshop and/or use the electronic tool on their own to conduct Road Weather Management Capability Maturity assessments. The Capability Maturity Framework workshop and electronic tool will evaluate the agency's ability to effectively manage operations during adverse weather conditions. When the existing capability levels are determined, a list of concrete actions is created for agencies to raise their capabilities to the desired levels.

5 REFERENCES

1. AASHTO, "511 Deployment Coalition," <http://www.deploy511.org/>.
2. FHWA, "Road Weather Management Program Web Site," Office of Operations, <http://www.ops.fhwa.dot.gov/weather/>.
3. FHWA, "Highway Statistics Publications," Office of Highway Policy Information, <http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm>.
4. FHWA, "Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel," Publication No. FHWA-RD-95-202, June 1996, <http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm>.

5. Goodwin, L., "Weather-Related Crashes on U.S. Highways in 2001," prepared for the FHWA Road Weather Management Program by Mitretek Systems, December 2003.
6. National Center for Atmospheric Research (NCAR), "Maintenance Decision Support System (MDSS) Web Site," Research Applications Programs, www.rap.ucar.edu/projects/rdwx_mdss/.
7. NCHRP, "Guidelines for Snow and Ice Control Materials and Methods," Description for Project 6-13, Transportation Research Board, October 2004, <http://www4.trb.org/trb/crp.nsf/0/02c3a2b01547add785256748005619f5?OpenDocument>.
8. NCHRP, "Performance Measures for Snow and Ice Control Operations," Research Project Statement for Project 6-17, Transportation Research Board, September 2004, <http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/e852202779b-b7dd685256f100053441f?OpenDocument>.
9. NOAA, "Local Climatological Data," National Climatic Data Center, <http://www.ncdc.noaa.gov>.
10. OFCM, "Weather Information for Surface Transportation: National Needs Assessment Report," FCM-R18-2002, December 2002, http://www.ofcm.gov/wist_report/wist-report.htm.
11. OFCM, "3rd National Surface Transportation Weather Symposium Summary Report," August 2007, <http://www.ofcm.gov/wist/3NSTWSP-Summary-Report-Final.pdf>.
12. Pletan, R. and Stapp, D., "Best Practices of Outsourcing Winter Maintenance Services," www.sicop.net/Best_Practices.pdf.
13. Pisano, P., et al, "Surface Transportation Safety and Operations: The Impacts of Weather within the Context of Climate Change," presented at the Potential Impacts of Climate Change on Transportation Workshop, October 2002, <http://climate.volpe.dot.gov/workshop1002/pisano.pdf>.
14. SICOP, "Automatic Vehicle Location (AVL) Applications to Winter Road Maintenance Operations," December 2002, <http://www.sicop.net/avl%20matrix.pdf>.
15. Transportation Research Board, "Sixth International Symposium on Snow and Ice Control Technology," Transportation Research Circular E-C063, June 2004, <http://trb.org/publications/circulars/ec063.pdf>.
16. Transportation Research Board, "Surface Transportation Weather and Snow Removal and Ice Control

- Technology," Transportation Research Circular Number E-C126, June 2008, <http://onlinepubs.trb.org/onlinepubs/circulars/ec126.pdf>.
17. U.S. Department of Commerce, "U.S. Census Bureau Web Site," www.census.gov.
18. U.S. Department of Transportation, "Intelligent

Transportation Systems Benefits, Costs, Deployment, and Lessons Learned: 2008 Update," Intelligent Transportation Systems Joint Program Office, September 2008, http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_te/14412.HTM.



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