TECHNICAL EXCHANGE IN THE EUROPEAN NORTHERN PERIPHERY TO IDENTIFY BEST PRACTICES IN WINTER MAINTENANCE

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Abstract

This paper presents, in concise form, some of the results of a comparison study made about the current winter maintenance practices of five Northern European regional road authorities: Lappi Region in Finland, the Northern Region in Sweden, Troms County in Norway, the Highland Council in Scotland, and the Public Road Administration of Iceland. The operations and considerations documented and presented here include road design and complementary installations from a winter maintenance perspective; snow removal techniques and standards; friction control methods and standards; *g*athering of information on weather and road conditions; communication to the public; and special operations during severe winter conditions. The practices of each region are compared, giving due consideration to local differences in climate, terrain and national policy.

Introduction

In 1998, the regional road administration bodies Lappi Region (Finland), Northern Region (Sweden), Troms County (Norway), and the Highlands Council, Roads & Transport Service (Scotland) initiated a technical transnational collaboration for exchanging experiences, with the long-term aim of developing solutions for some of the road management problems common to the regions. The Public Road Administration of Iceland joined the pilot project "Roadex", Sub Project B, on winter maintenance issues.

Each of the four project partners is responsible for a comparatively large network of public roads located in a sparsely populated region. The total area of the four road districts is greater than the land area of Germany, but the population of the area is only 1.4 million. Low traffic volume roads with less than 1000 AADT account for 73-90% of each region's public road networks. The traffic is usually long distance traffic, with a high percentage of heavy goods vehicles, such as transport for the timber and fishing industries, which are sensitive to time delays and road closures.

Although all Northern and European, the Roadex regions represent three different climatic zones: the cold maritime climate in Iceland and Troms County (Norway); the mild maritime climate in the Scottish Highlands, and eastwards the more continental climate of Northern Sweden and Finnish Lapland. The varying topography, from plateaux to high alpine mountains, and variations between coastal areas and inland also greatly affect winter conditions in these areas.

Common winter maintenance challenges in all regions include the high cost of winter maintenance - annual winter maintenance costs consume 45-60% of the total budget for road maintenance in the regions - complying with high service standards on remote roads and traffic safety problems caused in particular by drifting snow and low friction.

The most difficult conditions for maintaining winter roads are found in the areas of the maritime climate zone in Norway, Iceland, and Scotland, characterized by frequent snowfall, strong winds, and the formation of black ice on roads. In cold maritime climates it may be very difficult to keep mountainous road sections passable during snowstorms, due to bad visibility and heavy snow drifts. The frequency of snow ploughing is at its highest in Norway and Iceland, and snow must also be removed from time to time from junctions, ditches and signposts in order to improve sight distances. Drifting snow also causes difficulties in the more continental regions in Sweden and Finland - areas characterised by long winters with low temperatures and low precipitation.

The Roadex sub-project B work group, composed of representatives from each partner region and led by an external consultant, Harald Norem (Sintef, Norway), defined the following key themes for the comparison study on current winter maintenance practices of each Roadex region:

- Use of road design and complementary installations to improve winter roads and to facilitate their maintenance
- Snow removal techniques and standards
- Friction control methods and standards
- Gathering of information on weather and road conditions; communication to the public
- Special operations during severe winter conditions

The study was carried out by the means of questionnaires, visits to partner regions, and workshops to evaluate and discuss the gathered information. In co-operation with local supervisors and engineers, answers to the questionnaires were collected in the form of text, drawings, photos and videos.

Road Design

Road design can be used to prevent or mitigate some of the effects of harsh winter conditions. In an optimal road design, roads should be designed with fills as high as the local snow depths and any cut sections should have gentle slopes, with gradients of 1:6 in flat terrain where the slopes are found at the windward side of the roads. Roads should generally be located in areas less exposed to strong winds and where snow depths are lower than average. The visibility is improved and less snow accumulates on the road, if the roads are aligned parallel to the prevailing wind direction.

In general, national road design standards in all regions studied pay only minor consideration to the winter maintenance perspective in road design procedures. Neither are there any set routines for the interaction between road design and winter maintenance; maintenance equipment adapts to the actual road design.

In all the Nordic countries there are, however, guidelines for road design which include the following recommendations:

- road embankments should be high and flat, so that snow blows away from the road
- cross sections need to be wider in cuttings, to provide space for snow storage
- steep cuts and terrain features which cause drifting problems should be removed
- slopes should be filled in to avoid the need for guard-rails
- deep and wide ditches are needed to store snow

In addition, the following complementary practices were found in each region:

In Finland, area supervisors generally assist the road design project team by pointing out locations where special snow drifting problems can occur, and by taking part in the discussions concerning the location and design of the road.

In Sweden, special consideration was given to winter road design, as roads E10 and 95 were constructed in the mountainous area close to the Norwegian border. During the planning stages, wind directions were investigated and taken into consideration in the design; snow depth was also measured for the design basis of road E10.

In Norway, special designing procedures exist for roads in areas, where road sections frequently have to be closed due to poor visibility and heavy snowdrifts. In areas where convoy driving is required during storm periods, the roads are sometimes designed with extra space for lining up cars in front of the gates. In recent years, critical road sections have been constructed with an extended shoulder, or special "blower lanes" where rotary blowers can operate to remove the snow. The blower lanes also offer increased snow storage capacity and improve the visibility during snowstorm periods.

In Iceland, the design of new roads routinely takes into consideration the winter conditions in the area. The embankment height and slope are always designed with due consideration of snowdrift and winter maintenance conditions. A special feature in Iceland are the short-distance winter roads used in those places where the main road occasionally has to be closed because of snowdrift problems. The winter roads run parallel to the main roads, but are located where snow seldom collects. The length of a winter road varies from a few hundred meters up to one kilometre; they are low quality gravel roads and are only in use when the main road is closed.

Roads which are not well located or designed can be protected by snow fences or tree planting. Snow fences have been used in all Roadex regions over the last 50 years and are effective in collecting snow and improving visibility on the road during snowdrifts, especially when the prevailing wind direction is stable and the fence can be placed optimally with respect to the road. The height of the snow fence is dependent on the frequency of strong winds and on local snow depth, varying from 2 to 5 meters.

In most cases the fences are made of wood, but other materials such as aluminium, plastic and fabrics have also been tested. Wooden fences can last up to 40 years, but they require constant maintenance. Lack of maintenance has caused many fences to collapse and loose effect in all Roadex regions. Plastic fences are cheaper and quicker to install, and are suitable for temporary use. Fences made of recycled plastic have proved very promising during test use in Iceland.

Planting trees to shelter the road from snow drifts has been tested recently along short sections of road in Finland and Scotland, with positive results. In Troms County, Norway, natural forests have been used in the same way. In Iceland the use of trees as snow drift prevention is more problematic due to the poor growing conditions. In some cases, snow fences have been used as a temporary shelter, in order to help the trees to grow faster to an effective height.

In Finland and Sweden, snow banks are also used in some places as snow drift protection instead of snow fences, and have proven to be effective in accumulating drifting snow. For the snow bank, a wall of a height of about 2 metres is formed using snow collected at 10-40m distance from the road.

The use of guard-rails is often a hindrance for cost-effective winter maintenance. If the guard-rails are of an unfit design for use on winter roads, they can cause heavy snow deposits on the road during snowdrift periods, which tends to increase the height of the drift and thus considerably reduces visibility during snowstorms. As the guard-rails also make it difficult to remove the snow from the shoulders of the road, melting water from the snow banks may flow onto the road surface and freeze overnight. Guardrails are also often damaged by snow loads and winter maintenance operations. To better suit conditions requiring winter maintenance, the northern regions have sought to change the common W-profile guardrails to more streamlined and narrow designs, such as "Kohlswa" in Sweden, pipe-style guardrails in Finland and wire rope safety fences in Scotland. Adequate pole distances of about four meters also facilitate maintenance operations and prevent damage to the guardrails caused

by maintenance equipment. In Northern Norway the use of guardrails is avoided wherever possible, e.g. by reducing where possible the embankment slope for new roads.

Snow Removal – Techniques and Standards

In most of the Roadex regions, the main stipulation for winter maintenance is to keep the roads free of loose snow and to assure that the friction fulfils the required standard. In Iceland, Troms County, the Northern Region of Sweden and the Lappi Region of Finland, one may accept snow and ice on the roads. Norway has two national winter maintenance policies: one for clear roads, which is applied on some high traffic volume roads in the south of the country; and one for winter roads, which is applied throughout most of the country, including Troms County. In the Scottish Highlands, the requirement is to keep roads "black", i.e. trafficable with summer tyres year round.

Access to the entire public road network is another national policy issue, which varies between the Roadex regions. In Iceland, part of the lower trafficked road network is regularly closed throughout the winter season, whilst part is only serviced on certain weekdays. In Norway, roads which cannot be kept passable during heavy snowfall can be temporarily closed to public transport by the road authority. In Finland, as in Sweden, with the exception of some roads close to the Norwegian border in Sweden, all public roads must be kept passable during all conditions. In the Scottish Highlands, the police may close hazardous (small) roads temporarily.

Finland and Sweden impose reduced winter speed limits on main roads; in Finland from 100 km/h to 80 km/h, and in the Northern Region of Sweden typically from 110 km/h to 90 km/h or from 90 km/h to 70 km/h.

The public road network is usually divided into different winter maintenance service classes according to the volume of traffic and/or the strategic importance of the road for the area. The aim is to maintain a uniform level of service on roads, avoiding unexpected circumstances for road users. Table 1 presents the classification of roads for different winter maintenance categories, based on traffic levels in Finland, Sweden and Norway. In Scotland and Iceland, the roads are also divided into five service categories, but the classification is to a great extent based on the function of each road.

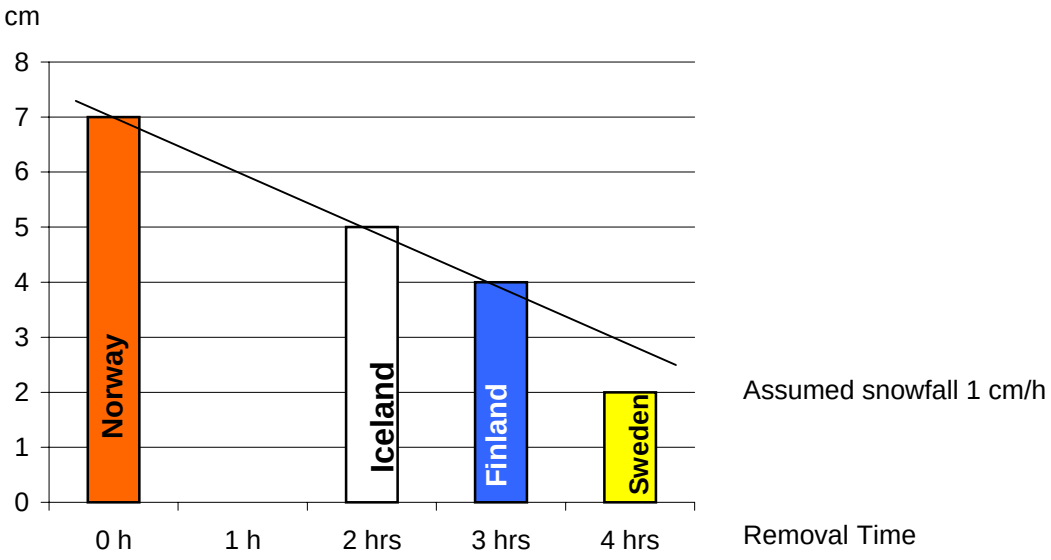
Table 1. Winter Maintenance Classes of Roads with Respect to Traffic Volume (AADT)

Finland		Sweden		Norway
IS	> 6000	B1A	≥ 8000	> 10000
I	3000 – 6000 *	B1B	2000 - 8000	5000 - 10000
Ib	< 4000 *	B1C	250 - 2000	1500 - 5000
II	<1500 *	B2A	< 250	< 1500
III	< 350 *			

* Winter maintenance classes based on traffic volume and function of the road

Finland, Sweden, Norway and Iceland have nationally defined service standards for each road class, defined by friction value, maximum permitted snow/slush cover on road, and surface evenness. The standards are a combination of the maximum permitted level, or critical level, for starting remedial operations, and the maximum response time, or operation time, to achieve an accepted service level. Requirements are also given for time margins for improving sight distance at junctions and for clearing road signs. In the Scottish Highlands, service level standards are currently being established and will be enforced for the first time during winter 2001/2002. At the time of carrying out the Roadex study, roads were being divided into five priority groups according to the availability of services, from a 24h cover to a 10h cover.

Figure 1. Maximum Permitted Level of Loose Snow and Removal Time in the Highest Maintenance Class



A comparison of the critical depth of loose snow and removal response times (Figure 1) shows that the national standards for the highest service classes (main roads) are fairly similar. The range of variation between service level requirements for each maintenance class differs from country to country (Table 2), being quite narrow in Sweden, and widest in Norway and Iceland. In Iceland, the availability of snow removal services varies from a 24h service to a once weekly service. In the Highlands of Scotland, it is advised to begin ploughing main roads, for practical reasons, once a snow depth of 3 cm has been reached. Ploughing and salting continue until the road is cleared. Minor roads receive treatment when resources come available.

Table 2. Standards for Snow and Slush Removal in each Winter Maintenance Class

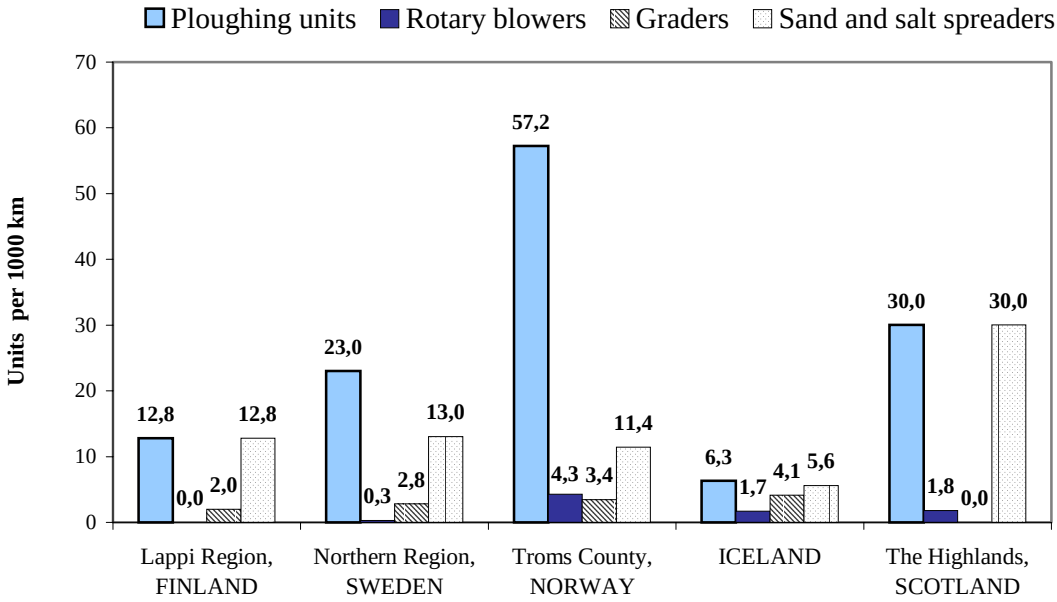
Finland		**Sweden**		**Norway/ Winter roads**		**Iceland**	
Is	max 4 cm snow / 2 cm slush	**B1A**	max 2 cm snow	**> 3000** AADT	max 7 cm dry snow / 6 cm wet snow	**Cat.1**	max 2 cm snow / 5 cm in snowfall
	removal in 2,5 hrs		removal in 4 hrs		(no time margin)		removal in 2 hrs
I	max 4 cm snow / 2 cm slush	**B1B**	max 2 cm snow (5 cm at night)	**1501-3000** AADT	max 10 cm dry snow / 7 cm wet snow	**Cat.2**	max 4 cm snow / 12 cm in snowfall,
	removal in 3 hrs		removal in 4 hrs		(no time margin)		removal in 3 hrs
Ib	max 4 cm snow (8 cm at night) / 2 cm slush	**B1C**	max 3 cm snow (5 cm at night)	**501-5000** AADT	max 12 cm dry snow / 8 cm wet snow	**Cat.3**	max 6 cm snow / 16 cm in snowfall
	removal in 3 hrs		removal in 5 hrs		(no time margin)		removal in 3 hrs
II	max 8 cm snow (10 cm at night) / 4 cm slush	**B2A**	max 4 cm snow (6 cm at night)	**< 500** AADT	max 15 cm dry snow / 12 cm wet snow	**Cat.4**	max 8 cm snow / 18 cm in snowfall
	removal in 4 hrs		removal in 6 hrs		(no time margin)		removal in 4 hrs
III	max 10 cm snow / 5 cm slush					**Cat.5**	no snow depth limits
	removal in 6 hrs						removal in 4-6 hrs

In all Roadex regions, vehicles equipped with snow ploughs form the basic fleet for winter maintenance (Figure 2). Diagonal ploughs are most common in the Nordic countries, but side ploughs are also used, mainly on main roads when the width of the road is sufficient. V-ploughs are used in heavy snow conditions, to break through heavy snow after a temporary road closure. In the Highlands, smaller versions of the V-blade are also used on single-track roads. The Highlands also employ slush blades of conical form, which can be used at higher speeds, and straight blades, which vary from light rubber blades to a heavy-duty steel blade.

Rotary blowers are important in areas prone to heavy snowstorms, and are used after periods of snowstorms on the main roads in Troms County (Norway), in Iceland, and in Northern Sweden on roads close to the Norwegian border. The Highland Council also has blowers located close to known problem areas, where deep snow can cause roads to become blocked. When using snow blowers, a sharp edge of snow remains. To prevent snow-drifting problems, in the Northern Region (Sweden), the edges are cut off by snow blowers or tractors.

In the Lappi Region (Finland), all trucks are equipped with so-called underbody blades mounted under the truck; this has decreased the need for a common grader. About 85-95% of all levelling work is done with underbody blades. In the Northern Region (Sweden), underbody blades are mounted on only 26 % of snow removal trucks; in Iceland the share is 17 %, and in Troms County (Norway) 6 %. In Scotland, graders are not used.

Figure 2. The Amount of Winter Maintenance Equipment per 1000 km of Public Roads in Each Roadex Region



The removal of snow from road shoulders and ditches is required from time to time, in order to restore visibility, prevent snow drifting problems, provide storage for snow, and prevent melting snow from pooling and forming ice on the road. The maximum permitted height of a snow bank in Finland is 0.8 m and in Sweden 0.9 m. In a cross-section, the maximum permitted height of a snow bank in Finland is 0.5 m and in Sweden is 0.6 m. In Norway, the guideline is to keep snow banks in areas prone to drifting snow as low as possible. Snow cover on ditches can also have beneficial effects, as it prevents the build-up of ice in ditches during the winter.

Side ploughs mounted on trucks or graders are mostly used to cut and clear snow banks on roadsides in Sweden and Finland; in Norway and Iceland blowers are also used for this purpose. In Troms County the blower usually follows a grader, which cuts the snow bank with a "snow wing".

In Finland, Sweden and Norway, snow banks are pushed away from the road shoulder onto the slope in spring time, to prevent melt water from draining and freezing on the road. Troms County has a practice to provide drainage through the snow bank where melt water ponds on the road before the snow banks have been pushed back.

In Scotland, snow normally thaws within days of falling and as such there are not the same problems as in the Nordic countries. On rare occasions, prolonged periods of freezing without thaw may occur, and in these situations snow blowers or excavators are used to remove snow walls from the edge of the road.

The formation of ice in ditches, sub-drains and cuts can be a considerable problem in all Roadex regions, especially during cold winters with little snow. As ditches and sub-drains become clogged, the flooding water builds-up a layer of ice on the road surface. In Troms County, several methods have been tested to prevent this, including the construction of diversion ditches some distance from the road, which has proven to be very successful in some cases; the installation of heater cables within sub-drains; and the installation of double sub-drains, whereby an overflow sub-drain is placed above the normal drain. To remove ice from the ditches, excavators are often used. Steam aggregates are used to unblock frozen sub-drains.

Ice formation in steep rock cuts can also prove a traffic hazard, when the connection between the rock cut and the heavy ice blocks starts to melt, causing the ice blocks to slide down onto the road. To prevent this, ditches can be constructed at the top of the cut to divert water. The cut wall may also be equipped with wire nets to prevent the ice from falling down onto the road during the spring thaw. Another method is the removal of dangerous ice with, for example, excavators or other machines in the spring.

Friction Control – Techniques and Standards

To improve friction on winter roads, all Roadex regions spread sand, salt, or a sand/salt mixture. The Roadex regions in Norway, Sweden and Finland use sand to a greater extent than in Iceland or the Highlands. The magnitude of sand spread varies between 5.1 and 8.2 t/km in Northern Scandinavia, to only 0.8 t/km in Iceland and 1.1 t/km in Scotland (Table 3).

The type of salt used in all regions is ordinary rock or sea salt (NaCl). Salt can effectively prevent ice forming on the road at temperatures as low as -6 to -8 C. In the Highlands, the formation of ice on the road surface is the dominant problem throughout the winter, and salt is used as the primary friction control method; an average of 11.6 tons of salt is used per treated road km. The majority of Scottish road users use summer tyres in the winter and drivers are generally inexperienced when it comes to driving on snowy or icy surfaces. As the temperature also frequently fluctuates around 0 °C during the winter, the need for friction control and the use of salt gets very high. In Iceland, extensive amounts of salt are used on those few roads treated by salt.

In the Lappi Region, a large number of roads, about 200-300, are treated with salt during autumn and spring, but there is relatively little use of salt during the winter. When necessary, crossroads, bends and slopes or even entire road sections are sanded. Salt may also be mixed with the sand. The Northern Region in Sweden treats only the major roads regularly with salt.

Table 3. The Use of Sand and Salt in Friction Control in Roadex Regions

		Lappi Region, Finland	Northern Region, Sweden	Troms County, Norway	Iceland	Highlands, Scotland
Total road network in the region	km	9 052	18 008	3 523	8 207	7 790
Total use of sand	t	46 000	147 995	20 800	6 800	8 500
Sand per km	t/km	5.1	8.2	5.9	0.8	1.1
Total use of salt	t	1 000	5 048	365	5 300	90 000
Roads treated with salt	km	260	639	250	351	7 790
Roads treated with salt of total		2.8 %	3.5 %	7.1 %	4.3 %	100 %
Salt per km	t/km	3.8	7.9	1.5	15.1	11.6

Surprisingly, in Troms County in Norway, no roads are treated regularly with salt. Salt is used only on major roads and then only during the critical periods in autumn and spring. The consumption of salt is thus very low, a mere 1.5 t/km. In other parts of Norway, saline solution is used along with salt.

The large differences in the use of salt and sand are partly due to a reduced need for skid prevention in the northern parts of Sweden and Finland, as the winters there are relatively cold and dry. Nevertheless, climatic conditions do not explain all the differences; a national winter roads policy, availability of sand, and environmental considerations connected to the use of salt in the Nordic countries (protection and/or use of groundwater reserves) are probably more significant explanatory factors.

Figure 3. Use of Sand and Salt in Friction Control, Tons per km of Treated Road

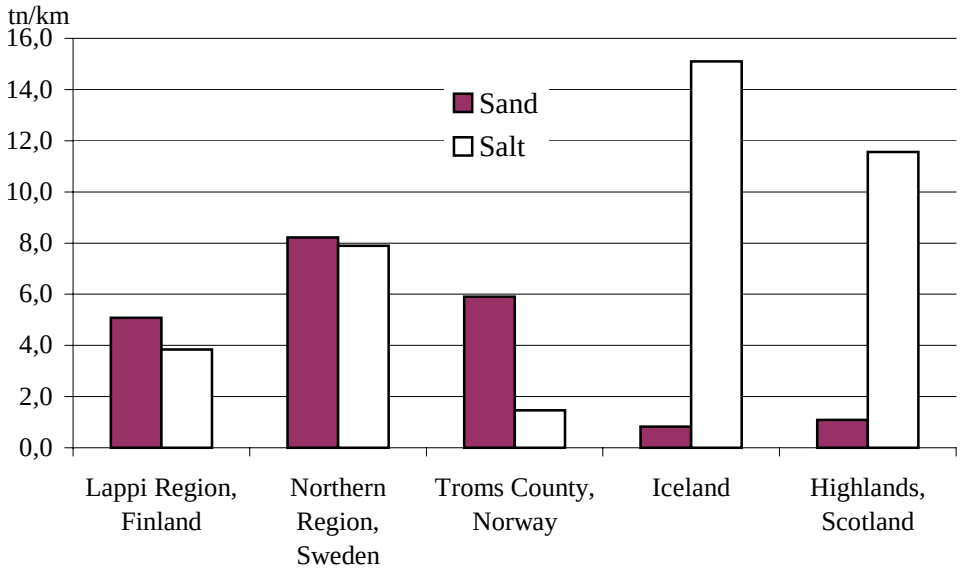


Table 4. National Standards for Friction on Roads

Finland		Sweden			Norway/ Winter roads		Iceland
Is	0.3	**B1A**	≥ 0.25	**> 1 500** AADT	0.25	**Cat.1**	> 0.25
	cycle time 2 hrs		cycle time 4 hrs		cycle time 2 hrs		
I	0.28	**B1B**	≥ 0.25	**501-1 500** AADT	0.25	**Cat.2**	> 0.15 / > 0.25 on dangerous sections
	cycle time 2 hrs		cycle time 4 hrs		cycle time 4 hrs		
Ib	0.25 / 0.20 in stable winter conditions	**B1C**	≥ 0.25	**< 500** AADT	0.15 / 0.25 at bends, slopes, junctions	**Cat.3**	> 0.15 dangerous sections / > 0.25 on very dangerous sections
	cycle time 3 h/4 h		cycle time 5 hrs		cycle time 4 hrs		
II	sufficient friction for the needs of traffic	**B2A**	≥ 0.17			**Cat.4**	> 0.15 dangerous sections
	cycle time 6 hrs		cycle time 6 h				
III	sufficient friction for the needs of traffic					**Cat.5**	no limit, except on special occasions on very dangerous sections
	cycle time 10 h						

The comparison of friction standards (Table 4) indicates that the range for friction requirements is wider in Finland than in the other Roadex countries, whereas Norway permits little difference in friction level between road classes. Iceland's policy allows the lowest friction values in the lowest maintenance classes. In the Highlands, comparable skid resistance standards had not yet been established at the time of this study.

Gathering of Information and Communication of Winter Driving Conditions

The effective operation of winter maintenance is dependent on reliable systems for the assembling and distribution of information regarding weather and driving conditions. All Roadex regions use similar techniques for the gathering and distribution of information through their traffic information centres (TIC).

Information is gathered via maintenance units on the road, weather stations operated by the road authorities, national weather forecasting services, and via the public through a telephone service at TIC. The Highland Council uses an additional network of 65 ice detection sites, which provides real time information on road conditions. In Northern Sweden, an avalanche warning system is also in place along road E10. The system is activated when an avalanche starts whereby it automatically closes the road with red lights and bars.

Road users and the public are informed via the TIC using all available possibilities for modern media: TV, local and national radio stations, leaflets, internet, and an around-the-clock telephone centre service, in addition to temporary or variable traffic signs on roads. The TICs are also connected to

other TICs throughout the country, to the police and the emergency units. A connection is also established between regional TICs in the Northern areas of Finland, Sweden, Norway and Russia.

In Iceland, the use of the data provided by weather stations deviates somewhat from the other regions, in that the data downloaded on TIC computers is automatically formatted for different user groups and then distributed to the media and through the internet. The information displayed on the internet is in real-time and is also more complex, including wind speed, temperature, driving conditions and the volume of traffic on each monitored road. In comparison, when informing the public of road conditions in Finland, conditions are classified as 1) normal, 2) poor, or 3) hazardous.

Special Operations During Severe Conditions

The most common actions taken under severe conditions, where winter maintenance operations cannot ensure adequate traffic safety, are road closures, convoy driving, reduced speed limits and traffic surveillance.

In Iceland and Scotland the police have the authority to close public roads. In Norway, Sweden and Scotland there are special procedures for temporary road closures and convoy driving (in Northern Sweden only on roads E10 and 95 at the Norwegian border). Convoy driving is usually imposed when visibility on the road is so poor it endangers the traffic, or when there is a high risk of cars getting stuck in the snow. In Norway, convoy driving is also sometimes applied when, after a heavy snowfall, a road is temporarily so narrow that two vehicles cannot pass.

In Sweden and Norway, the maintenance contractor or the foreman of the maintenance personnel has the authority to decide on road closures and when to impose convoy driving, in accordance with a set policy. Road maintenance personnel close a road by placing a bar, studded with red lights, across the breadth of the road and setting up illuminated information signs, after which the maintenance contractor ensures there are no cars within the closed section. The maintenance contractor decides how many vehicles may be permitted in one convoy; usually no more than 10-20 cars are allowed. Before the convoy starts, maintenance personnel inspect participating cars and ensure that they are adequately equipped; unsuitable vehicles may be rejected. The convoy is then led by a maintenance vehicle (e.g. a plough truck), whilst another maintenance truck or car takes up the rear; the maintenance crew have radio connection with one another.