Winter maintenance in Sweden

Compiled for COST 344 ”Improvements to Snow and Ice Control on European Roads”. Task Group ”Best practice”
27 March 2002

Anita Ihs, VTI
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Foreword

Effective snow and ice control is a vital service provided by European highway authorities in order to ensure, as far as possible, that road users can travel safely and with minimum disruption in cold and severe climatic conditions. The need for innovative snow and ice control techniques and processes has continued to grow as national and European road networks have developed substantially over recent decades. The demand for improvement, including the sophistication of the techniques and technology used, continues to be driven by the increasing need for safe and efficient national and international road freight and passenger transport and by the environmental and other policies affecting highways.

European Commission project, COST Action 344: Improvements to snow and ice control on European roads and bridges, started in April 1999, is a three-year project with participation from eighteen European countries.

The project aims are:

1) Review of existing international practices.
2) Definition of snow and ice control requirements in different European climatic regions.
3) Specification of ‘Best Practice’ in different European climatic regions.
4) Development of guidelines for the integration of specified snow and ice control methods into network level road management and maintenance systems.
5) Recommendations for improvements to driver information and traffic management systems.
6) Recommendations for future research.

The COST Action will promote the exploitation of technological advances in the application and distribution of snow and ice control measures, with a view to providing significant environmental and safety benefits and lower operational costs.

This report has been compiled for Task group 3: Best practice, within COST Action 344. It covers mainly the winter maintenance on the Swedish state roads. The winter maintenance in the municipalities is only briefly mentioned in some chapters. The winter maintenance on private roads is not covered at all.

Linköping, October 2002

Anita Ihs
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1. Fundamental issues
1.1 Climatic conditions

The southernmost parts of Sweden belongs to the warm temperate zone where the summer period is relatively warm and long while the winters are not to severe. Towards the north the climate gets colder. About two thirds of Sweden is in the cold temperate zone. This is characterised by a shorter vegetation period and long winters. Most part of the annual precipitation in this zone falls during the vegetation period.

Through its elongated form in north-southerly direction the temperature climate in the south differs considerably from that in the northern parts. The situation is further complicated by the influence from large lakes, the see, the Golf Stream and the height above sea level.

In southern Sweden the winter period is about four months and in northern Sweden about seven months.

The areas in lee of the Scandinavian Mountains have a local continental climate, which means larger differences in temperature and precipitation between summer and winter and also relatively small amounts of precipitation compared to the areas more close to the coast. Along the west coast and parts of the east cost the climate is more maritime, which means less difference between summer and winter.

In the southern parts of Sweden the winter climate changes between cold periods with snow and mild periods when the snow melts, whereas the northern parts are snow-covered throughout the whole winter.

In the northwestern mountains a snow-cover is formed in the beginning of October and it doesn’t melt until the end of May or June. In the southern parts of Sweden there is a snow-cover only for short periods during winter.

The three tables below show statistical data calculated from a 30 year period (1961–1990) by the Swedish Meteorological and Hydrological Institute (SMHI).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>-16,7</td>
<td>-18,8</td>
<td>-17,6</td>
<td>-13,9</td>
<td>-8,0</td>
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<td>-4,0</td>
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<td>-2,7</td>
<td>1,1</td>
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<tr>
<td><strong>Göteborg</strong></td>
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<td>-3,2</td>
<td>-3,5</td>
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<td>-2,5</td>
<td>-0,5</td>
<td>2,4</td>
</tr>
<tr>
<td>City</td>
<td>Daily maximum snowfall</td>
<td>Maximum snow depth</td>
<td>Cumulative depth of snow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------</td>
<td>--------------------</td>
<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kiruna</td>
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<td>132</td>
<td>243</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luleå</td>
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<td>111</td>
<td>233</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Östersund</td>
<td>31</td>
<td>100</td>
<td>251</td>
<td></td>
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<td></td>
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<td>Stockholm</td>
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<td>60</td>
<td>153</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Göteborg</td>
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<td>52</td>
<td>131</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jönköping</td>
<td>27</td>
<td>102</td>
<td>225</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malmö</td>
<td>26</td>
<td>38</td>
<td>113</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| City      | Precipitation (mm) |  |
|-----------|--------------------|  |
| Kiruna    | 41     | 37    | 30   | 26    | 22    | 23    | 26    | 488   |
| Luleå     | 51     | 49    | 35   | 31    | 24    | 29    | 29    | 488   |
| Östersund | 46     | 43    | 45   | 36    | 28    | 30    | 32    | 563   |
| Stockholm | 49     | 52    | 42   | 33    | 24    | 25    | 30    | 514   |
| Göteborg  | 87     | 87    | 85   | 68    | 41    | 54    | 42    | 791   |
| Jönköping | 63    | 66    | 53   | 48    | 31    | 38    | 37    | 641   |
| Malmö     | 57     | 61    | 60   | 50    | 31    | 40    | 38    | 603   |

*Figure 1.1* The division of Sweden into zones with comparable climates often used in connection with studies of different aspects of winter road maintenance.
For winter maintenance purposes in Sweden statistics on weather conditions are at the present time often described in the form of so called weather situations.

The basis for the weather descriptions is data collected from the individual stations in the Swedish National Road Administration (SNRA) system for road weather information. Through using special definitions, the data is translated into eight weather situations at an hourly level.

These situations are:
- Snowfall (3 situations)
- Drifting snow (4 situations)
- Slipperiness caused by rain or sleet on a cold roadway
- Slipperiness caused by water or moisture on the road freezing over
- Slipperiness caused by moderate hoarfrost formation
- Slipperiness caused by intensive hoarfrost formation
- Special weather conditions, type 1: drifting snow with extra high wind velocity
- Special weather conditions, type 2: snowfall with extra high snow intensity

During recent years an experimental work has begun calculating a number of winter indices starting from these weather situations. Mean values are calculated for each month and for each county. Representative RWIS stations are chosen for each county.
- The weather indices describes the number of occasions with slipperiness, snow and snow drift, respectively
- The salt index describes the actual salt consumption (kg/km) compared to the recommended use of salt (kg/km) for each type of weather situation. A value $> 1$ means more salt than recommended, and a value $< 1$ means less salt than recommended.

**Figure 1.2** The weather index for the winter season 2000/01 calculated for the seven regional road management areas of the SNRA (see chapter 2.1 below).
Figure 1.3 The salt index for the winter season 2000/01 calculated for the seven regional road management areas of the SNRA (see chapter 2.1 below).

1.2 Standards
1.2.1 General standards
Legal obligation
There are several laws and regulations that have an influence on winter maintenance on roads and streets.

According to the Swedish constitution the Swedish National Road Administration (SNRA) is responsible for the road transports system and must work for attaining the objectives of the transport policy. The SNRA must especially work for securing that the road transport system is available, accessible and effective and that it contributes to the regional balance. The SNRA must also work for adapting and designing the road transport system according to high demands on environment and traffic safety.

In one paragraph of the “Road Statute” (SFS 1971:954) 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.

There are also special regulations for the municipalities on street cleaning (including winter maintenance) and road signs (SFS 1998:814). In these regulations it is stated, in short, that the municipalities are responsible for keeping streets, squares, parks and other public places in such a condition that any inconvenience for peoples health is avoided and so that the requirements for comfort, availability and traffic safety are satisfied.

Classification of roads according to level of winter serviceability
Sweden has a total of about 420 000 kilometres of road. 98 000 kilometres (23 %) of these are state roads for which the Swedish National Road Administration (SNRA) is responsible and about two thirds of the vehicle mileage is done on
these roads. The other roads are municipal streets and roads, 38 500 kilometres (9 %), and private roads 284 000 kilometres (68 %).

The state roads are classified as national trunk roads, regional roads and other state roads.

**General description**

The winter maintenance on the state roads in Sweden is carried out according to the "General technical description of road operation service levels during winter. OPERATION 96".

The operating requirements contain six different standard classes, ranging from the highest volume roads with an AADT of 16 000 or more to the lowest volume roads with an AADT less than 500. There is a considerable difference in standard between these two classes; e.g., the requirements stipulate that the roadway on a highest volume road shall be free from snow and ice no later than two hours after the snow has stopped falling if the road surface temperature is above -8°C (18°F). Further, during the period when the snow is actually falling, the depth of the snow shall not exceed 2 cm and the slush depth shall never be more than 1 cm.

As regards the lowest volume road network, snow ploughing and any necessary skid control measure shall be completed no later than eight hours after it has stopped snowing, and the snow depth during the snowfall may be up to 8 cm. The operating requirements are written in functional terms, which means that they describe the road surface condition during different weather conditions. Thus, these requirements do not stipulate when measures are to be carried out. This is up to the contractor to decide upon.

**Detailed description**

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

The choice of standard classes for a certain road network is done according to the following recommendations given in the technical description:
The standards must at all times be fulfilled. Exceptions may only occur in extreme weather conditions. In these situations continuous de-icing or ploughing must be done.

The roadway is divided into three areas, the traffic lane, the hard shoulder and parking areas and bus stops, for which requirements during different weather situations are given. For standard class A1 the requirements can be summarised as follows:

The traffic lane must
- have less than 2 cm loose snow in precipitation and up to 2 hours afterwards.
- be continuously treated during rain that cause slippery condition.
- be free from ice within 1 hour after the rain that caused slippery condition have stopped. If the road surface is colder than -8°C the traffic lane must have satisfactory friction within 2 hours.
- be free of snow and ice in fair weather during other time. If the road surface is colder than -8°C the traffic lane must be free from loose snow, be even and have satisfactory friction. When the road surface temperature rises above -8°C again the traffic lane must be free from snow and ice within one day and night.

The hard shoulder must
- have less than 10 cm loose snow in precipitation and up to 4 hours afterwards.
- be free from ice on at least half the width closest to the traffic lane within 1 hour after the rains that caused slippery condition have stopped. If the road surface is colder than -8°C the hard shoulder must have satisfactory friction within 4 hours.
- in fair weather during other time be free of snow and ice on at least half the width closest to the traffic lane and on the remaining part have less than 2 cm loose snow and be even. If the road surface is colder than -8°C the hard shoulder must be free from loose snow, be even and have satisfactory friction. At the most 2 cm loose snow may be present on the half of the hard shoulder closest to the ditch. When the road surface temperature rises above -8°C again the hard shoulder must be free from snow and ice on at least half the width within one day and night.

Parking areas and bus stops must
- have less than 10 cm loose snow in precipitation and up to 4 hours afterwards.

<table>
<thead>
<tr>
<th>Traffic flow, AADT</th>
<th>National road network</th>
<th>Regional and local road network</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥16 000</td>
<td>A1</td>
<td>A2</td>
</tr>
<tr>
<td>8000–15 999</td>
<td>A2</td>
<td>A3</td>
</tr>
<tr>
<td>2000–7999</td>
<td>A3 or B1</td>
<td>A3 or B1</td>
</tr>
<tr>
<td>500–1999</td>
<td>B1 or A4</td>
<td>B1 or A4</td>
</tr>
<tr>
<td>&lt;500</td>
<td>B1</td>
<td>B2</td>
</tr>
</tbody>
</table>
- have satisfactory friction within 4 hours after the rains that caused slippery condition have stopped.
- in fair weather during other time have satisfactory friction and be even. The snow depth must not exceed 2 cm loose snow.

For the lower standard classes more snow and longer treatment times are accepted. The temperature limit above which the road surface must be free from snow and ice is also higher.

For snow-covered roads the requirements are similar to those above except that snow and ice is accepted at all times as long as the friction is satisfactory. There is also a limit for maximum allowed snow depth.

<table>
<thead>
<tr>
<th>Type of requirement</th>
<th>Standard class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic lanes</td>
<td>A1</td>
</tr>
<tr>
<td>Max. snow depth, cm loose snow</td>
<td>2</td>
</tr>
<tr>
<td>Max. snow depth, cm slush</td>
<td>1</td>
</tr>
<tr>
<td>Free from ice and snow within ___ hours after snowfall.</td>
<td>2</td>
</tr>
<tr>
<td>Road surface temperature above which the road surface has to be snow and ice free, °C</td>
<td>-8</td>
</tr>
<tr>
<td>Max. time with slippery conditions after rain when warmer than temperature limit given above.</td>
<td>1</td>
</tr>
<tr>
<td>Satisfactory friction after rain within ___ hours if colder than temperature limit given above.</td>
<td>2</td>
</tr>
<tr>
<td>Max time (days) going from snow-covered to snow- and ice-free road surface when temperature changes from colder to warmer than limit temperature.</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of requirement</th>
<th>Standard classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic lanes</td>
<td>B1</td>
</tr>
<tr>
<td>Max snow depth, cm loose snow</td>
<td>6</td>
</tr>
<tr>
<td>Max snow depth, cm slush</td>
<td>3</td>
</tr>
<tr>
<td>Max 2 cm loose snow within ___ hours after snow-fall.</td>
<td>6</td>
</tr>
<tr>
<td>Satisfactory friction within ___ hours after rain.</td>
<td>6</td>
</tr>
</tbody>
</table>

Both B- and C-classes should have less than 2 cm loose snow in fair weather during other times than given in the table above.
Definitions
In the table below are given the threshold values for defining satisfactory friction, slippery and very slippery conditions.

<table>
<thead>
<tr>
<th>Friction class</th>
<th>Friction coefficient*</th>
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</thead>
<tbody>
<tr>
<td>Satisfactory friction</td>
<td>$\mu \geq 0.25$</td>
</tr>
<tr>
<td>Slippery</td>
<td>$\mu &lt; 0.25$</td>
</tr>
<tr>
<td>Very slippery</td>
<td>$\mu \leq 0.15$</td>
</tr>
</tbody>
</table>

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

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

Climatic comparisons
A normal winter (1993/1994) the state roads, in different winter maintenance classes and in different climate zones (see Figure 1.1), have the following percentage of bare road condition.

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Maintenance class</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>B1</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td></td>
<td>96</td>
<td>94</td>
<td>89</td>
<td>82</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td>97</td>
<td>95</td>
<td>89</td>
<td>80</td>
<td>69</td>
<td>58</td>
</tr>
<tr>
<td>Lower North</td>
<td>No roads</td>
<td>86</td>
<td>79</td>
<td>64</td>
<td>58</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Upper North</td>
<td>No roads</td>
<td>77</td>
<td>54</td>
<td>No roads</td>
<td>28</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

Municipalities
As bases for prioritising maintenance actions normally some kind of classification of streets and paths according to the importance of availability is done. The priority is expressed in different types of standard requirements, starting criteria and action times. An example from the municipality Umeå in the northern part of Sweden is given below.

Classification:
A Prioritised streets are main streets, bus streets, city centre and central parking places.
B Other streets and parking places
C Prioritised pedestrian and cycle paths are main thoroughfares for pedestrian and cycle traffic and pedestrian paths in city centre
D Other pedestrian and cycle paths
Requirements:

<table>
<thead>
<tr>
<th>Starting criteria</th>
<th>Snow removal</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Ploughing</td>
</tr>
<tr>
<td>Driving lanes</td>
<td>2–5 cm</td>
</tr>
<tr>
<td>Pedestrian and cycle paths</td>
<td>&gt; 5 cm</td>
</tr>
<tr>
<td>C</td>
<td>2 cm</td>
</tr>
<tr>
<td>D</td>
<td>2–5 cm</td>
</tr>
</tbody>
</table>

2 Strategic organisation of winter maintenance

2.1 General

Organisation

In 1991, the Swedish Government passed a decision that the design and construction of new roads, as well as all road operation and maintenance works within the state road transportation network, were to be contracted through competitive bidding. This entailed major changes at the SNRA. From having been a traditional central government agency, exercising the role of public authority while simultaneously carrying out construction and maintenance works in-house, the SNRA was to be divided into a client / contractor organisation. In addition, it was stipulated that the contracting arm of the organisation was to function like a private contractor, i.e., that it was to be subject to competitive terms on the open market and furthermore required to show a profit for its owner.

The SNRA today has one head office, seven regional road management directorates and four profit centres. The regional directorates are responsible for the SNRA’s regional road management. The seven regions vary both in size, in square kilometres as well as in kilometres of road, and total traffic volume (see figure 3 below). The northernmost region “Region Norr” is very large with a total road length of close to 30 000 kilometres, but the total traffic volume is low. On the other hand the area of “Region Stockholm”, which includes Stockholm and Gotland (Swedens largest island) county is small with a total road length around 10 000 kilometres, but the traffic volume is high.

The profit centres function as businesses and one of the profit centres is SNRA Construction and maintenance.

Sweden is divided into about 140 maintenance contract areas. The regional directorates are responsible for purchasing the maintenance of the contract areas within their region. The SNRA Construction and maintenance today has about
70 % of all the maintenance contract areas. The other areas have gone to private contractors.

![Map of Sweden showing regional road management directorates/areas of SNRA](image)

**Figure 2.1** The seven regional road management directorates/areas of the SNRA. The head office of the SNRA is in Borlänge. (Source: SNRA)

**Municipalities**

There are about 290 municipalities in Sweden and they vary very much in size, both in area and in number of citizens. It is also up to each municipality to decide how to organise their activities, including the maintenance of streets and roads. Therefore the organisation of the municipalities varies within wide limits.

Usually the road maintenance is the responsibility of a special committee and its administration, often called the “street committee” and the “street office”, respectively.

The street office handles the procurement of all road maintenance. Both external contractors and internal (the municipal service office) are used.

### 2.2 Information provision

**The Road Weather Information System (RWIS)**

**Field stations**

The SNRA today has about 680 field stations all over the country connected to RWIS. The stations are equipped with sensors for measuring air and surface temperature, humidity, amount and type of precipitation, and wind. Due point
temperature is also calculated and delivered for every station. Some stations are also equipped with cameras.

The stations are placed more densely in the parts of Sweden where the temperature fluctuates around 0°C, i.e. in the southern parts of Sweden. In the northern parts of Sweden where the temperatures are lower and more stable there are fewer stations. See figure 2.2 below.

The stations are primarily placed on sites that are prone to slipperiness. The sites are chosen through thermal mapping. Thermal mapping has been repeated in some cases but is not done regularly.

In the northern parts of Sweden the positions of some of the stations are chosen so that situations with snowdrift and precipitation can be registered in the best way.

![Figure 2.2 The distribution of the 680 RWIS field stations (black, blue and white dots) (Source: SNRA)](image)

**Meteorological information**

During the winter season (1\(^{st}\) October – 30\(^{th}\) April) the Swedish Meteorological and Hydrological Institute (SMHI) delivers radar and satellite information 24 hours a day to the RWIS. SMHI also delivers weather forecast maps twice a day.
Internet

The information from the field stations and from SMHI is collected and compiled at an information centre at the head quarters of SNRA, some parameters are calculated, and all this information is then distributed to a Server. This information can then be accessed with a WEB-browser (Internet Explorer or Netscape). An example of how the RWIS-information, in this case road surface temperature, is presented on the screen is shown in figure 2.3 below. By “clicking” on one station, all data collected at this station for the past 12 hours can be viewed in graphs or tables. Some stations are also equipped with cameras so that the road condition can be observed.

![Figure 2.3 An example of how the RWIS-information, in this case road surface temperature, is presented on the screen.](image)

Expert systems

A prototype of a decision support system has been developed within a doctoral study financed by the SNRA.

2.3 Methods

Preparative programme for winter activities

The winter maintenance period is from around October 15\textsuperscript{th} until April 30\textsuperscript{th}, the period being longer in the north of Sweden and shorter in the south.

Contract for a maintenance area is usually signed for a period of three years. The procurement process starts in early spring with documentation and invitation to qualified bidders. A contractor is chosen and after negotiations the contract is signed in the end of spring. The starting date for the contracts usually is in July or
August. This date is set for the contractors to get enough time to prepare for the winter season.

Examples of preparative activities done by the contractors:
- Schedules for ploughing and gritting
- Schedules for the foremen on call (must be ready one month before the winter maintenance period starts)
- Signing contracts with subcontractors (men and vehicles).
- After each winter season the equipment (trucks, spreaders, ploughs, etc.) is inspected and repaired or replaced. Damaged/lost snow poles are replaced.
- Signing contract with a garage (for repairing of equipment). The garage must have full preparedness round the clock during the winter season.
- Sand and salt is purchased
- Obtain information about areas for snow disposal from the municipalities.
- Planning for exceptional weather situations. A network with extra resources is established. For example agreements are made with airfields to be able to use their equipment.
- Check if there has been any updating of the RWIS
- Meeting to inform all personnel about the different schedules and the levels of service

Schedules for ploughing and gritting
Detailed ploughing and salting schedules are made up, one for each truck, before the winter season starts. Each truck is given a specified route. Many of the contract areas use a software planning tool for winter road maintenance, called WinterPlan. The planning is preferably done as soon as possible after the previous winter maintenance period is ended so that the experiences achieved from this period can be used.

The schedules are made up so that the requirements given in the "General technical description of road operation service levels during winter. OPERATION 96.” (see section 1.2.1 above) can be fulfilled.

From the schedules for ploughing and gritting the need of resources (men and trucks) for the winter maintenance can be planned.

2.4 Equipment
Twenty-five percent of the SNRA appropriation for road maintenance and operations, a total of almost SEK 1.5 billion, is spent on snow ploughing, skid control and other winter road maintenance works. Of this sum, approximately 50 % are fixed costs, i.e., for stand-by, truck stations, storage facilities, etc. All in all, there are about 2 500 contracted pieces of equipment, mostly trucks, but also road graders, snow blowers and tractors that are part of the winter maintenance organisation. In addition to this, there are several less extensive work units for the maintenance of pedestrian and cycle paths.

As mentioned earlier, there are about 140 maintenance contract areas, covering the state roads, in Sweden. The maintenance contract areas comprise between 600 and 1 000 kilometres of road, centreline. This size has proven sufficient to be financially viable for contractors. The annual turnover for such an area is between SEK 10 and 20 million. In the former organisation of SNRA, an area containing 500 kilometres of road was considered large. The disadvantage in the new, more
extensive areas can be the difficulty in obtaining a good general picture of the area and solid knowledge of the locality. This is particularly apparent in winter road maintenance. Another variable is related to where in Sweden the area is found. In the northern part of the country, roads are situated far apart, meaning that the maintenance contract is geographically large. Around major cities and in the southern parts of the country the conditions are quite the opposite.

The SNRA “Construction and maintenance” is the contract manager for about 70 % of the maintenance contract areas. Private contractors manage the contracts for the other areas. There are three major private contractors in Sweden.

The SNRA has about 70 % subcontractors (men and trucks) in their maintenance contract areas while the private contractors have almost 100 % subcontractors.

The contractor normally owns the plows, spreaders and the mounting equipment for these on the trucks. The contractor does not normally own more than a few, 1–3, of the trucks that are used for winter maintenance. The remainders, up to 30, are the subcontractors’ own trucks and tractors. These subcontractors have their trucks on call during the entire winter season. They use the contractor’s plows and spreaders.

**Example of a maintenance contract area: “Eskilstuna“**
The total length of the road network in the maintenance area is 820 kilometres.

Vehicle fleet:
- Own trucks 5
- Contracted trucks 12
- Road graders 1
- Contracted tractors 14

Equipment for cycle and pedestrian paths are not included

**Example of a maintenance contract area: ”Jönköping“**
The total length of the road network in the maintenance area is 831 kilometres. The distribution of roads in the different standard classes is shown in the table below.

<table>
<thead>
<tr>
<th>Road standard class</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>B1</th>
<th>B2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>35</td>
<td>170</td>
<td>102</td>
<td>17</td>
<td>204</td>
<td>303</td>
<td>831</td>
</tr>
</tbody>
</table>

The maintenance centre is located in an industrial area in the southern part of Jönköping. There are four supervisors and nine workers employed at the maintenance area. In addition there are several subcontractors used for carrying out the different winter road maintenance activities.
The maintenance area has 11 units for combined salting and ploughing and 20 units only for ploughing. In addition there are 8 tractors used for ploughing pedestrian and cycle paths.

2.5 Materials
For recommended spreading rates see chapter 3.3.
NaCl (rock salt) is the only salt used for de-icing/anti-icing. The NaCl should be 98 % pure and must not contain more than 100 g of Potassium or Sodium Ferrocyanide per tonne NaCl. A gradation curve is specified and the maximum allowed grain size is about 3–4 mm.

2.6 Manpower, training and privatisation

2.6.1 Training and education
All foremen/supervisors, i.e. those who take the decisions about winter maintenance actions, must have gone through a certain education and training in winter road maintenance and in the RWIS given by the SNRA Road Sector Training and Development Centre.

The SNRA Road Sector Training and Development Centre also give a special course in winter road maintenance for truck drivers.

2.6.2 Privatisation
In 1991, the Swedish Government passed a decision that the design and construction of new roads, as well as all road operation and maintenance works within the state road transportation network, were to be contracted through competitive bidding.

The SNRA “Construction and maintenance” is the contract manager for about 70 % of the maintenance contract areas in Sweden. Private contractors manage the contracts for the other areas. There are three major private contractors.

The SNRA has about 70 % subcontractors (men and trucks) in their maintenance contract areas while the private contractors have almost 100 % subcontractors.

Forms of payment
Two forms of payment are used at present: current accounts and unit-price payment based on weather data statistics. There are advantages and disadvantages to both. Current account payments are calculated on the number of hours worked, or number of kilometres on which action has been taken. The advantage of this type of payment is that the contractor always knows that he will be paid for what he does. The disadvantage is that it does not foster the development of either methods or equipment, since the contractor is always paid, irrespective of the efficiency of his work methods. Moreover, this payment model can mean that the contractor is paid regardless of whether the action was right or wrong.

The advantage in regulating costs according to weather statistics is that this model encourages working with cost-effective methods, since the contractor profits directly from method development. One disadvantage could be that the contractor could occasionally fail to carry out measures to the extent desired. This however, would be reflected in the quality system and random inspections.
Moreover, the terms of payment are according to the functional standard, with the information being provided by an unbiased party.

Recently a new compensation model for regulating costs for winter road maintenance between client and contractor has been developed in Sweden and is tried by the SNRA.

The compensation model consists of two sub-models:
- one that describes the weather during the winter season
- one that links the weather descriptions to the need to take measures/set in resources

The basis for the weather descriptions is data collected from the individual stations in the SNRA system for road weather information, RWiS. Through using special definitions, the data is translated into eight weather situations at an hourly level.

The hour-by-hour weather descriptions are then summarised into clearly defined weather periods, for instance drifting snow during 6 hours or a snowfall lasting 20 hours with an amount of snow of 10 cm, measured as loose snow. The final result of weather descriptions for a winter is a number of clearly defined weather periods.

The compensation model is based on the number of weather periods for each RWiS station chosen as representative for a certain maintenance area. Starting from each weather period the number of weather outcomes is calculated being the basis of compensation. In this step the connection is made between weather and the need to take measures.

3 Operational organisation of winter maintenance
3.1 Getting information

All operational centres have PCs connected via Internet to the Swedish RWIS system where the road weather conditions can be monitored through the 680 field stations at all times. The information is updated every half-hour.

Meteorological information is obtained from SMHI. Every half-hour images from the Nordic radar network in different scales are distributed to the RWIS systems central computer. Weather radar stations are currently located at about 10 sites in Sweden and cover almost the whole country.

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 at least twice a day, at about 01:00 and 13:00 hours. Forecasts for 6, 12 18 and 24 hours are given. All day and night special cloudiness forecasts are produced for a combined statistical and energy model that every hour predicts the road surface temperature for the next two hours.

As a complement to the information distributed to the RWIS the local SMHI office goes through the information on telephone with the SNRAs information and production centres and the contractors at the operational centres.

The RWIS system also delivers surface and due point temperature forecasts for 2 hours ahead for each field station. A warning is also given for the following situations:
Rain.

- Prognosis for warning 1: The road surface temperature will be in the critical temperature interval between 0 and -2°C within one hour.
- Warning 1: The road surface temperature is in the interval between 0 and -2°C.
- Prognosis 2 for warning 2: An indication that hoarfrost will start to form within one hour is given.
- Warning 2: The road surface temperature is at least 0,5°C below the due point temperature and the road surface temperature is 0°C or lower. This means that hoarfrost is forming at the field station.

The foreman on call takes the decision of an intervention

The SNRA has organised Road User Information Centres (the TIC), one in each of its seven regions. The centres give information to road users and also to the contractors of the operation centres. The contractors in turn have to report immediately to the TIC each time any activities are performed that has an influence on the accessibility of the road. This applies especially to winter maintenance activities since the road conditions can change quickly.

3.2 Methods, equipment and materials for snow control

The winter maintenance on the state roads in Sweden is carried out according to the "General technical description of road operation service levels during winter. OPERATION 96". The operating requirements are written in functional terms, which means that they describe the road surface condition during different weather conditions. Thus, these requirements do not stipulate when measures are to be carried out. This is up to the contractor to decide upon. (See chapter 1.2.1.)

Snow removal

The main types of ploughs used are diagonal (wing) ploughs in combination with ploughs mounted on the side of the truck. The ploughs normally have steel or hard metal cutting edges. There are also cutting edges with a combination of rubber and steel.

There are special ploughs for removing the slush that is formed after salt spreading. These ploughs have cutting edges made of rubber. These cutting edges are durable and follow the surface irregularities, such as ruts, better than cutting edges of steel.

In extreme weather situations the use of V-shaped ploughs can be necessary.

Also snowblowers/cutters are used when needed.

Strategies for clearing multilane-carrigeways

The snow on dual lane motorways is normally removed from the left to the right, and always with two units, the one in the right lane following the one in the left. The distance between the units can vary but is normally, if traffic is to be able to pass, between 200 and 300 m.

The units are normally equipped with a diagonal plough and a plough mounted on the side.
Snow and Ice grading
Snow and ice grading means the removal of snow or ice that has got stuck on the road surface. Snow and ice grading is done when ruts or slipperiness has developed due to this circumstance. The equipment used for this is called a road grader. During a normal winter the use of road graders on salted roads is limited, while the need for this is larger on other roads, particularly in the northern regions of Sweden.

There are several different steel cutting edges for road graders. There are for example smooth, serrated or perforated edges and there is also a system with hard metal pins.

Cutting of snow walls
The snow wall produced by the snowplough at the side of the road should not be higher than 1 meter in order to provide good visibility.

Low snow walls make the snow removal during the next snowfall easier. During situations with drifting snow the gathering of snow of the roads is smaller if the snow walls are kept low.

Cutting of snow walls is normally performed with a side wing mounted on a road grader. The snow should not be removed all the way down to the road surface. About 20 cm of snow should be left as a driving guide for the road users.

Removal of snow from ditches
Snow is removed from the slope alongside the road during the late winter before the snow melting starts. This is to ascertain the drainage of the melted snow and prevent flooding, slipperiness, surface damage and other problems.

White roads
The level of service on the roads with low traffic volumes is often “snow covered” or ”white” road (called standard class B1-B2. Se table in chapter 1.2.1). On these roads salt is normally not used at all.

To fulfil the requirements the surface of the snow covered roads have to be even (smooth).

For snow removal diagonal (wing) ploughs in combination with ploughs mounted on the side of the vehicle are normally used.

In order to remove snow and ice that has got stuck on the road, for example when ruts have formed or it is slippery road graders are used.

3.3 Methods, equipment and materials for ice control
Chemical de-icing
In Sweden the only chemical used for de-icing is NaCl (rock salt). CaCl₂ has previously had some limited use, mainly for prewetting of NaCl, but is not used at all at present. The main reason for this is the negative effect on concrete, which some investigations have shown.

Several tests with alternative chemical de-icers have however been done over the years. But so far they have all been rejected due to too high prize and/or insufficient effect. One of the most extensively studied alternatives is Calcium Magnesium Acetate (CMA). The first tests were done in the beginning of the 80-
ies. The main drawback with CMA is the high prize, which is at least 20 times that of NaCl.

Table 3.1 Guidelines for de-icing. Road width 7 meter.

<table>
<thead>
<tr>
<th>Road condition</th>
<th>Predicted surface temp. (°C)</th>
<th>Spread adjustment</th>
<th>Salt consumption per 10 km</th>
<th>Brine consumption m³/10 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-wetted salt</td>
<td>Brine (20 % solution)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width (m)</td>
<td>Width (m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(gr/m²)</td>
<td>(gr/m²)</td>
<td></td>
</tr>
<tr>
<td>Pre-wetted salt spread prior to temperature fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry or moist</td>
<td>±0 / -5</td>
<td>4</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>11</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Wet</td>
<td>±0 / -5</td>
<td>4</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>13</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>Wet prior to snowfall</td>
<td>±0 / -5</td>
<td>4</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>25</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Measures to be taken during snowfall. Combined operations. Risk of surface freezing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snowfall 1-5 cm</td>
<td>±0 / -5</td>
<td>2 × 3</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>18</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Snowfall &gt; 5 cm</td>
<td>±0 / -5</td>
<td>2 × 3</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>24</td>
<td>7</td>
<td>33</td>
</tr>
<tr>
<td>Measures to be taken on black ice in dry weather.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation of ice</td>
<td>±0 / -5</td>
<td>4</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>15</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Thin ice</td>
<td>±0 / -5</td>
<td>4</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>25</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Thick ice</td>
<td>±0 / -5</td>
<td>4</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>25</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>Measures to be taken on freezing rain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation of ice</td>
<td>±0 / -5</td>
<td>4</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-5 / -10</td>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The SNRA strive for a reduced use of salt. Some examples of this are given below:
- Roads with less than about 2000 AADT should not be treated with salt, except during autumn and spring. The limit is lower in the south of Sweden than in the north.
- Increased use of brine, especially for preventive actions.
- Improved weather forecasts.
- Improved equipment for snow removal and ice control.
Mechanical de-icing
The material normally used is sand, 0–8 mm, mixed with about 3 percent by weight salt. On roads with speed limit above 70 km/h the maximum allowed grain size is 4 mm. The salt is added primarily to facilitate the storage of sand in cold weather and partly to improve its adhesion and durability.

Crushed stone aggregate, usually of 2–5 mm fraction, has been used for several years mostly in urban areas. Crushed stone aggregate, 2–4 mm, is used for pedestrian and cycle paths. No addition of salt is needed.

A material that also has come to some use, mainly by the municipalities, is crushed limestone.

An alternative method that has been successfully tested during recent years is wet sand where the sand is sprayed with hot water before spreading. With this method the sand will melt the snow or ice a little and then get stuck as it freezes again. The method is most suitable in regions with a stable climate and low temperatures. The results from the tests have shown that a longer lasting effect is obtained compared to conventional methods.

3.4 Methods, equipment and materials for special problems

Porous asphalt
Porous asphalt is not very commonly used in Sweden. On the few road sections where it is used the main purpose is to reduce noise.

There are no special instructions for winter maintenance on porous asphalt. However, it is considered by many of those involved in winter maintenance that this type of asphalt requires more frequent spreading of salt and/or larger amounts of salt at each spreading.

Bridges
Either an RWIS station is placed on the bridge or just a sensor for surface temperature that is connected to a nearby RWIS station.

Salt was considered a problem before, but not so much any more. The quality of concrete has been improved and the steel construction parts are protected.

Cycle paths
The SNRA is responsible for the cycle paths along the state roads, which means about 2 200 km. There are special regulations for these in the "General technical description of road operation service levels during winter. OPERATION 96". Three standards classes are defined: C1, C2 and C3. For standard class C1, which is the highest standard, the following applies:

− During snowfall and up until four hours after the snowfall has ended, the snow depth is not allowed to exceed four centimetres of loose snow.
− The cycle path should have satisfactory friction within two hours after rain that has caused slipperiness has ended.
− The cycle path should have no more than two centimetres of loose snow, be even and have satisfactory friction, during dry weather at any other time.
The requirements should be fulfilled for at least 75 percent of the width, but not less than 0.5 metres though.

The cycle paths that the SNRA are responsible for are relatively few compared to those that the municipalities are responsible for. The cycle paths belonging to the municipalities correspond to about 8 700 km. Each municipality prepares its own requirements for winter maintenance (levels of service) on cycle paths. Most municipalities have a certain snow depth, ranging from 3–10 centimetres, as a criteria for when winter maintenance actions have to start.

Sand or crushed stone aggregates are normally used on cycle paths. Some municipalities use limestone. Salt is almost never used. The sand can however sometimes be mixed with salt. In some cities pavement heating systems are used.

Normally tractors equipped with ploughs, snow blowers, spreaders, etc. are used.

Avalanches
Avalanches are not a very big problem for the main parts of the Swedish road network. In the northern parts of Sweden, in the mountainous areas, passive defence systems are used (fences/walls). *(The avalanche risk is given in a scale of five (1–5) in the whole mountainous area. Whether this is used for road purposes also is unclear.)*

Snow drift
Snow fences are put up where the phenomenon regularly occurs. Also “living” snow fences, that is bushes and trees, are used to prevent snow from drifting on to the road.

In the northern parts of Sweden the positions of some of the RWIS stations are chosen so that situations with snowdrift and precipitation can be registered in the best way.

3.5 Measurements of efficiency

Internal

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

![Graph showing salt consumption and salt index per winter season.](image)

**Figure 3.1** The total salt consumption and the calculated salt index per winter season on the state roads.

External

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

In Sweden the studded tires (wear) and also the heavy traffic (deformation) causes ruts in the pavement surface. Although there have been no studies of this, a common opinion is that the ruts make it more difficult to get the road clear from snow and ice through ploughing and that more salt is needed to get a bare pavement.

The wear of road markings caused by snowploughs is a problem, but to what extent?

4 Information to road users

The figure below gives an overview of the SNRA Traffic Information Support System (TRISS). Data is collected into the system, processed, quality checked and distributed in different ways to the road users.
Figure 4.1 An overview of the SNRA Traffic Information Support System (TRISS).

For example, all operation centres (the contractors in the figure above) have to report at least 3 times a day to the TIC (Traffic Information Centre) and also every time there is a change in road condition (e.g. after a turnout). The information is then distributed from the TIC in different ways:

- Local radio stations get information from the TIC.
- Traffic Message Channel (TMC): There have been TMC transmissions in Sweden since 1998 via the Swedish Broadcasting Corporation P3 station’s Radio Data System (RDS) channel. The TMC messages are presented either as text, voice messages, or on a map. In order to receive TMC messages it is necessary to have a special receiver. This can be installed in the car radio or connected to a special display presenting maps, text and symbols.
- Newspapers
- Internet: A map showing the present road conditions based on TRISS and RWIS can be found at the home page of SNRA
- Road users can also call the TIC to get information.

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

The municipalities often distribute information in brochures and/or via Internet (on their homepage) to the citizens about contractors and the level of service before the winter season.
5 References

Most of the information in this report has been gathered through personal communication with persons working at the Swedish National Road Administration (SNRA) and at the Swedish Meteorological and Hydrological Institute (SMHI).

Information was also obtained from the Internet on the home pages of for example SNRA, SMHI and the Swedish Association of Local Authorities.

Another source of information has been the compendium “Winter maintenance roads, streets, railways and airfields”; editor-in-chief Alf Johansson, Chalmers Lindholmen University college, 2000 (in Swedish). The compendium was written on commission by the Centre of research and education in infrastructure maintenance and operations (CDU) at the Royal Institute of Technology.