COST 344

DOCUMENTATION FOR THE FINAL SEMINAR COST 344

IMPROVEMENTS TO SNOW AND ICE CONTROL ON EUROPEAN ROADS AND BRIDGES

LJUBLJANA DECEMBER 9.-10. 2002
COST 344

DOCUMENTATION
FOR THE
FINAL SEMINAR
COST 344

DECEMBER 9.-10. 2002
# Table of Contents

## Improvements to Snow and Ice Control on European Roads and Bridges
- Marilyn Burtwell
- Gudrun Öberg

## Winter Maintenance in Europe - Practice and Research
- Didier Giloppe
- Marilyn Burtwell
- Dr. Stefan Bald
- Dr. Valérie Muzet

## Improvements to Snow and Ice Control on European Roads - Main Results
- Dr. Risto Kumala

## Future Research Topics Related to Road Weather
- Dr. Risto Kulmala

## Introduction and Objectives
- Gudrun Öberg

## Information Gathering
### Task Group 1
- Gudrun Öberg
- Dr. Christian Holldorb
- Didier Giloppe

## Best Practices in Europe
### TG 3
- Dr. Stefan Bald
- Dr. Valérie Muzet
- Roland van Doorn

## Appendix 1:
- COST 344 TG3 Subject List

## Appendix 2:
- Information Provision

## “Winter Maintenance Management System”
- Final Draft of TG5
- Dr. Christian Holldorb
- Dr. Anita Ihs
- Ljiljana Herga-Luis
- Manfred Skerlan
- Xavier Cocu

## Future Research Topics
### Final Report of Task Group 4
- Dr. Risto Kulmala

## Benefits of the Project to Different User Groups
- Gudrun Öberg

---

4
Improvements to Snow and Ice Control on European Roads and Bridges

Marilyn Burtwell
TRL Limited Old Wokingham Road
Crowthorne, Berks RG45 6AU, UK
mburtwell@trl.co.uk

Gudrun Öberg
Swedish National Road and Transport Research Institute (VTI)
58195 Linköping, Sweden
gudrun.oberg@vti.se
Abstract

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.

This 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. Millions of ECUs could be saved through lower operational costs and a reduction in adverse effects on the highway infrastructure and the environment. For the road users, more effective management of winter operations could lead to a reduction in traffic delays and accidents. For practitioners, implementation of ‘Best Practice’ should enhance standards and lead to Best Value being achieved. The implementation of Best Value could provide the means to measure the performance of the winter maintenance service within various road administrations.

Interim results of the COST Action are being disseminated to European and national policymakers, regional planners, engineers, road and vehicle operators, industry and academia. This approach ensures maximum dissemination of knowledge. The Internet, a CD-ROM, Email, handbooks and events such as workshops, conferences and seminars are being used to target a wider audience.
Introduction

Effective snow and ice control is vital to ensure, as far as possible that road users can travel safely and with minimum disruption in cold and severe weather conditions. However, it is important that the winter maintenance service is provided at an affordable price and that ‘Best Value’ is achieved with minimum environmental impact and traffic disruption, and with high standards of safety. Information on ‘Best Practice’ is therefore essential to ensure widespread implementation of appropriate standards of service.

The need for innovative snow and ice control techniques and processes has grown over recent decades in line with the development of national and European road networks. 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 road freight and passenger transport, and by the environmental and other policies affecting highways.

The COST Action 344: Improvements to snow and ice control on European roads and bridges, started in April 1999 and is part funded by the European COST (Co-operation in the field of Scientific and Technical Research) programme (EU, 1999). The Action (www.cordis.lu/cost-transport/home.html) is a three-year project with participation from eighteen European countries. TRL is the Chair of the COST Action and represents the UK Highways Agency, which is responsible for the operation and maintenance of the Trunk Roads and motorways in England. VTI is the Vice Chair and represents the Swedish National Roads Administration, which is responsible for the operation and maintenance of the Swedish national road network. These organisations are members of the COST 344 Management Committee.

Objectives of the research

The main aim of the COST project is to improve the performance of snow and ice control methods and operations by defining the requirements for ‘Best Practice’ in different climate domains, across the EU and other COST member states. This will provide national highway authorities with information on the best materials, techniques and procedures to meet the changing demands of the European road infrastructure and, at the same time, harmonise safety and environmental standards. It will thus provide guidance to decision makers.

A significant contribution will be provided to meet the stated goals of the Transport European Road Network (TERN) as below:

- Sustainable mobility of persons and goods within the EU under the best possible social and safety conditions (Article 2.2a).
- Integration of environmental concerns into the design and development of the network (Article 5d).
- Promotion of network interconnection and inter-operability between the EU and the third world countries (Article 6).

Assessments of operational practices, employed at national level, are also expected to result in the development of objective criteria and benchmarks for various aspects of snow and ice control and their impact.
The aims of the research project are:

a. To review existing international practices, involving the following elements:
   - terminology review and creation of a European glossary;
   - literature review covering the years 1990 to 2000 to establish the state-of-the-art practice and research in snow and ice control methodologies;
   - review of current research and development work, in both the public and private sectors;
   - review of current practices by evaluating selected case studies in targeted EU regions; and
   - creation of an inventory of snow and ice control methods, equipment and materials.

b. to define snow and ice control requirements in different European regions;

c. to determine 'Best Practice' in different European regions;

d. to develop guidelines for the integration of specified snow and ice control methods into network level road management and maintenance systems;

e. to make recommendations for improvements to driver information systems and traffic management systems; and

f. to make recommendations for future winter maintenance research, which has potential benefits for practitioners and road users.

Particular areas where further investigation has been proposed are:

- the most effective and least environmentally harmful de-icing/anti-icing materials, and
- the most effective treatments in the various climates encountered across COST member states;
- implications resulting from the introduction of innovative road surfacings to establish benchmarks for safe and effective winter maintenance;
- innovative Road Weather Information Systems (RWISs), which would benefit from a review of accuracy, reliability and the introduction of developing capabilities such as residual salt sensors; and
- road icing information and prognosis systems.

Investigations are also underway on the following:

- Operational procedures:
- driver information systems using existing methods and innovative developments employing advanced telematics; and
- the impact of methods designed to maximise traffic flows and reduce accident severity in winter conditions.

Information on many of these research elements has been drawn from the experience and knowledge of participating member states through detailed assessments and a review of current and ongoing research. The common interests and general objectives are shared by the member states and the planned work is drawing upon most of the relevant work currently in progress and planned within all COST countries together with the results of work undertaken previously.
Task Groups

Six Task Groups, TG1 to TG6 with nominated leaders, will run through the three-year life of the Action. The seventh group, TG7 will start in year 3 of the project. These Groups involve the most appropriate blend of technical expertise for the tasks from a broad geographical distribution across Europe to ensure an extensive input and high quality outputs. The Groups are:

TG1 - Information gathering, literature review and glossary
TG2 - Definition of requirements
TG3 - ‘Best Practice’
TG4 - Future research
TG5 - Road management system
TG6 - Driver information systems
TG7 - Final report

Each Group has submitted at least one technical deliverable and, these will form a major part of the final report of the Action.

1. Task Group 1 – information gathering, literature and glossary

A glossary of winter maintenance terms in six languages – Dutch, English, French, German, Swedish and Spanish has been produced. It is expected that PIARC will adopt the COST glossary, in 2002 at the end of the Action, to complement its own glossary. A European review of literature from 1990 to 2000, which includes over 600 research papers and reports, has been divided into topics (weather and climate, equipment, effects, management, de-icing products, equipment for road users, risk management, strategy, design and construction of the road, costs of winter maintenance, road user information and overview).

The work has also identified about 150 current research projects throughout Europe on winter maintenance practice and management issues.

The review of literature and current projects has identified the gaps in our knowledge and thus where future research efforts should be directed.

2. Task Group 2 – definition of requirements

The objectives of TG2 were to consider safety, environmental and information criteria, the management and operations of snow and ice control and, to identify improvements that would enable delivery of a more cost-effective and efficient service. To achieve this it is important to set down the components of a winter maintenance management system which, on balance, will produce a quality service. The work of TG2 complements the work carried out in TG3 - ‘Best Practice’.

TG2 members have identified the following generic business areas as being of fundamental importance to road administrations:

a. Service levels - Relate to the winter maintenance operation itself and includes the effectiveness of the treatment in preventing ice and snow adversely affecting the highway. It does not however include safety and traffic movement considerations, which it is argued, are secondary effects and can be influenced by factors other than the quality of the winter maintenance operations.
b. **Environment** - Includes the effect of winter maintenance operations on the natural environment, including flora, fauna and marine life.

c. **Safety** - Includes the safety of the winter maintenance operatives and the road users. Care must be exercised to ensure that the reasons for safety performance are understood since factors other than the quality of winter maintenance may be relevant.

d. **Traffic movement** - Includes traffic flow during winter conditions, which may again be affected by factors other than effectiveness of the winter maintenance operation.

e. **Cost optimisation** - Includes analysis of all the factors that contribute to the delivery of a cost-effective winter maintenance service.

f. **Information to the administration** - Includes the provision and management of information about the performance of the operation so that proper accountability can be achieved.

g. **Information to the road users** - Includes the appropriate level of information to road users in various forms both before and during the journey made.

These generic issues are set out graphically in Figure 1. They have been disaggregated to a) identify more detailed issues requiring analysis and b) deliver the appropriate quality of winter maintenance service. Items (a), (b), (e), (f) and (g) above are those issues over which the administration has a significant level of control whereas items (c) and (d) are random occurrences influenced by other factors including driver behaviour.

The type of climate is also a prime factor - this depends on the altitude and geographical location, and is manifest through the frequency, duration and intensity of the winter weather conditions (COST 309, 1992). Conventional classifications can be made ranging from mild to very cold climates. A winter index is a given function of the number of days with icy conditions with the minimum and mean temperature. This determines the frequency and duration of ice on the roads. A Road Weather Information System (RWIS) determines the adverse winter conditions in order to make the necessary decisions with sufficient time in hand. Winter weather conditions include snowfalls, ice, freezing rain, fog, snowdrifts, avalanches etc. Their frequency, duration and intensity depend on the meteorology of each area. The onset of winter weather triggers the resources needed to re-establish the serviceability of the road.

Important characteristics of the road are the road type (high capacity or conventional), carriageway width, layout, gradient, pavement type, frequency and length of bridges and tunnels etc.

---

**Figure 1. Schematic diagram of the links in the winter maintenance processes**

**Key:**
- --- Issues over which the administration has substantial control.
- --- Issues over which the administration has significant control.
- --- Issues over which the administration has limited control.
3. **Task Group 3 – ‘Best Practice’**

The objectives of TG3 are to identify ‘Best Practice’ in the field of winter maintenance, including the impact of operations on the environment and benefits to service providers and road users. The identification of ‘Best Practice’ will encompass all the needs of the European Community specific to particular countries and/or climates involved in winter maintenance activities. A questionnaire, in the form of a detailed subject list, was prepared and distributed to EU member states to determine current winter maintenance practices. The responses have been compiled and compared for common climate domains (Scandinavian, Maritime, Central European, Continental, Mediterranean and Alpine). The climate domains differ especially in temperature (daily and yearly), humidity, probability of snow, wind and expectations of the user. A wide range of practice, environmental issues and benefits have therefore been compared and evaluated.

When preparing a winter maintenance procedural statement, it is necessary to consider climate and weather information, methods, resources (eg manpower, equipment and materials) that will need to be employed. This will include information about chemical de-icers, gritting materials, mechanical snow and ice removal equipment, and special treatments applicable to certain types of road surfacing materials, bridges, cycletracks and pedestrian footways. It will also include developments in RWISs, specifically the measurement of residual chemical on the road surface. The efficiency of the chosen procedures can be measured using internal performance audit methods. An external audit could measure the number and severity of accidents, travel time delay, user satisfaction and environmental impact.

It is also important to have in mind the owner of the road, contract manager, operational staff and road users before decisions about winter maintenance procedures are taken. Fundamental issues, which influence winter maintenance, are climatic conditions, standards and legal obligations. Consideration of the points covered above will enable improvements in ‘Best Practice’ to be made throughout Europe.

4. **Task Group 4 – future research**

At present, various institutions are carrying out work into improvements in winter maintenance management, procedures, techniques, treatments, weather and climate, safety and other effects. Whilst valuable, these are largely uncoordinated initiatives and the COST Action has brought these together to identify ‘Best Practice’.

The objective of TG4 was to identify the most important topics for future research activities in the domain of COST 344. The work of the task group was carried out in three phases:

- identification of topics for future research;
- prioritisation of future research topics; and
- selection and task description of the most important topics for future research.

The topics for future research were collected via an e-mail survey sent to the COST 344 Management Committee and other international experts. About 90 respondents sent proposals for research topics. TG4 members analysed the list of about 200 different topics received and produced, by merging, a list of 93 research topics for prioritisation.
This topic list was used as a basis for an Internet survey, where experts from different countries and representing different organisations (authority, industry, research or academia) were asked to prioritise the research topics. In all, 57 experts completed the survey.

A number of topics were regarded as very important or important and TG members produced tentative research task descriptions for these topics. The six most important future research topics are:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
5. More cost-effective, efficient and environmentally friendly de-icing products.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.

5. Task Group 5 – road management system

A Winter Maintenance Management System (WMMS) is an important integral part of an integrated Road Management System (RMS) and financial, quality, legal and social aspects need to be considered.

There are two levels of a WMMS that should be considered - the strategic level where the socio-economic consequences of a chosen winter maintenance strategy are calculated, and the day-to-day level used for the management of the winter maintenance activities.

On a strategic level, it is not the objective to define the level of service but to define which parameters have to be considered when defining the level of service. In practice, it is an optimisation process between costs and benefits, as far as is practicable, because of the limited funds available. The efficiency and effectiveness of the service provision and the chosen optimisation process, which must be continually reviewed, determines delivery. New research ideas need to be fed into this optimisation process to continually improve it and the subsequent service.

A WMMS on the day-to-day level may consist of several parts/systems such as:
- administrative information;
- route planning;
- Road Weather Information System (RWIS);
- call-out system;
- reporting and documentation of actions;
- information to road users; and
- follow-up of actions.

Some European countries have a WMMS that includes many of the above parts but many countries have one or more of the parts as separate systems, eg Road Weather Information System (RWIS). A RWIS includes outstations, which measure parameters close to the road, eg road surface temperature, and common meteorological information, eg wind speed, humidity etc.

TG5 members are considering the components and inputs and outputs required for a WMMS and its compatibility with other modules or systems in a RMS. Comments on the benefits of introducing a WMMS into a RMS will be included in the final report from the Action.
6. Task Group 6 – driver information systems

TG6 members are considering the effectiveness and benefits of driver information and traffic management systems for road users in adverse weather conditions. Information for drivers is essential if they are to travel safely on the road network in winter but the nature of the information given needs to be timely and accurate. Ways of disseminating the information could include telematics (in-driver vehicle systems), the Internet, radio, telephone, journals, teletext and variable message signs alongside the road.

It is recognised that road users comprise different driver groups, which have different needs for pre-trip and on-trip information.

The driver groups have been identified as:
- Professional drivers (e.g., public transport, haulage, security services)
- Frequent drivers (e.g., commuters)
- Occasional drivers (e.g., school errands, tourists)
- Related businesses (e.g., travel agencies, private information services).

It is important to identify what sort of information each driver group requires. For example, Finland has carried out a study of the frequent and occasional drivers, and this is being examined in detail for the purposes of the Action. This work may be considered as a good example of ‘Best Practice’ and much can be learned from it.

A questionnaire has been compiled by TG6 members and circulated to all the European members of the Action to seek answers to a series of questions regarding driver information and related information systems.

The questions include:
- What actions are used now?
- What are the effects of these actions?
- What are the costs and benefits of driver information systems?
- What do road users need?
- What could be done better?
- What could be provided but is not?

The usefulness of information needs to be considered to avoid information ‘overload’ and the timing of this information is also important. Three stages of the information process are essential – at the onset of winter weather, during winter events, and in the case of a crisis. This will ensure that the drivers have timely information and can plan their journeys in advance or during their travel on the road network. When faced with exceptional circumstances such as heavy snowstorms and traffic difficulties, collaboration with the police and other bodies is essential.

Private radio systems utilise the information services of the roads administration in Iceland and Finland. For example, TRAVEL-GUIDE is a current project undertaken in Finland and is concerned with traffic management and information services. The approach is to specify a commonly agreed data exchange interface, via which private service providers have access to public organisation information and vice versa. The Viking Travel and Traffic Information Service (www.ten-t.com/viking) and its guidelines propose quality requirements for road weather and road surface condition information. Systems such as these described above are being investigated further in the COST Action.
7. Task Group 7 – final report

The final report will include summaries of the Task Group reports, benefits of the project to different user groups, a discussion, and conclusions together with overall recommendations.

Dissemination of information from the Action

A dissemination plan has been produced to promote the results of the Action to European and national policymakers, regional planners, engineers, road and vehicle operators, industry and academia. This approach will ensure maximum dissemination of knowledge. Results of the Action are to be disseminated to a wider audience by means of events such as workshops, conferences and seminars in the participating EU countries and member states and by e-mails and the Internet. At the end of the Action, the final report, a CD-ROM and a series of handbooks will be made available to interested winter maintenance personnel in the participating EU Countries and member states.

Summary

The COST Action will:

- Identify ‘Best Practice’ and emerging developments within and between EU and other COST member states.
- Investigate necessary improvements to RWISs to introduce any latest available features such as residual salt sensors.
- Ensure that treatments are carried out to reduce any harmful effects in the environment.
- Assess the impact of methods designed to maximise traffic flows and reduce accident severity in winter conditions.
- Generate recommendations for the integration of specified snow and ice control methods into network level road management and maintenance systems.
- Develop recommendations for further improvement in the dissemination of up to date and reliable information to practitioners and road users.
- Generate recommendations for improving the level and quality of user input information in snow and ice control decision making.
- Identify future research.
Benefits

The Action has promoted exploitation of technological advances in application and distribution of snow and ice control measures leading to significant environmental benefits. With the application of the knowledge gained, millions of ECUs could be saved through lower operational costs and a reduction in adverse effects on highway infrastructure and the environment.

For the road users and communities, more effective management of winter operations will lead to a reduction in traffic delays and accidents.

9. Acknowledgements

The authors wish to thank the members of COST Action 344 Management Committee for their contributions to the project. The work described in this paper forms part of the UK Highways Agency's research programme carried out by TRL and is published by permission of the Chief Executives of the UK Highways Agency and TRL.

The work described in this paper forms part of the Swedish National Roads Administration research programme carried out by VTI and is published by permission of the Swedish National Roads Administration and VTI.

10. References


Winter Maintenance in Europe – Practice and Research

Giloppe Didier
Ministère de l’Equipement et des Transports, CETE de Normandie Centre,
10 chemin de la poudrière, BP 254, 76121 Le Grand Quevilly, F,
didier.giloppe@equipement.gouv.fr

Burtwell Marilyn
TRL Ltd, Old Wokingham Road, Crowthorne Berkshire, RG45 6AU, UK,
mburtwell@trl.co.uk

Dr. Bald Stefan
Technical University, Petersenstrasse 30, 64287 Darmstadt, D,
jsbald@verkehr.tu-darmstadt.de

Dr. Muzet Valérie
Ministère de l’Equipement et des Transports, CETE de l’Est, 71,
rue de la Grande Haie, 54510 TOM BLAINE,
valerie.muzet@equipement.gouv.fr
**Introduction**

Effective snow and ice control is an important service for national governments, in order to ensure as far as possible, that road users can travel safely and with minimum disruption in cold and severe climatic conditions. Since national and European road networks have developed substantially over recent decades, so too has the need for innovative snow and ice control techniques and processes. Practices, standards, level of equipment differ among Europe depending on national government and climatic zones (see Figure 2).

The European commission project entitled COST Action 344 : “Improvements to snow and ice control on European roads and bridges” is an exchange platform between 19 European countries (see Figure 1). This three-year project began in 1999 and is a part of COST Transport “Research for sustainable mobility”.

Winter conditions affect all member states, often for 5 or 6 months of each year, and even those states in Southern Europe can suffer from such conditions in localised areas. The cost of disruption and injuries through road accidents is substantial, so that measures to further improve winter maintenance arrangements are likely to produce significant benefit in term of safety for road users. The project will provide improvements in the area of programme management, quality of operation for planning, operational practice, less harmful anti-icing products and spreading controls, measures to treat modern surfaces and better driver information.

The action will generate the basis for full-scale European experiment and evaluation of improved winter measures to be carried out under a future transport programme of the Fifth Framework programme for research and development. For road users, more effective management of winter operation will lead to reduce traffic delays and accident.

Different axes of investigations are ongoing and a final technical report will be produced during 2002.

- Task Group 1 : Information gathering
- Task Group 2 : Definition of requirement
- Task Group 3 : Best Practice
- Task Group 4 : Recommendations for future research
- Task Group 5 : Integration into a pavement management system
- Task Group 6 : Recommendations on driver information systems

Since the different task groups did not begin their work simultaneously, the work of TG 1, 2 and 3 will be presented at SIRWEC 2002. The work of TG4 is presented in another paper (Kulmala, 2001).

**Figure 1 : State members of COST Action 344**

Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Ireland, the Netherlands, Norway, Poland, Romania, Slovenia, Spain, Sweden, Switzerland, United Kingdom.
The objective of the Task Group 1 was to gather information on winter maintenance among Europe. The experts of COST 344 come from different European countries and since English is not their mother language there can be misunderstanding and inaccuracies. These problems can be due to the language itself or because the concepts of certain words are not necessarily the same ones in all the countries. While building international exchanges it is important to make a formalisation of the language through words but also through the definition of these words and of the concept they cover for each country. This is why the task group 1 decided to make of a glossary specific to Winter Maintenance.

It is also very important to know what has been done in winter maintenance in every participating country since administrative road services have a lot of knowledge and documents that are not published in international review. So a state of the art was made with bibliographical collection of various publications and documents proposed by the countries.

Glossary of terms for winter maintenance called WINTER TERM

In the framework of the European COST 344 Action 'Improvements to Snow and Ice Control on European Roads and Bridges' a Glossary of Terms for Winter Maintenance was developed. It is now available as a preliminary version. The glossary includes about 180 terms and explanations in 8 languages (Dutch, English, Finnish, French, German, Hungarian, Spanish, and Swedish). There is an example for 3 words in the following page.

The terms are sorted in 8 categories: Weather/Climate, Ice, Snow, Spreading, Snow clearance, Ice and Snow Protection, Management of Winter Maintenance and Others.
The database can be used for translations of specific terms and/or to create bilingual dictionaries. It is free on [http://www.durth-roos.de/sb/dsbi00n1.htm](http://www.durth-roos.de/sb/dsbi00n1.htm) and provided in Microsoft Access 97 and Access 2000 format. There is the possibility to add new terms and new languages. Registered users are informed about new releases of WINTERTERM by e-mail and this dictionary will be available on the Cost 344 and on the PIARC Web site.

### State of the art and on going projects among Europe

Each of the COST 344 participating country was asked to make a national literature review of his most important documents with an English translation of the title and a brief abstract in English. All these 707 documents were compiled and can be sorted : by item, by country, by author, with the references of the documents.

The classification items are the following:

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weather and climate</td>
<td>94</td>
</tr>
<tr>
<td>2</td>
<td>Equipment</td>
<td>83</td>
</tr>
<tr>
<td>3</td>
<td>Effects</td>
<td>106</td>
</tr>
<tr>
<td>4</td>
<td>Management</td>
<td>112</td>
</tr>
<tr>
<td>5</td>
<td>De-icing products</td>
<td>96</td>
</tr>
<tr>
<td>6</td>
<td>Equipment for road users</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>Risk management</td>
<td>39</td>
</tr>
<tr>
<td>8</td>
<td>Strategy</td>
<td>49</td>
</tr>
<tr>
<td>9</td>
<td>Design and construction of the road</td>
<td>53</td>
</tr>
<tr>
<td>10</td>
<td>Cost of winter maintenance</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>Road user information</td>
<td>17</td>
</tr>
<tr>
<td>12</td>
<td>Overview</td>
<td>29</td>
</tr>
</tbody>
</table>

The consultation of the state of the art is possible on the Web site of COST 344.

Example of 3 terms for 4 languages:

<table>
<thead>
<tr>
<th>Cat</th>
<th>Deutsch</th>
<th>English</th>
<th>French</th>
<th>Swedish</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 2</td>
<td>gefrierender Regen</td>
<td>freezing Rain</td>
<td>pluie verglaçante</td>
<td>Frysande regn</td>
</tr>
<tr>
<td></td>
<td>Definition</td>
<td>A dangerous condition</td>
<td>Conditions dangeureuses durant</td>
<td>Ett farligt tillstånd då regndroppar med en temperatur över noll grader faller på en yta under 0°C och efterhand fryser till glansis.</td>
</tr>
<tr>
<td></td>
<td>Regen der bei Oberflächenstemperatur</td>
<td>where raindrops fall on to</td>
<td>lesquelles les gouttes d'eau, à une</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unter 0 °C fällt, dabei sofort gefriert und zu</td>
<td>surfaces below 0 °C, thus</td>
<td>température supérieure à 0°C, qui</td>
<td></td>
</tr>
<tr>
<td></td>
<td>großflächigem Glatteis führt</td>
<td>freezing instantly and</td>
<td>tombent sur le sol, gelent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>causing widespread glaze ice.</td>
<td>instantanément et provoquent un</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>verglas généralisé.</td>
<td></td>
</tr>
<tr>
<td>C 2</td>
<td>Schneematsch</td>
<td>Slush</td>
<td>neige fondue</td>
<td>snöslask</td>
</tr>
<tr>
<td></td>
<td>Definition</td>
<td>Snow with a lot of water</td>
<td>Neige au sol à forte teneur en eau</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mit wasser angereicherter schnee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 1</td>
<td>Präventivstreuung, vorbeugende Glättebehandlung</td>
<td>Pre-salting (UK), anti-</td>
<td>Epandage préventif</td>
<td>Förebyggande saltning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>icing (USA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Definition</td>
<td>Salting procedure to prevent</td>
<td>Procédure d’épandage pour prévenir</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>snow and ice formation by</td>
<td>la formation de neige et de verglas en</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lowering the freezing point</td>
<td>diminuant le point de congélation de</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the solution on the road</td>
<td>la solution sur la surface de la</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>surface</td>
<td>route</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
**PRESENTATION OF TG2: DEFINITION OF THE REQUIREMENT**

Task Group 2 are considering safety issues, environmental and information criteria, the management and operations of snow and ice control, and the identification of improvements that would enable delivery of a more cost-effective and efficient service. To achieve this, it is important to set down the components of a winter maintenance management system which, on balance, will produce a quality service. The work of TG2 complements the work carried out in TG3 - 'Best Practice'.

TG2 members have identified the following generic business areas as being of fundamental importance to road administrations:

a. **Service levels** - These relate to the winter maintenance operation itself and include the effectiveness of the treatment in preventing ice and snow adversely affecting the highway. It does not however include safety and traffic movement considerations, which it is argued, are secondary effects and can be influenced by factors other than the quality of the winter maintenance operations.

b. **Environment** - The effect of winter maintenance operations on the natural environment, including flora, fauna and marine life.

c. **Safety** - The safety of the winter maintenance operatives and the road users. Care must be exercised to ensure that the reasons for safety performance are understood since factors other than the quality of winter maintenance may be relevant.

d. **Traffic movement** - Traffic flow during winter conditions, which may again be affected by factors other than effectiveness of the winter maintenance operation.

e. **Cost optimisation** - Analysis of all the factors that contribute to the delivery of a cost-effective winter maintenance service.

f. **Information to the administration** - The provision and management of information about the performance of the operation so that proper accountability can be achieved.

g. **Information to the road users** - The appropriate level of information to road users in various forms both before and during the journeys made.

The factors above have been disaggregated a) to identify more detailed issues requiring analysis and b) to deliver the appropriate quality of winter maintenance service. Items (a), (b), (e), (f) and (g) above are those issues over which the administration has a significant level of control, whereas items (c) and (d) are random occurrences influenced by other factors including driver behaviour.

The type of climate is also a prime factor - this depends on the altitude and geographical location, and is manifest through the frequency, duration and intensity of the winter weather conditions (COST 309, 1992). Conventional classifications can be made ranging from mild to very cold climates. The onset of winter weather triggers the resources needed to re-establish the serviceability of the road. Important characteristics of the road are the road type (high capacity or conventional), carriageway width, layout, gradient, pavement type, frequency and length of bridges and tunnels etc.

For the road users and communities, more effective management of winter operations will lead to a reduction in traffic delays and accidents. For practitioners, implementation of 'Best Practice' should enhance standards and lead to Best Value being achieved. The implementation of Best Value could provide the means to measure the performance of the winter maintenance service within various road administrations.
Presentation of TG3: Best Practice

The main **objective** of this task group is to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states. This work should provide governments with best materials, techniques and procedures. Impact on the environment and value for money shall be regarded. In addition, as a result of the study of management and operational practices employed at national level, the process shall assess the effectiveness of these within the various situations and conditions encountered.

The specification of best practice will encompass all the needs of the European community and will therefore be specific to particular countries and or climate involved in winter activities. The group will consider a wide range of practice. The aim of this group is not to suggest that one solution is better than another, because regional contexts of the states in term of policy and climate (see Figure 2) are very different and so are the required solutions. There will be no single “best practice” over Europe. Nevertheless, it seems probable that “better practices” for certain contexts can be shown.

The first task was to prepare a **list of topics** able to define winter maintenance practices. This subject list contains 4 chapters:

- **Chapter 1** deals with “Fundamental issues” (climatic conditions and standards)
- **Chapter 2** is called “Preparing Winter Maintenance and Organisation” and relates to general decisions (strategic decisions; for one winter period or longer).
- **Chapter 3** provides information about “Operational issues” that relate to the organisation of individual winter maintenance actions (tactical decisions) - “.
- **Chapter 4** is for road users.

A more detailed description of the topics of the different chapters is given in the following page.

Each member of the COST Action was asked to write a **country report** to describe their winter maintenance practices. Because recommended practice or expert knowledge sometimes differ from operational and actual practices, both were considered and each country presented recommended and actual practices. The country reports collected are the first description of winter maintenance practices across Europe and contain a great deal of information. Their final versions will be accessible to the public and available on a CD-ROM.

The compilation of the country's reports is ongoing for each topic in the subject list. It has been very difficult to extract best practices since there are no indicators of the quality of the results. Almost no country has an effective measurement of efficiency so it has not been possible to compare practices on the same basis and with reliable indicators. Thus, this report describes actual practices in Europe, with emphasis on similarities and differences with the corresponding reasons where possible. Since this report is not yet finished, only general comments are presented in this paper.

It seems that there are not many differences in winter serviceability in Europe. The concept of “Classification of the roads according to level of winter serviceability” is widespread. Practices differ more concerning the type of salt used (for example, rock salt or wetted salt) in different climatic zones. Rock salt is mostly employed for maritime climatic regions (humidity is important) and wet salt in drier regions. Some common problems and concerns have emerged with sometimes no satisfying solution (for example, for the treatment of porous asphalt).

When countries have more knowledge on some topics than others, there will be references in the TG3 final report to the corresponding country report. This international exchange of practice is fundamental to win time and money. This “best practice” report is also a base for international winter maintenance needs. It is important to have an international approach since the needs are closely related and independent of borders. One solution found by a country is useful information for other countries.
DESCRIPTION OF COST 344 TG3 SUBJECT LIST

1. Fundamental issues
   1.1 Climatic conditions
   Climatic regions in Europe, corresponding winter events, winter indices ...
   1.2 Standards
   General standards
   Legal obligation to do winter maintenance?
   Classification of the roads according to level of winter serviceability
   Service classes: desired road condition, reaction and service times
   Standards on Man Power
   Standards on equipment and material

2. Preparing Winter Maintenance and Organisation
   2.1 General : codes of practice, overview, how obligatory
   2.2 Information provision
   Meteorological information, Data collection and transmission, Control posts and patrols
   RWIS-Systems, Thermal mapping, Expert systems...
   2.3 Methods
   Preparative programme for winter activity, Procedures,
   Prevention, Route optimisation, Schedules for ploughing and gritting...
   2.4 Equipment
   Operation centres, equipment : vehicles, ploughs, de-icer spraying installations...
   2.5 Materials
   Spreading : recommended average rate of spread for m2, quantity of stored material ...
   2.6 Man power, training and privatisation

3. Operational issues
   3.1 Getting Information
   Warning and detecting of critical situations
   Position of man in the decision process.
   3.2 Methods, equipment and materials for snow control
   Snow removal, Strategies for clearing multilane-carriageways, “white roads”,
   Special regulation for traffic...
   3.3 Methods, equipment and materials for ice control
   Chemical de-icing : type of salt, spread rates, storage...
   Gritting, abrasive, mechanical ice removing
   3.4 Methods, equipment and materials for special problems
   Case of porous asphalt and thin surface pavements, of bridges...
   Avalanches (prevention, warning and removal)
   3.5 Measurements of Efficiency
   Internal : Reports on activities, Forecast verification, Cost of winter maintenance...
   External : Accidents, Travel time, Environment, User satisfaction...

4. Information of Drivers
   Nature of information given (preparatory information, actual information)
   Ways of dissemination
   How much information is useful : before winter, during winter events, in case of a crisis.
CONCLUSIONS

The COST Action should provide valuable outcomes as follows:

- ‘Best Practice’ and emerging developments within and between EU and other COST member states.
- Necessary improvements to RWISs to introduce any latest available features such as residual salt sensors.
- Effective treatments to reduce any harmful effects in the environment.
- Knowledge of the impact of methods designed to maximise traffic flows and reduce accident severity in winter conditions.
- Recommendations for the integration of specified snow and ice control methods into network level road management and maintenance systems.
- Recommendations for further improvement in the dissemination of up to date and reliable information to practitioners and road users.
- Recommendations for improving the level and quality of user input information in snow and ice control decision making.
- Future research that will enable a more efficient and effective winter service to be provided.

BENEFITS

The Action should promote the exploitation of technological advances in the application and distribution of snow and ice control measures leading to significant environmental benefits. With the application of the knowledge gained, millions of EUROs could be saved through lower operational costs and a reduction in adverse effects on highway infrastructure and the environment.

REFERENCES


Risto Kulmala, 2001, Future Research Topics Related to Road Weather, SIWEC proceedings, 11th International Road Weather Conference, Sapporo, Japan.
IMPROVEMENTS TO SNOW AND ICE CONTROL ON EUROPEAN ROADS - MAIN RESULTS

DR. RISTO KUMALA
VTT Building and Transport, P.O.Box 1800, 02044 VTT, Finland
risto.kulmala@vtt.fi
Introduction

The paper describes the main results of the COST 344 action “Improvements to Snow and Ice Control on European Roads and Bridges”. COST is the abbreviation of European Co-operation in the Field of Scientific and Technical Research, which provides a co-operation platform for nationally funded research efforts by covering concertation-related costs (meetings, secretary work, etc.)

According to the COST 344 Memorandum of Understanding (COST 1999), the main objective of the COST 344 action was to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states. In all, 19 countries (Finland, Germany, Spain, Sweden, Switzerland, Poland, United Kingdom, Romania, Hungary, Ireland, Austria, Denmark, Belgium, Iceland, France, Czech Republic, the Netherlands, Slovenia and Norway) have signed the Memorandum of Understanding of the COST 344 action. There are many differences in the methods, systems and practices between these countries, which is not surprising taking into account the varying climatic conditions in Europe.

Most of the work of the COST 344 action was carried out within task groups or task groups concentrating on the key issues related to the domain of COST 344. The task groups were:

1. Information gathering, literature review and glossary
2. Definition of Requirements
3. Best Practice
4. Future Research
5. Route Management Systems
6. Driver Information Systems
7. Final Report

The paper will present the results of the individual task groups.

Information gathering and Glossary

In international information exchange it is important to formalise the language through words but also through the definition of these words and of the concept they cover for each country. This is why COST 344 developed a glossary specific to Winter Maintenance called WINTERTERM. The current version includes ca.180 terms and explanations in 8 languages (Dutch, English, Finnish, French, German, Hungarian, Spanish, and Swedish). See example in Table 1.
### Table 1. Example of 3 terms for 5 languages (Giloppe et al 2002).

<table>
<thead>
<tr>
<th>Cat</th>
<th>German</th>
<th>English</th>
<th>Finnish</th>
<th>French</th>
<th>Swedish</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 2</td>
<td>gefrierender Regen</td>
<td>freezing Rain</td>
<td>jäätävä sade</td>
<td>pluie verglaçante</td>
<td>frysande regn</td>
</tr>
<tr>
<td></td>
<td>Regen der bei Oberflächen-temperaturen unter 0 °C fällt, dabei sofort gefriert und zu großflächigem Glatteis führt.</td>
<td>A dangerous condition where raindrops fall on to surfaces below 0 °C, thus freezing instantly and causing widespread glaze ice.</td>
<td>Vaarallinen tilanne, jossa sadepisaroi-ta sataa pinnoil, joiden lämpötila on alle 0°C. Tällöin vesi jäätyy välittömästi ja muodostaa mustaa jäättä.</td>
<td>Conditions dangereuses durant lesquelles les gouttes d'eau, à une température supérieure à 0°C, qui tombent sur le sol, gélent instantanément et provoquent un verglas généralisé.</td>
<td>Ett farligt tillstånd då regndroppar med en temperatur över noll grader faller på en yta under 0°C och efterhand fryser till glansis.</td>
</tr>
<tr>
<td>C 2</td>
<td>Schneematsch</td>
<td>slush</td>
<td>sohjo; loska</td>
<td>neige fondue</td>
<td>snöslask</td>
</tr>
<tr>
<td></td>
<td>Mit Wasser angereicherter Schnee</td>
<td>Snow with a lot of water</td>
<td>Lumi, jonka seassa on paljon vettä</td>
<td>Neige au sol à forte teneur en eau</td>
<td>Snö med hög vattenhalt</td>
</tr>
<tr>
<td>D 1</td>
<td>Präventivstreuung, vorbeugende Glattebehandlung</td>
<td>Pre-salting (UK), anti-icing (USA)</td>
<td>Ennakkosuolaus, jäätymistä ehkä-sevä suolaus</td>
<td>Epandage préventif</td>
<td>Förebyggande saltning</td>
</tr>
<tr>
<td></td>
<td>Streuen von Auftausalzen vor zu erwartender Eisglätte oder beim einsetzenden Schneefall, um Eisbildungen oder das Anfrieren von Schnee auf Verkehrsflächen zu verhindern</td>
<td>Salting procedure to prevent snow and ice formation by lowering the freezing point of the solution on the road surface.</td>
<td>Sulolaus, joka ehkäisee lumi-pelt-teen ja jään muodostumista alentamalla tien pinnalla olevan kostauden jäätymispiestä.</td>
<td>Procédure d’épandage pour prévenir la formation de neige et de verglas en diminuant le point de congélation de la solution sur la surface de la route</td>
<td>Saltning för att förbygga att snö och is bildas genom att sänka fryspunkten i lösningen på vägen</td>
</tr>
</tbody>
</table>

The terms are sorted in 8 categories: Weather/Climate, Ice, Snow, Spreading, Snow clearance, Ice and Snow Protection, Management of Winter Maintenance and Others. The database is freely available on [http://www.durth-roos.de/sb/dsbio001.htm](http://www.durth-roos.de/sb/dsbio001.htm) and provided in Microsoft Access 97 and Access 2000 format. There is the possibility to add new terms and new languages to the glossary. Registered users are informed about new releases of WINTERTERM by e-mail and this dictionary will be available on the Cost 344 and on the PIARC Web site.

Each of the COST 344 countries was asked to make a national literature review of the most important national documents with an English translation of the title and a brief abstract in English. In total, 707 documents were compiled and sorted. This state of the art report and material are available via the COST 344 Internet site. (Giloppe et al 2002).

### Definition of requirements

COST 344 considered safety issues, environmental and information criteria, the management and operations of snow and ice control, and the identification of improvements that would enable delivery of a more cost-effective and efficient service. COST 344 found it important to set down the components of a winter maintenance management system, which will produce a quality service.
The following areas were identified as fundamentally important to road administrations:

- Service levels
- Environment
- Safety
- Traffic movement
- Cost optimisation.
- Information to the administration
- Information to the road users

Items (a), (b), (e), (f) and (g) above are those issues over which the administration has a significant level of control, whereas items (c) and (d) are influenced by a number of other factors as well including driver behaviour.

The type of climate is also a prime factor - this depends on the altitude and geographical location, and is manifest through the frequency, duration and intensity of the winter weather conditions (COST 309, 1992). Conventional classifications can be made ranging from mild to very cold climates. The onset of winter weather triggers the resources needed to re-establish the serviceability of the road. Important characteristics of the road are the road type (high capacity or conventional), carriageway width, layout, gradient, pavement type, frequency and length of bridges and tunnels etc.

For the road users and communities, more effective management of winter operations will lead to a reduction in traffic delays and accidents. For practitioners, implementation of ‘Best Practice’ should enhance standards and lead to Best Value being achieved. The implementation of Best Value could provide the means to measure the performance of the winter maintenance service within various road administrations. (Giloppe et al 2002)

Best Practice

COST 344 wanted to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states. For this purpose, winter maintenance practice framework was defined as a list of issues. This list contains the following sections:

1. Fundamental issues (climatic conditions and standards)
2. Preparing Winter Maintenance and Organisation (strategic decisions; for one winter period or longer).
3. Operational issues (related to tactical decisions)
4. Road users.

Each COST 344 country produced a country report describing their winter maintenance practices. Because recommended practice or expert knowledge sometimes differ from operational and actual practices, both were considered and each country presented recommended and actual practices. The country reports collected form the first collected description of winter maintenance practices across Europe and contain a great deal of information. Their final versions will be accessible to the public and available on the COST 344 CD-ROM.

The specification of best practise has suffered from the lack of indicators of quality in the country reports. Almost no country has an effective measurement of efficiency so it has not been possible to compare practices on the same basis and with reliable indicators. Nevertheless, some observations have already been made. It seems that there are not many differences in winter serviceability in Europe. The concept of “Classification of the roads according to level of winter serviceability” is widespread. Practices differ concerning the type of salt used (for example, rock salt or wetted salt) in different climatic zones. Rock salt is mostly employed for maritime climatic regions (humidity is important) and wet salt in drier regions. Some common problems and concerns have emerged with sometimes no satisfying solution (for example, for the treatment of porous asphalt).
When countries have more knowledge on some topics than others do, there will be references in the final report to the corresponding country report. This international exchange of practice is useful in order to save resources.

Future research

The topics for future research were collected via an e-mail survey sent to the COST Action 344 Management Committee and other international experts. About 90 respondents from 16 different countries sent proposals for research topics. The Task Group analysed the list of 200 different topics received, and produced a final topic list by merging a list of 93 research topics for prioritisation.

This topic list was used as a basis for an Internet survey, where experts from different countries and representing different organisation types (road administration, industry, research or academia) were asked to prioritise the research topics. In all, 57 experts from 17 different countries filled in the survey.

A number of topics were regarded as very important or important. The Task Group identified the most important research topics out of the important ones on the basis of analyses of the survey results. The analyses included weighted means of priority scores, histograms, and comparison to current research and finally, combined expert judgement of the Task Group members. The Task Group also produced tentative research task descriptions for these topics. The six most important future short-term research topics are:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
5. More cost-effective, efficient and environmentally friendly friction improvement products.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.

The topics identified should also be used as input when developing the contents of future European and national R&D Programmes, e.g. the 6th Framework Programme or a possible COST action as a follow-up to COST Action 344. The Task Group also identified a number of long-term research topics in the domain. (Kulmala 2001)

Route Management Systems

The work on route management systems produced an overview about Winter Maintenance Management Systems (WMMS, see Figure 1), their use in Europe and different aspects of their use. During the processing it became clear, that at present views and experiences about other aspects of the operation of WMMS are seldom published except those about financial aspects. So no further statements can be given in relation to Quality Aspects, Legal Aspects and Social Aspects. COST 344 also gave an overview about the links and interfaces to other Management Systems, recommendations about implementation of WMMS, and recommendations about the integration of WMMS in an Integrated Road Management System. The work on route management systems dealt only with computer-based WMMS. (Holldorb et al 2001).
The different processes of the WMMS were described and discussed in detail with regard to their status and development in the COST 344 countries, and a common model for the WMMS was produced. New methods for WMMS were proposed through the use of the latest management, communication and positioning technologies such as e.g. 2.5G, 3G, GPS or Galileo. (Holldorb et al 2001)

Driver Information Systems

COST 344 wanted also to study the use of transport telematics in order to improve the safety and efficiency of wintertime transport.

The study identified the driver information and traffic management systems used in a number of countries: Belgium, Finland, Germany, Iceland, and the United Kingdom. The information collected was used to

- classify the road users and their needs
- identify the driver information systems used
- identify the traffic management system used
identify the information management systems used
identify the organisational setups used
compile available information of the benefits and costs of the systems

The work on driver information systems is still ongoing.

Final report and exploitation of results

The COST 344 will produce its final report by the end of April 2002 for approval of the member countries and the European Commission. The final report contains a summary of the achievements of the various task groups as well as overall conclusions and recommendations of the COST 344 action. A CD-ROM will be enclosed to the final report including all reports and other results of the action.

A specific seminar to disseminate the results of COST 344 will be arranged in the summer of 2002.

The experts involved in COST 344 have drafted a proposal for the continuation of the COST 344 aiming for integrated strategies for winter maintenance and traffic management in order to increase the safety of winter traffic on European roads.

References


FUTURE RESEARCH TOPICS

RELATED TO ROAD WEATHER

Dr. Risto Kulmala
VTT Building and Transport,
P.O. Box 1800, FIN-02044 VTT, Finland
risto.kulmala@vtt.fi
Introduction

The paper describes the results of Task Group 4 “Future research” of the COST 344 action “Improvements to Snow and Ice Control on European Roads and Bridges”. COST is abbreviation of European Co-operation in the Field of Scientific and Technical Research, which provides a co-operation platform for nationally funded research efforts by covering concertation-related costs (meetings, secretary work, etc.)

According to the COST 344 Memorandum of Understanding (COST 1999), the main objective of the COST344 action was to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states. In all, 19 countries (Finland, Germany, Spain, Sweden, Switzerland, Poland, United Kingdom, Romania, Hungary, Ireland, Austria, Denmark, Belgium, Iceland, France, Czech Republic, the Netherlands, Slovenia and Norway) have signed the Memorandum of Understanding of the COST 344 action.

Most of the work of the COST 344 action was carried out within task groups or task groups concentrating on the key issues related to the domain of COST 344. The task groups were:
1. Information gathering, literature review and glossary
2. Definition of Requirements
3. Best Practice
4. Future Research
5. Route Management Systems
6. Driver Information Systems
7. Final Report

The objectives of the task group on future research were:
- to identify short-, medium- and long term research issues and topics related to road traffic and infrastructure in the wintertime, and
- to identify those topics with optimum expected benefits

Method

Figure 1 presents a schematic description of the method. A detailed description of the method is given later in the chapter.

![Diagram of the method](image.png)

Figure 1. The description of the working procedure used by the study.
Identification of research topics

Firstly, the task group agreed a tentative classification to be used in the identification of issues and topics for future research. The classification was to be sent along with a letter to experts asking them to identify up to five important research topics (in a priority order, if possible) that should be addressed in the national and European R&D programmes in the near future. The letter was sent to all TG4 and Management Committee members, who were asked to send it (possibly after translation) to road authorities, researchers and meteorological offices in their country, and collect the replies. The replies were to contain contact information at least in terms of e-mail addresses. The letter was also sent to industry via the TG4 contacts. More than 90 persons replied to this letter after two reminders had been sent. In all, more than 200 topics were proposed as future research topics. After merging by TG4, the list of topics included less than 100 topics.

Some of the respondents did not specify a detailed topic, but instead prioritised the research areas in the classification enclosed in the letter. After classifying the topics accordingly, the research area prioritisation by the survey respondents was established (Table 1).

<table>
<thead>
<tr>
<th>Topic/Research area</th>
<th>Priority of topic/research area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1. Weather and climate</td>
<td></td>
</tr>
<tr>
<td>1.1 Monitoring and data exchange</td>
<td>11</td>
</tr>
<tr>
<td>1.2 Modelling and forecasting</td>
<td>21</td>
</tr>
<tr>
<td>1.3 Effects on traffic (safety, efficiency, ...)</td>
<td>2</td>
</tr>
<tr>
<td>1.4 Implications to infrastructure design</td>
<td>4</td>
</tr>
<tr>
<td>2. Winter maintenance</td>
<td></td>
</tr>
<tr>
<td>2.1 Maintenance management</td>
<td>8</td>
</tr>
<tr>
<td>2.2 Operational practice</td>
<td>2</td>
</tr>
<tr>
<td>2.3 Maintenance equipment</td>
<td>5</td>
</tr>
<tr>
<td>2.4 De-icing products</td>
<td>7</td>
</tr>
<tr>
<td>2.5 Effects on traffic</td>
<td>1</td>
</tr>
<tr>
<td>2.6 Costs and benefits of maintenance</td>
<td>2</td>
</tr>
<tr>
<td>3. Road users</td>
<td></td>
</tr>
<tr>
<td>3.1 Vehicle control and tyres</td>
<td>1</td>
</tr>
<tr>
<td>3.2 Driver information</td>
<td>4</td>
</tr>
<tr>
<td>3.3 Traffic management and control</td>
<td>1</td>
</tr>
<tr>
<td>3.4 User acceptance and requirements</td>
<td>3</td>
</tr>
<tr>
<td>3.5 Education</td>
<td>1</td>
</tr>
<tr>
<td>4. Strategic research</td>
<td></td>
</tr>
<tr>
<td>4.1 Policies and strategies</td>
<td>5</td>
</tr>
<tr>
<td>4.2 Harmonisation of quality levels</td>
<td>1</td>
</tr>
<tr>
<td>4.3 Relations to other domains</td>
<td>1</td>
</tr>
<tr>
<td>4.4 Emerging new technologies</td>
<td>3</td>
</tr>
<tr>
<td>5. Other</td>
<td></td>
</tr>
<tr>
<td>5. Other</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Priorities of the research areas as indicated in the survey on identifying future research topics.
The most frequently mentioned research areas were modelling and forecasting, de-icing products, maintenance management, monitoring and data exchange, and driver information. These research areas were also most frequently mentioned as the ones with the highest priority. There was a bias in the replies as very many replies have been received from the same organisation in the same country. This was not a problem as this phase was primarily to identify as many relevant research topics as possible.

**Internet survey for prioritisation of topics**

After the merging had been completed, the topics were prioritised. The task group decided to employ an Internet survey to accomplish this.

The Internet survey was set up on the web site of VTT (Technical Research Centre of Finland), and its address was sent to the persons who had contributed to the first round of topic identification with some exceptions. Firstly, only five respondents were selected from those countries with more than five authority, research or academic respondents responding to the original survey. Secondly, the Internet address was sent to experts known to the task group members, who had not participated in the first round, in the countries with less than five respondents. All industry respondents were retained in the list.

The Internet survey respondents were asked to classify each topic in the four priority categories:

1. very important - should be studied as soon as possible;
2. important - should be studied within five years;
3. quite important - should be studied in the future; and
4. not important.

In addition, a fifth category was provided:

5. no priority given (in case you do not feel competent or willing to judge it).

All forms had the fifth category ticked as a default value, enabling the respondents to only classify the topics that they wanted to prioritise. This made the filling of the survey form easier. Subsequent comments from the respondents also confirmed that this had been a well-accepted solution.

After two reminders, 57 respondents had completed the survey at the end of March 2001, when the survey was finally closed. Out of these respondents, one third belonged to the COST 344 Management Committee. Most of the respondents were road administration representatives (31). Nine (9) were from industry, fourteen (14) from research institutes and three (3) from the academia. The final respondents came from 17 different countries.

**Future research topics**

*Topics proposed by international experts*

As a result of the first e-mail survey, the task group received about 200 distinctive research topics. Some of the topics were very similar, and after analysis the task group combined some of the topics. In all, after the analysis by the task group, the list included 93 topics. These topics were then used as the list of topics in the Internet survey.
**Topics of highest priority**

According to the Internet survey to prioritise the research topics, the research areas of:

- monitoring and data exchange,
- modelling and forecasting,
- effects of weather on traffic,
- maintenance management, operational practice,
- de-icing products,
- effects of winter maintenance on traffic,
- driver information as well as traffic management and control were considered important. This means that these areas contained topics, where the mean priority was at least 2 (1 = very important, 2 = important, 3 = quite important and 4 = not important) in two of the three organisation groups.

The most important topics (means less than 1.7) by the various groups were:

**Roads Administrations**
- Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures.
- Level of services on winter roads.
- Effects of different winter road maintenance quality levels on traffic accidents and traffic flow.

**Industry**
- Integration of road and meteorological data and real-time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations).
- Development of real-time information systems via different media (VMS, radio, cellular phone,) to affect driver behaviour (especially speed choice) in low friction conditions, based on user requirements.
- Preventive use of anti-icing materials.

**Research/Academia**
- Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures.
- Development of improved methods (contactless, remote, etc.) for road surface condition measurement (e.g. friction, freezing temperature, water film thickness).
- Integration of road and meteorological data and real-time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations).
- Effects of different winter road maintenance quality levels on traffic accidents and traffic flow.
- Development of in-vehicle road surface condition detection system, and its communication to road and maintenance operators.
- Effects of the weather and road conditions on traffic and driver behaviour
- Impacts of ice warning systems on road safety.

There are clear differences between the priorities assessed by the various organisations, but there are also similarities. The low priorities given to topics relating to strategic research (area 4) were, nevertheless, quite unexpected. The task group analysed the responses, and decided to recommend six priority topics for future research in the short term. These six topics were chosen so as to cover the most important topics as revealed by the Internet survey. The most important and urgent future research topics were:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.

A detailed task description of these topics is presented in the task group report (Kulmala 2001). A separate analysis was undertaken to identify the future research topics in the long term. For this purpose, topics with many responses of "3. quite important - should be studied in the future" were selected if not many considered the topic unimportant or if the topic was already among the short-term priorities. There were again large differences between the various organisations. The most important long-term research topics were for the various organisation groups:

**Road Administrations**
- Identification of the maintenance equipment long-term strategy in terms of each department operational organisation and co-operation between different organisations.
- Effects and benefits of unrestricted and free weather data delivery policy to winter road maintenance in Europe.
- Impacts on congestion avoidance on the Trans-European Road Network by preventive de-icing.
- Environmental impact of winter maintenance: impact on ecosystems (hydrological, fauna, flora - roadside and landscape as a whole - what is the actual extent of impact from salt urea etc).
- Comparison of specialised and multipurpose maintenance vehicles.
- Development of international co-operation in winter maintenance in different levels of integration, based on a continuous level of service and the improvement of operational winter maintenance in border regions.
- Improvement of weather and road surface prediction and observation for local areas.

**Industry**
- Development of modelling and forecasting for the management of rest time for maintenance personnel.
- Development of road weather oriented advanced driver support and vehicle control systems.
- The study of institutional, legal and social issues related to co-ordinated winter road maintenance and driver information services.

**Research/Academia**
- Behaviour of tyre friction in changing winter conditions as a function of amount and type of ice as well as the used de-icer compound.
- Feasibility of using aerial thermal imagery.
- Alternative methods for snow and ice control on porous asphalt.
- The effect of possible climate change in planning long-time strategies for road maintenance (methods and equipment).
- Comparison of de-icing methods and products for specific road surfaces.

The long-term priorities include also topics in strategic research such as the identification of maintenance equipment long-term strategies, effects of unrestricted and free weather data delivery policies, effect of possible climate change in winter maintenance, and feasibility of aerial thermal imagery.

**Assessment and recommendations**

There are three main categories of research: 1) innovative and fundamental research, 2) implementation-related research with the operational point of view, and 3) strategic research. The task group on future research approached the problem of identifying the most important research topics by asking experts from road administrations, industry, research organisations and academic institutes for their opinions. The topics obtained in the surveys represent all three categories of research. When prioritising the most urgent research topics, however, the topics of highest priority concentrated on implementation-related research with the operational point of view, and to a smaller extent on innovative and fundamental research.
In all, six priority short-term research areas were identified:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.

These research areas include the most essential elements among the often very detailed research topics regarded as very important or important by the survey respondents.

All of the six priority short-term research areas have an international, global dimension. All of the research areas require field studies and pilot experiments or demonstrations. These should be undertaken at the national level.

In addition to the short-term research areas, a number of long-term research topics were identified. The long-term priorities include also topics in strategic research such as:

• identification of maintenance equipment long-term strategies,
• effects of unrestricted and free weather data delivery policies,
• effect of possible climate change in winter maintenance, and
• feasibility of aerial thermal imagery.

The long-term topics also included:

• innovative fundamental R&D such as development of road weather oriented advanced driver support and vehicle control systems,
• behaviour of tyre friction in changing winter and de-icing conditions, and
• methods for snow and ice control on porous asphalt.

The research topics, and especially the results of research on these short- and long-term topics, can be exploited in winter maintenance management as well as in the actual snow and ice control operations. The industry can utilise the results for provision of improved tools and products. The results can also be utilised in the development and operation of the eventual future road management system, which will integrate all management functions of the road operator e.g. winter management, traffic management and information services.

The research topics identified in this COST Action and additional study ideas are needed to solve issues relating to the interaction between client and contractor, quality assurance, the use of modern technology, and specifications and performance standards to describe and measure the target condition(s).

The COST Action was a useful platform for identifying the most important topics for short- and long-term research. COST 344 is one of the few actions involving so many countries in the domain of winter maintenance and road weather. Hence it provided a good network for contacting the relevant experts in Europe, and through them, experts elsewhere.

Due to the good experiences with the COST 344 action, the task group proposes a new COST action to continue research on the domain and to build on the achievements of COST 344. A COST action is also suited well to these topics as most of them require active efforts and demonstrations/pilot implementations on the national level and co-ordination and integration between the national inputs.

A future COST action should take on board most of the short-term priority topics identified. Some of the research topics will also fit well in to the 6th R&D Framework Programme of the EU, especially the fundamental and strategic research tasks.
References


Acknowledgements

The paper was produced on the basis of the work of the Task Group 4 of COST 344 and is based on the final report of the Task Group. Gudrun Öberg, Yrjö Pilli-Sihvola, Marilyn Burtwell, Andreas Bark and Jon Berg contributed actively to the production of the final report of the Task Group.
INTRODUCTION AND OBJECTIVES

GUDRUN ÖBERG
Swedish National Road and Transport Research Institute (VTI)
58195 Linköping, Sweden
gudrun.oberg@vti.se
2.1 Background

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. However, it is important that the winter maintenance service is provided at an affordable price and that Best Value is achieved with minimum environmental impact and traffic disruption and with high standards of safety. Information on Best Practice is therefore essential to ensure widespread implementation of appropriate standards of service.

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.

COST Action 344: Improvements to snow and ice control on European roads and bridges, started in April 1999 (see end chapter 2) and is funded by the European COST (Co-operation in the field of Scientific and Technical Research) program (EU, 1999). With the start of this project, winter maintenance research now has a higher profile in Europe. COST Action 344 is a three-year project with participation from eighteen European countries.

COST is seen as the most appropriate mechanism for dealing with this subject because it is fundamental to have input from, and agreement between, experts representing governments, in order to maximise the benefits in this area. It will also be beneficial to involve those COST countries which are not yet a part of the European Union.

In terms of the network of experts to be established, each has been involved in this area of research for many years, and there are significant contacts between those mentioned at European level. This has ensured strong support at the research organisation level in the member states.

The following states have signed Memorandum of Understanding:

- Austria
- Belgium
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Hungary
- Iceland
- Ireland
- The Netherlands
- Norway
- Poland
- Romania
- Slovenia
- Spain
- Sweden
- Switzerland
- United Kingdom

National Road Administrations and/or research institutes and Universities have been members of the COST 344 Management Committee.
2.2 Objectives of the research

The main aim of the COST project is to improve the performance of snow and ice control methods and operations by defining the requirements for best practice in different climate domains, across the EU and other COST member states. This will provide national highway authorities with the best materials, techniques and procedures to meet the changing demands of the European road infrastructure and, at the same time, harmonise safety and environmental standards. It will thus provide guidance to decision makers, aimed at ensuring that improved snow and ice control methods are based on best practice.

A significant contribution will be provided to meet the stated goals of the Transport European Road Network (TERN) as below:

- Sustainable mobility of persons and goods within the EU under the best possible social and safety conditions (Article 2.2a).
- Integration of environmental concerns into the design and development of the network (Article 5d).
- Promotion of network interconnection and inter-operability between the EU and the third world countries (Article 6).

Assessments of operational practices, employed at national level, are also expected to result in objective criteria and benchmarks being developed for the various aspects and impacts of snow and ice control.

2.3 Benefits

Economic activity in all COST countries relies heavily on road transport for both passenger and freight traffic, and it is essential that the costs of this transport are kept to a minimum in order to preserve and enhance the competitive position of Europe. Snow and Ice control on the highway network brings benefits to European economic activity by reducing delays, minimising accidents, and preserving considerable financial investments by member states.

Winter conditions affect all member states, often for 5 or 6 months per year, and even those states in southern Europe can suffer from such conditions in localised areas. The cost of disruption and injuries through road accidents is substantial, so that measures to further improve winter maintenance arrangements are likely to produce significant benefits in terms of safety of road users.

Benefits results from the work through the exploitation of technological advances in application and distribution of snow and ice control measures, and that these improvements leads to significant environmental benefits.
2.4. Economic dimension

The number of experts and auxiliary staff in the member states (research institutes, government departments, universities and other academic organisations) working in areas related to COST 344 varied a lot from country to country. The total of these national levels estimate indicate the cost of associated work to be around EURO 19 million over the three year term of the Action.

The amount of direct effort to be put in by the members of the Management Committee and task groups estimates to EURO 1,2 million per annum.

2.5. Work programme

The aims of the research project are:

a. To review existing international practices, involving the following elements:
   • terminology review and creation of a European glossary;
   • literature review covering the years 1990 to 2000 to establish the state-of-the-art practice and research in snow and ice control methodologies;
   • review of current research and development work completed or underway, in both the public and private sectors;
   • review of current practices by evaluating selected case studies in targeted EU regions; and
   • Creation of an inventory database of snow and ice control equipment methods, equipment and materials products.

b. to define snow and ice control requirements in different European regions;

c. to determine best practice in different European regions;

d. to develop guidelines for the integration of specified snow and ice control methods into network level road management and maintenance systems;

e. to make recommendations for improvements to driver information systems and traffic management systems;

and

f. To make recommendations for future winter maintenance research, which has potential benefits for practitioners and road users.

Particular areas where further investigation and development of materials and techniques have been proposed are:

• the most effective and least environmentally harmful de-icing/anti-icing materials and the most effective treatments in the various climatic domains encountered across COST member states;

• implications resulting from the introduction of innovative road surfacings to establish benchmarks for safe and effective winter maintenance;

• innovative Road Weather Information Systems (RWISs), which would benefit from a review of accuracy, reliability and the introduction of developing capabilities such as residual salt sensors; and

• Road icing information and prognosis systems.
Operational procedures also being investigated are:

- driver information systems using existing methods and innovative developments employing advanced telematics; and
- The impact of methods designed to maximise traffic flows and reduce accident severity in winter conditions.

Many of these research elements have drawn on the experience and knowledge of participating member states together with innovative and advanced techniques through detailed assessments and a review of current and ongoing research.

### 2.6. Task Groups

Six Task Groups, TG1 to TG6 with nominated leaders, have been phased throughout the three-year life of the Action. The seventh group, TG7, started in year 3 of the project. These Groups involve the most appropriate blend of technical expertise for the above tasks from a broad geographical distribution to ensure an extensive input and high quality outputs. The Groups are set up as:

- TG1 – Information gathering, literature review and glossary
- TG2 – Definition of requirements
- TG3 – Best practice
- TG4 – Future research
- TG5 – Road management system
- TG6 – Driver information systems
- TG7 – Final report

They have each submitted at least one technical deliverable and these will form a major part of this final report of the Action.

The common interests and general objectives are shared by the member states and the planned work is drawing upon most of the relevant work currently in progress and planned within all COST countries together with the results of work undertaken previously.
Information Gathering

Task Group 1

Gudrun Öberg
Swedish National Road and Transport Research Institute (VTI)
58195 Linköping, Sweden
gudrun.oberg@vti.se

Dr. Christian Holldorb
Dorth Roos Consulting GmbH
Niederlassung Karlsruhe
Gartenstrasse 26, D-76133 Karlsruhe
christian.holldorb@durth-roos.de
3.1 Glossary

3.1.1 Objective

One of the difficulties encountered during the international exchanges held within a European or international framework often concerns language and comprehension between partners.

On the level of the language because the majority of the members doesn’t speak in their mother language and use international English who if it is about comprehensible by all does not comprise of it less one certain number of inaccuracies.

On the level of comprehension because the concept corresponding to a particular term is not necessarily the same in all the countries.

In addition the terms concerned, which are in a technical field particular good, are already in each mother language used by the specialists and loans sometimes of a specific connotation to this field.

The first stone at the building of international exchanges is thus well a formalization of the language through words but also through the definition of these words and of the concept they cover for each country.

Therefore the objective is double, to provide a literal translation of the terms used but also to specify the right concept which is assigned to this term in each country.

Indeed words in different languages but with the same orthography can sometimes have different signification.

What we sought to do is not indeed a translation from an initial language but rather to provide for each term the explanation most usually allowed by the specialists in each country.

That could lead sometimes to the situation that a single word covers concepts so much different that there is not possible translation due to non-existence of a concept.

Certain languages are particularly well adapted to the restitution of sophisticated technical concepts, German lends itself in particular very well to the composition of very precise words (ex: materials), it would then have been necessary to give a translation by restoring a sentence in the other languages what we did not do.

It is thus in a spirit of a language stabilization and mutual comprehension that the working group decided to undertake the realization of a glossary specific to the terms of Winter Maintenance.

The document proposed must not be considered as a result but as a first approach that as the time goes will have to evolve on the level of the quality of the definitions, the level of the number and choice of the definitions and of course on the level of the number of languages which appear in it.

The approach suggested thus allows:

- To integrate easily new terms (software access)
- To add new languages
- To create glossary on other technical fields
- To inform the users of the last modifications through Internet site
3.1.2 Method

Five countries initially attempted to develop this glossary: Germany, United Kingdom, Belgium, Sweden and France. Various sources were used, a first project developed within the framework of the committee C17 of the PIARC (French English glossary resulting to some extent of the dictionary from French road maintenance) as well as a glossary already existing in German/English.

On the basis of these two tools the work of the group consisted in structuring the vocabulary of winter maintenance in various sets of themes and in a form where it is easy to insert words again.

The terms were classified in 8 categories referring to the principal sets of themes of Winter Maintenance:

- Weather / climate
- Ice
- Snow
- Spreading
- Snow clearance
- Ice and snow protection
- Management of Winter Maintenance
- Others

Each of these topics was codified A, B, C, D, E, F, G, H, then subdivided in under-topics A1, A2... B1, B2.... with a reference for each term being the subject of a translation A11, A12... B11, B12... in order to be able thereafter to integrate new words.

The words, which appeared as being most significant, were then selected and the group attempted to analyse the concepts expressed by these words and to choose the definition, which appeared most adequate in each language.

From this first project came to be grafted new language: Spanish, Dutch, Finnish, and Hungarian, Danish, Italian and Icelandic. The last phase consisted in including photographs or illustration for the definitions that lent themselves to it.

3.1.3 Results

The glossary (called WINTERTERM) will be available in Version 1.4 in eleven languages and contains approximately 170 words and definitions distributed in the eight principal topics.

- German
- English
- Spanish
- Finnish
- French
- Hungarian
- Dutch
- Swedish
- Italian (in preparation)
- Danish
- Icelandic

Several approaches were first of all developed: the first work under a format word.doc and rtf then under Excel and finally a last version, which was the subject of a working in Access. In this version for nearly 50 terms illustrations are included to explain the term.
Thanks to the realization of a specific Query window this last version allows various types of interrogation starting from word or expressions containing a key word.

Use of Access software provides in addition an evolutionary tool through the following options:
- The possibility to integrate easily new terms (software access)
- The possibility to add an illustration to explain the term
- The possibility to add new languages
- The possibility to create glossary in other technical fields
- The possibility to inform the users of the last modifications through Internet site

Example of screens of the glossary under Access:

Various languages
Translation of a term
Translation in all languages
Search by letter, words or keyword
Bilingual dictionary by alphabetic order
Bilingual dictionary by item
3.1.4 Maintenance, evolution

As COST group has a limited lifespan and because a first project had been developed within the framework of the committee C17 of the PIARC, it appeared natural that this committee could be in charge the management of this tool again.

This proposal was formulated to the committee C17 who considers that the maintenance of the glossary belongs to the future missions significant to carry out.

The future thus appears assured. However it will be necessary to define the practical methods of future management of the current data and the terms of dissemination.

3.1.5 Dissemination

Currently the glossary is available (free) on the homepage of Durth Roos Consulting GmbH, (www.durth-roos.de) it is possible to download the files under a pdf format and with the request under Access format.

The objective is to create a link between COST 344 and PIARC sites with the site of Durth Roos Consulting GmbH.

3.2 State of the art

3.2.1 Objectives

Beyond a common language the richness of the exchanges also requires to know which studies were carried out in the different countries as regards to Winter Maintenance.

One of the means is to complete a state of the art review through bibliographical collection of the various publications proposed by the countries.

This state of the art becomes a common core of knowledge to which everybody can refer either by requiring the publication near the author or by contacting it directly to supplement information.

It is obvious that the data gathering cannot be exhaustive; indeed each country necessarily does not have an organization that centralizes the whole of the publications. However this approach makes it possible to determine the topics treated preferentially by each country and to have a first bases particularly interesting.

3.2.2 Method

The method consisted in inquire into the various countries taking part in the COST 344 to recover a list of the publications as well as a short summary in most of the time in English language.
3.2.3 Result

Eighteen countries took an active part in this collection

- Austria
- Belgium
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Hungary
- Iceland
- Ireland
- Norway
- The Netherlands
- Romania
- Slovenia
- Spain
- Sweden
- Switzerland
- United Kingdom

In the first version in the end of year 2000 96 pages of state of the art were published with 560 listed and classified documents.

A classification of this state of the art was established:

- By topic
- By country
- By author

With the reference of each document as well as a summary.

Example resulting from the document state of the art

<table>
<thead>
<tr>
<th>Country</th>
<th>References</th>
</tr>
</thead>
</table>

This instruction contains the quality requirements of the winter road maintenance and the specifications needed to describe acceptable quality. The instruction contains the quality requirements of the roadway, of the other parts of the road and of pedestrian and bicycle routes.
Initially an appendix was created in order to facilitate research of the reader.

This appendix reveals a classification by topics (up to two topics/report).

Example resulting from the appendix

1 Weather and climate

- **Austria**
  FELKEL H., STOCKINGER J.
  Report 460, Federal Ministry of Economy, Research of Roads.

  POPPER A., BISCHOF F., KOCH E., LANGER H., SPET G.

- **Belgium**
  LEDENT T.
  METEOROUTES: Le projet wallon de gestion des informations météorologiques pour un meilleur service à l’usager. The Walloon project of meteorological data management for a better service to the users.

- **Denmark**
  SAND KIRK J., KNUDSEN F.

In the second time, updating in spring 2002, in the end of this COST Action the whole of the data was gathered in an Access database. This step allows keyword queries and thus largely facilitates the reading of this document. Included in the database is 881 documents. The topics from the first version are still in use and the number of documents in each topic is shown below:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather and climate</td>
<td>122</td>
</tr>
<tr>
<td>Equipment</td>
<td>173</td>
</tr>
<tr>
<td>Effects</td>
<td>184</td>
</tr>
<tr>
<td>Management</td>
<td>164</td>
</tr>
<tr>
<td>De-icing products</td>
<td>134</td>
</tr>
<tr>
<td>Equipment for the road user</td>
<td>21</td>
</tr>
<tr>
<td>Risk management</td>
<td>46</td>
</tr>
<tr>
<td>Strategy</td>
<td>72</td>
</tr>
<tr>
<td>Design and construction of the road</td>
<td>68</td>
</tr>
<tr>
<td>Cost of winter maintenance</td>
<td>28</td>
</tr>
<tr>
<td>Road user information</td>
<td>25</td>
</tr>
<tr>
<td>Overview</td>
<td>44</td>
</tr>
<tr>
<td>Others</td>
<td>12</td>
</tr>
</tbody>
</table>

In each of the following headings is it possible to search:
Country, Author(s), Title, Document, Language(s), Abstract/Summary/Keywords, Topics.

On the next page is an example from the State-of-the-Art database and of the database screen.
<table>
<thead>
<tr>
<th>Country</th>
<th>Author(s)</th>
<th>Title</th>
<th>Document</th>
<th>Language(s)</th>
<th>Abstract/Summary/Keywords</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>BYLES, R</td>
<td>Salt Economies.</td>
<td>New Civil Engineer, 1988/08/18. (803) pp24-5. Pub: Thomas Telford Ltd, Thomas Telford House, 1 Heron Quay, London, E14 9XF, United Kingdom.</td>
<td>English</td>
<td>This article describes a very simple and inexpensive system for spreading pre-wetted salt on icy roads, which has been developed by transport engineering, a small specialist winter road maintenance equipment manufacturer in Accrington.</td>
<td>5;10</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>BURTWELL M H AND D J</td>
<td>Winter Maintenance Of Modern Surfacings: A Literature Review And De-Icing Product Study.</td>
<td>UK Highways Agency: TRL Report PR/CE/11/98 (unpublished), Project Record No. N615, Report No. 1, 1998. Transport Research Laboratory, Old Wokingham Road, Crowthorne, Berks RG45 6AU, England.</td>
<td>English</td>
<td>The objective of this study was to determine the winter maintenance requirements for modern surfacings, including multiple surface dressings, ultra thin surfacings, micro-surfacings and porous asphalt.</td>
<td>5;9</td>
</tr>
<tr>
<td>Sweden</td>
<td>Wallman, C-G</td>
<td>Tema Vintermodell: Olycksrisker vid olika vinterväglag</td>
<td>VTI NOTAT 60-2001, Statens väg-och transportforskningsinstitut, SE-581 95 LINKÖPING, SWEDEN</td>
<td>Swedish</td>
<td>Keywords: Sweden, Accident Risk, Winter, Road Condition</td>
<td>3</td>
</tr>
<tr>
<td>Sweden</td>
<td>Wiklund, M</td>
<td>En statistisk metod för att beskriva hur sannolikheten för vägtrafikolyckan varierar mellan olika vinterväglag</td>
<td>VTI Meddelande 924, Statens väg- och transportforskningsinstitut, SE-581 95 LINKÖPING, SWEDEN</td>
<td>Swedish</td>
<td>Keywords: Sweden, Accident, Analysel Model, winter, road condition, vehicle mileage</td>
<td>3</td>
</tr>
<tr>
<td>Sweden</td>
<td>Öberg, Gudrun; Nordström, Olle; Wallman, Carl-Gustaf; Wiklund, Mats; Wretling, Peter</td>
<td>Tung fordons däckanvändning: effekter vid is/ snöväglag</td>
<td>Statens väg- och transportforskningsinstitut. VTI meddelande 884 Linköping 2000, 69 s + bil, 887 KB [<a href="http://www.vti.se/">http://www.vti.se/</a> pdf/reports/M 884.pdf](<a href="http://www.vti.se/pdf/reports/M">http://www.vti.se/pdf/reports/M</a> 884.pdf)</td>
<td>Swedish</td>
<td>Keywords: Sweden, tyre, heavy vehicles, icy roads, snow, skidding resistance, accident, legislation</td>
<td>6,3</td>
</tr>
</tbody>
</table>
3.2.4 Dissemination

The consultation of the state of the art carried out is possible on the Web site of the COST 344 [http://www.trl.co.uk/cost344/cost344.htm](http://www.trl.co.uk/cost344/cost344.htm) and when the Action is ended at [http://www.cordis.lu/cost-transport/src/cost-344.htm](http://www.cordis.lu/cost-transport/src/cost-344.htm).

3.3 On-going projects

In the same spirit and in order to be informed of the last or future developments in the various countries the state of the art approach was supplemented by the most exhaustive possible list of the projects on-going.

3.3.1 Results

In the end of year 2000 almost 100 projects were on-going in the participating countries. When updating in the spring 2002 113 projects were running.

In each of the following headings it is possible to search: Country, Project, Title, Organisation, Abstract/Keywords, Topics.

Below is an example from the database with On-going projects:

<table>
<thead>
<tr>
<th>Country</th>
<th>Project Title</th>
<th>Organisation</th>
<th>Abstract/Keywords</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>VINTERMAN</td>
<td>Road Directorate</td>
<td>Winter Management System</td>
<td>4</td>
</tr>
<tr>
<td>Denmark</td>
<td>Forecasts model for road temperature</td>
<td>Road Directorate, Danish Meteorological Institut, Danish Road Institut</td>
<td>Forecasts for temperature along a road stretch. Thermal mapping and icy car are the technologies to obtain reliable data.</td>
<td>4</td>
</tr>
<tr>
<td>Denmark</td>
<td>Vinterindex</td>
<td>Road Directorate, Danish Meteorological Institut, Danish Road Institut</td>
<td>Documentation of used resources (Snow clearing, salt spreading and salt consumption)</td>
<td>2.5</td>
</tr>
<tr>
<td>Denmark</td>
<td>Salt distribution measurements with Brine</td>
<td>Road Directorate, County of Funen, The Ministry of the Environment</td>
<td>Validation of efficiency of Brine compared to Pre-wetted salt. Calculation of decomposition model</td>
<td>2.8</td>
</tr>
<tr>
<td>Germany</td>
<td>Optimizing winter road maintenance on motorways with heavy traffic load</td>
<td>Institute of Highway and Railroad Engineering, University of Karlsruhe; Prof. Dr.-Ing. Ralf Roos</td>
<td>The aim of that research project on behalf of the German Federal Minister of Transportation is to evaluate the winter maintenance of highway surveillance centres servicing roads with a heavy traffic load and to analyse the effects of certain organisational and technical measures by setting up and evaluating pilot projects.</td>
<td>3.2</td>
</tr>
<tr>
<td>Norway</td>
<td>Vinterfrikkjonsprosjektet: The winter friction project</td>
<td>Statens vegvesen, Vegdirektoratet: Vehedensk avdeling: Produksjonsteknisk konteror</td>
<td>The objective is to establish which actions and methods to improve friction should be used for different conditions like local-, traffic- and climatic conditions.</td>
<td>3</td>
</tr>
<tr>
<td>Norway</td>
<td>Salt og miljøundersøkelse. Investigation of salt and environment.</td>
<td>Statens vegvesen, Vegdirektoratet: Vehedensk avdeling: Produksjonsteknisk konteror</td>
<td>In this project roads were damages from the salt is observed will be followed and studied.</td>
<td>9</td>
</tr>
<tr>
<td>Norway</td>
<td>Norix - Vinterindeks for norske forhold. Norix - Winter index for Norwegian condition</td>
<td>Statens vegvesen, Vegdirektoratet.</td>
<td>The Public Roads Administration wants to use an index to estimate the medium value for winter maintenance. A winter index could be used both for planning and follow up. The estimates is based on information from many years in the past. It gives a good picture of the natural variations over the years and the need for actions on the winter roads.</td>
<td>4</td>
</tr>
</tbody>
</table>
The topics from the first version are still in use and the number of projects in each topic is shown below:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather and climate</td>
<td>15</td>
</tr>
<tr>
<td>Equipment</td>
<td>26</td>
</tr>
<tr>
<td>Effects</td>
<td>13</td>
</tr>
<tr>
<td>Management</td>
<td>32</td>
</tr>
<tr>
<td>De-icing products</td>
<td>19</td>
</tr>
<tr>
<td>Equipment for the road user</td>
<td>2</td>
</tr>
<tr>
<td>Risk management</td>
<td>4</td>
</tr>
<tr>
<td>Strategy</td>
<td>7</td>
</tr>
<tr>
<td>Design and construction of the road</td>
<td>4</td>
</tr>
<tr>
<td>Cost of winter maintenance</td>
<td>3</td>
</tr>
<tr>
<td>Road user information</td>
<td>4</td>
</tr>
<tr>
<td>Overview</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
</tr>
</tbody>
</table>

3.3.2 Dissemination

The consultation of the state of the art carried out is possible on the Web site of the COST 344 [http://www.trl.co.uk/cost344/cost344.htm](http://www.trl.co.uk/cost344/cost344.htm) and when the Action is ended at [http://www.cordis.lu/cost-transport/src/cost-344.htm](http://www.cordis.lu/cost-transport/src/cost-344.htm).
BEST PRACTICES IN EUROPE

TG 3 Leaders

DR. STEFAN BALD
Technical University, Petersenstrasse 30
64287 Darmstadt, D
jsbald@verkehr.tu-darmstadt.de

DR. VALÉRIE MUZET
CETE de l’EST, LRN, 71 rue de la Grande Haie
54510 Tomblaine, F
Valerie.muzet@equipement.gouv.fr
4. Introduction

The aim of the task group’s work was to find the “best practice” of winter maintenance in Europe. It became clear that there are variously shaped influences on the practice of winter maintenance. Actual practice variations within a country or between countries depend not only on the different climate situations, but also on historic, political and other conditions. So it seemed difficult to identify one “best practice”, even impossible to compare practices directly.

The task group decided (in concordance with the Management Committee) to approach this by documenting the different practices in Europe with their characteristic boundary conditions. This allows a reader to select best practice according to his own boundary condition.

In addition, it was agreed during reorientation of TG2 (also in concordance with the Management Committee) that TG3 will concentrate on the description of the current approaches of the different countries, TG2 on its assessment.

First step of the work of TG3 was to collect the practice of the different countries. TG3 worked out a uniform structure of the subjects on which the delegates should report, which was referred to as “Subject List” (see appendix 1). This subject list was structured in four sections:

- In the first section “Fundamental Issues” some general information was requested: climatic conditions; regulations and codes of practice (general, manpower, equipment and material)
- The second section “Strategic Organisation of Winter Maintenance” concentrated on general organisation and practice (time scale one year and longer), subdivided in: general; information provision; methods; equipment; materials; manpower, training and privatisation.
- The third section showed the “Operational Organisation of Winter Maintenance”, that means the actual reaction on winter events, subdivided in: getting information; methods, equipment and materials for ice control; the same for snow control; the same for special problems (as porous asphalts, bridges, avalanches and so on); internal and external measurements of efficiency.
- In the last section “Information of Drivers”, some questions were posed on the application of old and modern telematics.

The task group consulted up to 18 country reports from as many countries (see CD-ROM in the Annex). It was not easy to compare these quite different reports. But in their differences they reflect the variation throughout Europe not only in relation to practice but also regarding:

- the different boundary conditions and external influences,
- the different cultures (history, economical thinking) and
- the different needs of the European citizens.

So in assembling the country reports the differences in practice and scale between counties are revealed. Only the combined documentation of practice and scale gives the possibility for the interested people to show up “best practice” for every place in Europe (which can be very different in the north or south, in the north or in the south, near the sea or in the mountains).

The following final report, also structured according to the subject list, summarizes different practice and scales throughout Europe. It tries to find equalities and differences and – so possible – the reasons for that.

The interested user should be able to find variations of regulations throughout the continent which are explicable and necessary. He should also find areas where the different countries can learn from each other and their practices
4.1 Fundamental Issues

Winter maintenance and its organisation must respect the climatic conditions, the framework of regulations and codes of practice which are valid for each country or region. For that it's quite important to describe these boundary conditions. In a European overview it's quite interesting to realize the quite important differences. Over all, it seems, that the regulatory framework, especially regulations on liability, influences practice of winter maintenance more than climatic conditions do.

As the road classes are not very uniform in Europe, an attempt was made to find a clear structure (see also table 2.1.1 for reference):

- In nearly all countries you find a (often quite old) network of nation-wide general roads, which is at least paid, mostly also directly administered by a national authority. These roads are referred to as “National Roads”.
- In nearly all countries you find an additional network of high quality roads, which often is limited for higher speed vehicles and which has higher quality standards by means of geometric design or maintenance level. They often have separate lanes for each direction and grade separated junctions. These roads are referred to as “Motorways, Trunk Roads”.
- In nearly all countries you find a network of roads, which supplements the national road system on the regional and county level. In smaller or uniformly organised countries these roads have the same level and sometimes are administered by the national road organisation. But often they are owned (and administered) by regional and local, political independent bodies of different levels (e.g. regions, “départements”, “Länder” or “Kantone” on a higher level and counties, “provinces” or districts on a lower level). As there are different levels (often with quite different administrative structures), these roads are referred to as “Regional Roads” for the higher and “County Roads” for the lower level, respectively.
- In many countries you find some very low level roads connecting villages in the neighbourhood, which are managed by the villages itself. They are in the same class as the roads inside the villages and urban areas and referred to as “Local and Urban Roads”.

Fig. 1.1.0 shows schematically, how these road classes differ in traffic volume and cruising speeds. Motorways and trunk roads form the top rank in the classification. In general they also demand the highest level of service for winter maintenance.

The investigation showed, that vice versa, for the lower road classes there was appreciably less information available. There may be many reasons for that. The most important seems to be, that there are many independent units to maintain these heterogeneous networks. The following chapters give plenty of information for the higher road classes. For the lower ones, all relevant information is mentioned, even if it is not complete. For cycle or foot paths, there is almost no information.
4.1.1 Climatic conditions

4.1.1.1 Overview of Climatic Conditions in Europe

Climatic conditions strongly influence the strategy of winter maintenance in all regions in Europe.

Climate must be specified for a place and time period because, like weather, climate varies both spatially and temporarily. Climate is usually described in terms of normals, means, and extremes of a variety of weather parameters, for example temperature, rainfall and sunshine. Sometimes however, when regions of similar climate are sought, an alternative subjective approach is required, which is known as a climatic classification scheme. The oldest type of climatic classification is based on meteorological causes and is known as ‘genetic’. Official meteorological climatic maps exist (see Figure 1.1.1) but are sometimes contradictory depending of the meteorologists (for example Sydow-Wagner and Köppen).

Moreover, each country has maps with well known and accepted climate zones (see the country reports of each participating country) but there is sometimes contradiction with the neighbouring country and with European climatic maps. This is why it is very difficult to have an accepted climatic map of Europe.
The Climatic Regions

On a world scale, the area north of the desert of Africa, which includes the studied area of this present project, belongs almost totally to the Temperate Zone. But some areas in the mountains of Norway and Northern Finland have a climate very close to the characteristics of the polar climatic zone.

The temperate zone within Europe can be subdivided into four different climatic areas:

• Northwest Europe, having mostly cool summers and mild winters
• Central-Europe, characterised by warm summers and relatively cold winters
• East-Europe, with warm summers and cold winters
• Mediterranean area, with hot and dry summers and mild winters

According to winter maintenance the following criteria are important

<table>
<thead>
<tr>
<th>Proximity of the sea</th>
<th>Close to the sea =&gt; much precipitation</th>
<th>Continental =&gt; much cold wind, long cold periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>North =&gt; colder</td>
<td>South =&gt; warmer</td>
</tr>
<tr>
<td>Altitude</td>
<td>Mountain =&gt; colder</td>
<td></td>
</tr>
</tbody>
</table>

And typical winter maintenance problems are the following:

• temperatures around 0°C
• much snow
• very cold temperature for long time
• snowdrift, wind
• humidity

For the purposes of COST 344, seven Climatic Regions are identified within Europe.

Maritime climate

• Temperature relatively warm
• Minimum temperature often near 0°C
• Temperature does not fluctuate greatly
• Relatively little snow
• High humidity

Cold Maritime climate (Scandinavian Coast)

• As maritime, but colder (more snow)
• Temperature changes
• More wind than maritime climate => frequent snowdrift

Northern climate

• Very cold
• Snow

Central-European climate

• Like maritime, but colder
- Temperature changes sometimes per day from below to above 0 °C
- Fog

**Mountain climate**
- Great fluctuations (big difference between daily minimum and maximum)
- Low temperatures
- Much snow
- Strong winds

**Continental climate**
- Often very cold, many frost days
- Long snowfall periods
- Relatively dry (limited amount of snow)
- Relatively stable weather over longer periods (especially long frost periods)
- Strong winds on some days
- Problems of snowdrift

**Mediterranean**
- Mild temperature (minimum temperature over 0 °C)
- Relatively high humidity
- Snow and frost is exception

The variation within countries is considerable with some countries mentioning as many as four climatic regions in their national reports – Table 1.1.1.

<table>
<thead>
<tr>
<th>Country</th>
<th>Maritime</th>
<th>Mediterranean</th>
<th>Cold maritime</th>
<th>Northern</th>
<th>Central European</th>
<th>Mountainous</th>
<th>Continental</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(CZ) Czech Republic</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(F) France</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>(GB) United Kingdom</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(HR) Croatia</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(N) Norway</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(PL) Poland</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>(SLO) Slovenia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Legend for the table
- : not present in this country
x : present in this country
? : no information available

Table 1.1.1 Climatic Regions Identified from the Country Reports

Figure 1.1.2 is a climatic map of Europe, which is derived from Table 1.1.1 and takes account of winter maintenance considerations.
4.1.1.2 Winter events to be mastered

Winter maintenance is identified as problem in all countries of Europe. Even in the regions which objectively have milder weather conditions, there is a big need for winter maintenance, possibly because of a higher subjective demand by its citizens. Or vice versa, winter maintenance practice in regions with more ice and snow recognises that people there are more used to coping with adverse road conditions. Regarding the reports of the countries it is quite interesting to remark, that there are great differences in describing climate conditions. In countries with big winter events to be mastered (e.g. much snow, long cold periods) the events themselves are the focus of the report (e.g. amount of snow; existence of snowdrift), whereas in the countries with objectively milder climates, especially in the maritime climate, there are extensive reports on weather conditions such as temperatures, precipitation and so on. The countries report the following winter events to be mastered:

**Maritime climate**

The main problems of countries with maritime climate are temperatures around 0 °C with daily melting and freezing as well as high relative humidity (moist air) and precipitation rates.

As there is little relatively snow, but bigger problems with slipperiness coming from freezing water (from rain, snow and moisture), there is less ploughing but frequent salting. The most dangerous event is black ice (sudden slipperiness by falling water on cold roads).

Ireland reports, that the number days salted varies between 20 to 60 depending on winter severity. Disruptive snow falls are rare; say once every 10 years. However local authorities are equipped with snow ploughs to deal with that.
Belgium reports that the number of days with snow varies considerably from one point of the territory to another: around 12 days/year on the coast to 60 days/year on the Ardennes plateaux. The number of days of frost in Brussels remains acceptable with 59 days/year. The number of freezing days increases when moving towards the Ardennes plateaux (mean of 115 days of frost per year). It reports also, that on a micro scale the differences in climatic conditions between road sections are great enough to create different types of slipperiness.

**Cold Maritime climate (Scandinavian Coast)**
In the cold maritime climate the temperatures are significantly lower than in the normal maritime climate. The low temperatures in combination with the high precipitation rates and the wind lead to big amounts of snow with snowdrifts and even avalanches, as reported from Norway and Iceland. Iceland reports removal of snow from the ditches as a problem to create storage capacity for the next snow fall.

**Northern climate**
As temperatures above 0°C are exceptional in mid-winter, most of the precipitation falls as dry snow. There is not much snow, but drifting causes visibility problems.

**Central-European climate**
The central European climate is somewhat similar to the maritime one. There is some more snow, but less moisture in the air. There problem of the temperatures changing around 0°C also exists in this climate zone, though it arises more on the warmer days (in contrast to maritime climate where it arises more on the colder days). France reports dry and quite tough winters with snowfalls and more days of frost.

The Czech Republic reports development of black ice, either by hard packing of snow-layers, or freezing moisture with frequent temperature fluctuations near freezing point in relatively high air humidity. In winter 2000/2001 there were 87 days with spreading operations (92 days the winter before) and 49 days with snow removal (52 days the winter before).

**Mountain climate**
Big amounts of snow combine with low temperatures in the mountain climate. Often there are long periods below freezing point. The biggest problem seems to be the snow, from its amount or coming from snowdrifts or avalanches.

**Continental climate**
The continental climate is characterised by long cold periods with many frosty days and normally not so much precipitation and moisture. Weather is relatively stable over longer periods. In this time only snowdrift may cause problems. If however, there is precipitation during cold periods, some amount of snow may arise.

Snow cover from the beginning of October until the end of May or June is reported for the northern parts of Sweden. In the northeastern parts of Germany, normally there is little snow.

**Mediterranean**
In the Mediterranean regions, normally there are less intensive winter events to be mastered. France reports between 20 and 30 days of frost a year in the plain and even less near the sea. Snowfalls are rare and people are not used to it when it is encountered.

### 4.1.1.3 Winter Indices

The purpose of a winter index is to give an objective indication of winter severity. Various weather indices have been devised to compare weather and seasons at different places and for different years.

However there have been fewer attempts at development and application of indices which engineers can use for winter maintenance purposes. Some important uses of winter indices are in the estimation of the cost of winter maintenance, in determination and optimum allocation of winter maintenance funds, in evaluation of salting efficiency and potential savings.

A short description of the different European winter indices is made here. To have a complete description see the corresponding country report.
France
There are several winter maintenance indices in France.

- The hardness of winter called Hi
  It is calculated from the mean numbers of days with snowfall and black ice. Five levels of winter hardness are defined in France. This index is used by the French equipment ministry since 1978 to calculate winter maintenance money allocation.
- A specific classification for snow called Ei
  It depends on the quantity of cumulative snowfall and of the snowfall rate per hour.
- Frost index IG:
  Another winter index, called IG (Indice de Gel or Frost Index) integrates days of frost.

\[
I_G = \int_{0}^{T} T_m(t) dt \quad \text{in } ^\circ\text{C}.\text{days when } T_m < 0 \, ^\circ\text{C} \quad \text{(with } T_m = \frac{T_r + T_s}{2} \text{) mean daily air temperature}
\]

This index is an absolute characterisation of winter and is not related to winter maintenance.

- A winter maintenance index called IVH:
  A winter maintenance index called IVH (for “Index de Viabilité Hivernale”) was defined in 1988. It is computed every year for each departmental meteorological office since 1980 (140 stations). It calculates the hardness of winter from meteorological data (daily minimum and maximum air temperature, liquid and solid precipitation) and takes into account the number of winter maintenance interventions. It can be used to compare one winter to another taking account of meteorological and road maintenance data.

Ireland:
The original version of the Hulme Index has been published in the Journal of Meteorology in 1982. Thornes of the University of Birmingham, U.K., investigated the modified form of Hulme’s index for winter maintenance which he called the Temporal Winter Index.

It uses three variables to assess the severity of a winter: mean maximum air temperature (T), number of days with snow lying at 9 a.m. (S) and number of nights with ground frost (F). To use RST (road surface temperature) would be better than ground frost, but the former data is less readily available.

\[
\text{Winter Index W.I.} = (10^4T) - F - 18.5(S^{1/3})
\]

It enables the severity of winters to be compared at a given location.

Thornes has reported a correlation between regional expenditure on winter maintenance in Scotland and the modified Hulme winter index.

The Irish meteorological service; Met. Éireann has used this winter index with data from their meteorological stations. The contours were plotted on a map of Ireland along with mean daily air temperature contours. This data is being used to assist in determining the allocation of winter maintenance funds.

Sweden:
For winter maintenance purposes in Sweden, statistics on weather conditions are 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 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

In recent years, 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 describe 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.

**Switzerland:**
A winter index is not yet in use.

However an ongoing winter index project is based on the method of simple regression. The index is basically the correlation of specific climate factors and the costs of winter maintenance.

The climate factors taken into consideration include:
- quantity of snow
- number of days below 0° C
- air temperature
- number of days with snowfall
- minimum air temperature
- amount of precipitation
- days with snow cover

The winter index will be different for each of the climatic regions of Switzerland.

### 4.1.2 Regulations and Codes of Practice

#### 4.1.2.1 General Regulations and Codes of Practice

In Table 1.2.1 there is a compilation of legal obligation, other regulations, codes of practice and service classes for winter maintenance in the different countries of Europe.

All countries organise their winter maintenance according to the "importance" of the roads, often measured by the network function and the traffic volume (or indirectly by road owner). Some countries use speed as discriminator. The scales are quite different, but the principle is always quite similar.

In many, but not in all countries there is a direct legal obligation to do winter maintenance. But even in the countries without direct legal obligation there is a high standard. Even in the states with legal obligation this obligation is often quite weak and stated more precisely by regulations and codes of practice of the administration.

There appears to be differences in the level of winter maintenance service provided. Densely populated countries with higher Gross National Product (GNP) and mild winters try to reach a higher standard ("black roads") than less populated countries with lower GNP and severe winters (often "white roads" with use of abrasives). Correlation between climatic zones alone and level of service is less significant.

In some countries there are different standards throughout the nation (inner national subsidiarity principle). Some countries force that by organising their maintenance in regional organisation units (e.g. Sweden) or using political structures (e.g. Belgium, Switzerland and Germany). There seems to be no need for an overall European standard (but possibly for a consistent set of criteria).
According to the amount and the type of privatisation there seems to be differences in the formulation of the requirements. In countries with more distinctive and regional privatisation more rules are defined (which – by the way – may result in higher costs).

<table>
<thead>
<tr>
<th>Country</th>
<th>General legal obligation</th>
<th>Other regulations or codes of practice</th>
<th>Service categories depending on</th>
<th>Service categories</th>
<th>Service times</th>
<th>Winter period</th>
<th>Equipment of traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>yes, legal obligation defined in the traffic regulations</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Road type, traffic volume, weather situation</td>
<td>classification A..D</td>
<td>A: 0..24 h</td>
<td>11-01..03-31 in the alpine region the time interval for winter maintenance activities can be expanded</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>Service provided to road user and to economy of the country</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Service provided to road user and to economy of the country</td>
<td>Service provided to road user and to economy of the country</td>
<td>A: 0..24 h</td>
<td>11-01..03-31 in the alpine region the time interval for winter maintenance activities can be expanded</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>yes (depending on possibilities)</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Traffic importance</td>
<td>Four Service Levels A...D; 3 priority levels 1..3</td>
<td>A: 0..24 h</td>
<td>11-01..03-31 in the alpine region the time interval for winter maintenance activities can be expanded</td>
</tr>
<tr>
<td>(CZ) Czech Rep.</td>
<td>by road owner-coordinated by common documents</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Road category (priority) and traffic intensity</td>
<td>Road type: importance of road</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>no (only for dangerous situations)</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Importance of roads</td>
<td>Traffic ability</td>
<td>motorways: 0.24 h important roads: 6..22 h other roads: 8..20 h</td>
<td>motorways: 0.24 h important roads: 6..22 h other roads: 8..20 h</td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>yes</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Type of road; traffic volume</td>
<td>Type of road; traffic volume</td>
<td>A: dry, wet; no slippery; max. service time for snow 2..3h</td>
<td>Type of road; traffic volume</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>yes</td>
<td>Service provided to road user and to economy of the country</td>
<td>yes</td>
<td>Service provided to road user and to economy of the country</td>
<td>Service provided to road user and to economy of the country</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
</tr>
<tr>
<td>(F) France</td>
<td>no</td>
<td>Service provided to road user and to economy of the country</td>
<td>no</td>
<td>by road owner-coordinated by common documents</td>
<td>by road owner-coordinated by common documents</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
<td>1st: entire width of road; chemical de-icers: treatment time 2..3 h</td>
</tr>
</tbody>
</table>

1: permanent transit on roads
2: some traffic disruption due to snow and ice
3: Definition of worst cases (applicable only some days per some years). Service time 2..3h

Service categories:
- A: Motorways and federal highways in direct connection to motorways
- B: Highways > 3000 ADT
- C: Highways 1000..3000 ADT or busses or tourism
- D: other highways

3 weather situations:
- 1st: entire width of road; chemical de-icers: treatment time 2..3 h
- 2nd: driven snow layers may be left on road; treatment time 4 h
- 3rd: ploughing and spreading of abrasives; treatment time 12 h

Equipment of traffic:
- Winter period

Service times:
- A: 0..24 h
- B: 4..20 h
- C: 5..20 h
- D: once daily
- A: max 3h, B: max 5h

Winter period:
- 11-01..03-31 in the alpine region the time interval for winter maintenance activities can be expanded

Equipment of traffic:
- Winter period

Service times:
- A: 0..24 h
- B: 4..20 h
- C: 5..20 h
- D: once daily
- A: max 3h, B: max 5h
<table>
<thead>
<tr>
<th>Country</th>
<th>General legal obligation</th>
<th>Other regulations or codes of practice</th>
<th>Service categories depending on</th>
<th>Service categories</th>
<th>Service times</th>
<th>Winter period</th>
<th>Equipment of traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN</td>
<td>yes</td>
<td>yes</td>
<td>Traffic volume, road class,</td>
<td>Maintenance classes for anti-slipping and snow removal:</td>
<td>05-22, a bit different values during night</td>
<td>10-01-04-30</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>regional climate</td>
<td>I, reaction time 2 hr 2,5 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I, reaction time 2 hr 3 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ib and T1B, reaction time 3-4 hr 3 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II, reaction time 6 hr 4 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>III, reaction time 10 h 6 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pedestrian and bicycle paths KI and KII, rec. time 2-4 h supplementary classes for 'precision maintenance' and 'Holiday quality' for certain traffic peaks e.g. Christmas, Easter...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GB</td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>yes</td>
<td>Guidelines</td>
<td>Road categories &amp; traffic volume</td>
<td>6 categories</td>
<td></td>
<td>11-15-03-15</td>
<td>Winter-tyres advised</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I: reaction time 1h; treatment time 4h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II: reaction time 2h; treatment time 6h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>III: reaction time 3h; treatment time 8h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IV: reaction time 5h; treatment time 24h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V: reaction time 5h; treatment time 24h, no salting, only snow clearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VI: reaction time; treatment time; no salting, only snow clearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRL</td>
<td>no</td>
<td>yes</td>
<td>Road class (importance of road)</td>
<td>A (Primary road): 2,5 h treatment time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B (Secondary road): 2,5 h treatment time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C (other important roads): when A and B are passable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IS</td>
<td>yes</td>
<td></td>
<td>Traffic volume; net function</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cat 1: 24 h all days; max 2.4 cm snow; max 2h after end of snowfall; ice requirem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cat 2: 4..12 cm snow; max 3h; ice requirem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cat 3: 6..16 cm; max 3h; de-icing at dang. pl.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cat 4: 8..18 cm; max 4h; snow may rest on surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cat 5: snow rests on surface; max 4h; de-icing only in extreme situations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>yes (&gt;standards)</td>
<td>by road owner</td>
<td>Traffic volume and Type of road (national road, county road, municipal road)</td>
<td>The Road should be passable for vehicles that are normally equipped for winter driving; max. snow heights; min. friction for de-icing &gt;1500ADT: black roads</td>
<td>before 6:00h</td>
<td>10-15-04-15</td>
<td>studded tires with special tax in a few towns when amount of studded tires is &gt; 20 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rest: winter roads: no salt (often white during winter) some: closed in winter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NL</td>
<td>yes</td>
<td>national</td>
<td>Importance</td>
<td>national roads: treatment within 0,75..1,5h regional roads (provinces): treatment within 1.2 h</td>
<td>0..24 h (preferred at night)</td>
<td>10 - 01-04-01</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Main Local roads (bus routes etc): spread within 1 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO</td>
<td>yes</td>
<td>yes</td>
<td>Road type; traffic volume</td>
<td>4 services levels, Max. service time: classification 1.4</td>
<td>1: 0... 24 h; 2: 0... 24 h; 3 and 4: 8 or 16 h if it is necessary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>And road importance</td>
<td>1. Reaction time 1h; de-icing treatment time: 2½ - 3 h and 10 h snow removal on one lane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Reaction time 2 h; de-icing treatment time: 3-6 h, snow removal: 1-2 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Reaction time 3 h; de-icing treatment time: 7-12 h and 4 days snow removal on one lane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. White roads; snow is cleaned only in special situations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tab. 1.2.1: Legal obligation, other regulations, codes of practice and service classes for winter maintenance in the different countries of Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>General legal obligation</th>
<th>Other regulations or codes of practice</th>
<th>Service categories depending on traffic volume and road category (national, regional or local road network)</th>
<th>Service categories</th>
<th>Service times</th>
<th>Winter period</th>
<th>Equipment of traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S) Sweden</td>
<td>yes</td>
<td>by road owner</td>
<td>State roads:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A: standard classes. Free from snow and ice during dry weather (black roads) above a given temperature limit. Salt is used.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A1: during snowfall no more than 2cm of snow; Free from snow and ice no later than 2h after end of snowfall; Temperature limit –8°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2: 4h; 4cm. Temperature limit –8°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A3: 6h; 6cm. Temperature limit -6°C/-3°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A4: 6h; 6cm. Temperature limit -6°C/-3°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B: Snow covered roads. During dry weather even and no more than 2 cm of loose snow. Salt is normally not used.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B1: During snowfall and up to 6 hours after no more than 6 cm of snow.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B2: During snowfall and up to 8 hours after no more than 8 cm of snow.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C: cycle and pedestrian paths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In extreme situations: continuous operation Roadway divided in three different areas (traffic lane, hard shoulder and parking areas/ bus stops)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(SLO) Slovenia</td>
<td>yes</td>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1.2.1 gives an example for defining service categories depending on road type and traffic volume (Iceland).
In many countries level of service are also related to the weather situation (e.g. Austria). France has an interesting model which combines traffic flow conditions and service times according to a given service class (Fig. 1.2.2). The traffic flow conditions range from C1 (no hindrance to traffic) to C4 (traffic movement possible only with special equipment, e.g. thick generalised black ice or thick fresh snow, rutted frost or important snowdrift). More information can be found in France’s country report.

![Traffic flow conditions and service times in France](image)

Spain tries to take into account the statistical effect of winter events by allowing worst cases for example 2 times in 5 years.

### 1.2.2 Regulations and Codes of Practice on Manpower

Table 1.2.2 gives on rough overview on the regulations on manpower, equipment and material for winter maintenance found in the different country reports. There should be mentioned, that in generally the European regulation on working times etc. apply. In some countries there are only exceptions for traffic safety or public works.

### 1.2.3 Regulations and Codes of Practice on Equipment and Material

see Table 1.2.2
Table 1.2.2: Regulations on manpower, equipment and material for winter maintenance in the different countries of Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Regulations on manpower</th>
<th>Regulations for equipment</th>
<th>Regulations for material</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>exceptions possible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>Flexible standby organisation. The work is scheduled following the application of the European directive.</td>
<td>Roads Administrations use their own requirements (based on experience). It concerns mainly spreaders (driving system, feeding system). Precise characteristics are imposed concerning machine safety (CE-label) and spreader signalisation</td>
<td>Only salts products (NaCl and CaCl₂) are used in Belgium. Roads Administrations use their own requirements: precise characteristics are imposed to salt (grading curve, chloride concentration ... )</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>exceptions possible; standby organisation, partly shift organisation</td>
<td>Engines; Attachments for ploughs; ploughs; signalling</td>
<td>yes</td>
</tr>
<tr>
<td>(CZ) Czech Rep.</td>
<td>exceptions possible; standby organisation, partly shift organisation</td>
<td>design standards for ploughs, spreader, marking etc.</td>
<td>yes</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>flexible standby organisation</td>
<td>attachment for ploughs and others</td>
<td>yes</td>
</tr>
<tr>
<td>(DK) Danmark</td>
<td>no</td>
<td>no</td>
<td>salt &gt; 70%; max 30 % water.</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>3 shifts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F) France</td>
<td></td>
<td>Spreader evaluation, attaching system, Traffic lights, signalling and marking</td>
<td>salt &gt; 88/98 %; max 0,6..8 % water; max 1; 5; 8 mm</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>yes</td>
<td>yes</td>
<td>yes (for maximum salt amount)</td>
</tr>
<tr>
<td>(GB) United Kingdom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H) Hungary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(HR) Croatia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>governed by EU directives</td>
<td>for spreaders</td>
<td></td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N) Norway</td>
<td>exceptions possible</td>
<td>attachment for ploughs</td>
<td></td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td></td>
<td>design standards for ploughs, spreader, marking etc.</td>
<td></td>
</tr>
<tr>
<td>(PL) Poland</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| (RO) Romania  | 1-3 shifts * for first and second service levels: 3 shifts * for services 3 and 4: 1 shift or 2 shift if it is necessary | yes                       | Salt > 96 %  
Humidity: max 1%  
Grading limits: 0-3,15  
(size under 1 mm < 50%) |
| (S) Sweden    |                          |                           |                          |
| (SLO) Slovenia |                          |                           | Only NaCl may be used. The salt should be fine graded (0-4 mm). |
4.2 Strategic organisation of winter maintenance

4.2.1 General

Winter maintenance in Europe is organised either by road classes (and so by owner) or by regional aspects (or by a combination of both). It seems, that the more varied the (climatic) conditions the more differentiated organisations are. In more regionally organised countries (e.g. Germany, Switzerland, Belgium) these organisations often correlate with the political divisions (e.g. provinces, “départements”, “Länder”, “Kantone”), in more uniformly organised countries you find also other divisions (e.g. Sweden; see Fig. 2.1.1).

The quality of the winter maintenance product is affected by criteria:
- The administration should have a degree of independence from political pressures, but not too much, (control, but no interference).
- There should be continuity in level of service along roads.
- There should be possibility (and the aim) of cooperation at the lowest level to avoid “border problems”.

Table 2.1.1 shows the organisation of winter maintenance for different road classes in European countries. As the road classes are not very uniform in Europe, an attempt was made to find a clear structure:

- In nearly all countries you find a (often quite old) network of nation-wide general roads, which is at least paid, mostly also directly administered by a national authority. These roads are referred to as “National Roads”.
- In nearly all countries you find an additional network of high quality roads, which often is restricted to higher speed vehicles and which has higher quality standards in respect to geometric design or maintenance level. They often have separate lanes for each direction and grade separated junctions. These roads are referred to as “Motorways, Trunk Roads”.
- In nearly all countries you find a network of road, which supplements the national road system on the regional and county level. In small or uniformly organised countries these roads have the same level of provision and sometimes are administered by a national road organisation. But often they are owned (and administered) by regional and local, politically independent bodies of different levels (e.g. regions, “départements”, “Länder” or “Kantone” on a higher level and counties, “provinces” or districts on a lower level). As there are different levels (often with quite different administrative structures), these roads are referred to as “Regional Roads” for the higher and “County Roads” for the lower level, respectively.
- In many countries you find some very low level roads which connect villages in the neighbourhood and are managed by the villages themselves. They are in the same class as the roads inside the villages and urban areas and referred to as “Local and Urban Roads”.
- Sometimes you find a last road class which could be part of a private domain or an urban development. These roads do not serve general traffic and therefore are often privately owned (even as private roads of public entities). They are referred to as “Other Roads”.

In countries, where one of these classes is not applicable, this is marked in Table 2.1.1 with “>>>” or “<<<” (pointing to the appropriate class to the right or to the left).

In summary one can say, that Motorways, National Highways and Regional Roads (and sometimes the County Roads) form a sort of higher quality network, which is in general administered by uniform organisations. The other roads are administered in a quite patchy way by local authorities.

Regarding winter maintenance, in nearly all countries varying degrees of privatisation, mostly only leased or rented vehicles (with and without drivers). In some countries there is full privatisation (e.g. Sweden, Great Britain? and some regions in Germany).

Fig. 2.1.1: Example where the administrative districts do not correspond to the political ones (Sweden; source: SNRA)
<table>
<thead>
<tr>
<th>Country</th>
<th>Motorways, Trunk Roads</th>
<th>National roads</th>
<th>Regional roads</th>
<th>County roads</th>
<th>Local and urban roads</th>
<th>Other roads</th>
<th>Authority</th>
<th>Org. Unit</th>
<th>Privatised</th>
<th>Winter period</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>1930 km</td>
<td>10000 km</td>
<td>&gt;&gt;&gt;</td>
<td>23000 km</td>
<td>71000 km</td>
<td></td>
<td>2:3: state 5: county 6: local (city or village)</td>
<td>240 centres</td>
<td>partly (vehicles)</td>
<td>1.11.-31.3. with local differences</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>1700 km</td>
<td>&gt;&gt;&gt;</td>
<td>12500 km</td>
<td>1300 km</td>
<td>129000 km</td>
<td></td>
<td>2:4: regions 5: provinces 6: municipalities</td>
<td>2:4: 76 regional centres</td>
<td>Execution partly privatized</td>
<td></td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>&gt;&gt;&gt;</td>
<td>1850 km</td>
<td>18300 km</td>
<td></td>
<td>51300 km</td>
<td></td>
<td>2:4: Kantone 8: local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CZ) Czech Rep.</td>
<td>500 km</td>
<td>6000 km</td>
<td>&gt;&gt;&gt;</td>
<td>49000 km</td>
<td>52500km</td>
<td></td>
<td>2:3: nat 5: county 6: local</td>
<td>2:13 centres 3:5: 200..240km 6: very different</td>
<td>partly</td>
<td></td>
</tr>
<tr>
<td>(D) Germany</td>
<td>11500 km</td>
<td>41000 km</td>
<td>87000 km</td>
<td>91000 km</td>
<td>400000 km</td>
<td></td>
<td>2:5: 16 states 5: county 6: local</td>
<td>2:5: 200..300km 6: very different</td>
<td>2:5: partly; vehicles 5:6: partly (vehicles)</td>
<td></td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>900 km</td>
<td>700 km</td>
<td>10000 km</td>
<td>60000 km</td>
<td></td>
<td></td>
<td>1:2: nat 4: county 6: municipality</td>
<td>1000 km</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>(E) Spain</td>
<td>&gt;&gt;&gt;</td>
<td>25000 km</td>
<td>&lt;&lt;&lt;&lt;</td>
<td></td>
<td>60000 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F) France</td>
<td>8900 km</td>
<td>24000 km</td>
<td>360000 km</td>
<td>580000 km</td>
<td></td>
<td></td>
<td>1: companies 3: 5: county 6: local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>730 km</td>
<td>8500 km</td>
<td>33000 km</td>
<td>360000 km</td>
<td></td>
<td></td>
<td>1:5 Road Adm. (9 road regions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GB) United Kingdom</td>
<td>3400 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>440 km</td>
<td>30000 km</td>
<td></td>
<td>105000 km</td>
<td>2500 km</td>
<td></td>
<td>state lokal</td>
<td>1:8 centres 3:6. 76 centres 7: local maintenance companies in larger cities</td>
<td>partly rented vehicles</td>
<td></td>
</tr>
<tr>
<td>(HR) Croatia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>2700 km</td>
<td>2700 km</td>
<td>12000 km</td>
<td>76000 km</td>
<td>2000 km</td>
<td>Nil</td>
<td>2:7: lokal</td>
<td>50 duty engineers (1 per local authority) 200..12000 km</td>
<td>vehicles partly</td>
<td></td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>4300 km</td>
<td>3900 km</td>
<td></td>
<td>2300 km</td>
<td>2200 km tourist roads</td>
<td>1:7: Nat</td>
<td></td>
<td></td>
<td>11-01..04-30</td>
<td></td>
</tr>
<tr>
<td>(N) Norway</td>
<td>2700 km</td>
<td>19300 km</td>
<td>27000 km</td>
<td>37000 km municipal roads</td>
<td>90000 km private</td>
<td>2:3: Nat 5: Country 6: local 7: private</td>
<td>70 Centres</td>
<td>partly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>2500 km</td>
<td>&lt;&lt;&lt;</td>
<td>800 km</td>
<td>6300 km</td>
<td>6a: 700 km 6b: 56000 km</td>
<td></td>
<td>2:4: Nat 5:6a Province 6b: municipalities</td>
<td>2:4: 26 nat. maintenance centres</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>114 km</td>
<td>14700 km</td>
<td>360000 km</td>
<td>48000 km</td>
<td>642 km private roads open to public traffic</td>
<td></td>
<td>2:3: - NRA (7 regional national Directories with 44 divisions); 5: County councils 6: Local Councils of Local Adm. Units 7: Road owner</td>
<td>partly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>March 15-November 15</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The table includes data on the length of different types of roads in different countries, along with information on the authority responsible for their maintenance, the organizational units, and the winter period for snow clearance.
<table>
<thead>
<tr>
<th>Country</th>
<th>Motorways, Trunk Roads</th>
<th>National roads</th>
<th>Regional roads</th>
<th>County roads</th>
<th>Local and urban roads</th>
<th>Other roads</th>
<th>Authority</th>
<th>Org. Unit</th>
<th>privatised</th>
<th>Winter period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>730 km</td>
<td>8500 km</td>
<td>33000 km</td>
<td>36000 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GB) United Kingdom</td>
<td>3400 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>440 km</td>
<td>30000 km</td>
<td></td>
<td></td>
<td></td>
<td>105000 km</td>
<td>25000 km</td>
<td>state local</td>
<td>1: 8 centres</td>
<td>partly rented vehicles</td>
</tr>
<tr>
<td>(HR) Croatia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>2700km</td>
<td>2700km</td>
<td>12000</td>
<td>7600 km</td>
<td>2000 km</td>
<td>Nil</td>
<td>2..7: local</td>
<td>1..7: Nat:</td>
<td>30 duty engineers (1 per local authority) 200 - 12000km</td>
<td>11.01. - 04.30.</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>7500 km</td>
<td>19300 km</td>
<td>2700 km</td>
<td>37000 km</td>
<td>municipal roads</td>
<td>90000 km</td>
<td></td>
<td></td>
<td>: 70 Centres partly</td>
<td></td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>2500 km</td>
<td>&lt;&lt;&lt;</td>
<td>800 km</td>
<td>6300 km</td>
<td></td>
<td>6a: 700 km</td>
<td>6b: 56000 km</td>
<td>2.4: Nat</td>
<td>2.4: 26 nat. maintenance centres no</td>
<td>March 15 - November 15</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>114 km</td>
<td>14700 km</td>
<td></td>
<td>36000 km</td>
<td></td>
<td>48000 km</td>
<td></td>
<td></td>
<td>2.3: NRA (7 Regional national Directorates with 44 divisions); 5: County councils 6: Local Councils of Local admin. Units 7: Road owner</td>
<td>partly</td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>1500 km</td>
<td>13500 km</td>
<td>&lt;&lt;&lt;</td>
<td>83000 km</td>
<td></td>
<td>284000 km</td>
<td>private roads</td>
<td>2.5: SNRAs (7 regional directorates) 6: Local Authorities (municipalities)</td>
<td>2.5: 139 M. int. centres (about 500 - 1000 km of road in each area) 6: the municipalities (differs very much in size and organisation of maintenance</td>
<td>2.5: yes</td>
</tr>
<tr>
<td>(SLO) Slovenia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 2.1.1: Organisation of winter maintenance for different road classes in European countries. In countries, where one of this classes doesn't apply, this is marked with ">>>" or "<<<" (pointing to the appropriate class to the right or to the left).
4.2.2 Information Provision

Introduction
This section deals with the systems that furnish information necessary for the provision of winter maintenance. There are 5 main headings:

1. Meteorological information
   What is the contract/practices of the meteorological office?
2. Technical and organisational systems of data collection
   Determination of the most suitable system of transmission of information
3. RWIS “Road weather information system”
4. Thermal Mapping
5. Systems of control posts and patrols

The responses of the various countries are given in appendix 2.

4.2.2.1 Meteorological information
Most of the countries surveyed have formal arrangements with their national meteorological agencies.

In France, each local administration must pay for the service from the meteorological organisation. There is neither a national contract nor centralisation.

In Denmark, the Danish Road Directorate has an agreement with the Danish Meteorological Institute since 1983. The service includes weather station forecasts, five-hour forecasts and radar images.

Considering the tradition and practises, almost all-contributing countries have a national agreement and contract with their respective meteorological institute. However, the service received depends on requirements. For example, all countries receive weather forecasts, while a few countries like Norway, Sweden, The Netherlands, Hungary and Finland also receive satellite pictures.

Not surprisingly, the forecasts received vary depending on the needs of countries. Most of countries are working with a forecast range of up to 24 hrs. ahead. For instance, Switzerland operates with 24 hour road weather forecasts and meteorological forecasts from “Meteotel”.

There are also a few countries like Austria and Sweden, which operates with 2-4 hour forecasts. These short terms forecasts enable the road authorities to prepare call outs in short time.

Other countries like Iceland operate with 6 day forecasts and Hungary with 72 hour forecasts for 6 regions.

4.2.2.2 Technical and organisational systems of data collection
This section deals with the systems that pass winter maintenance data to users in exact time and format.

All participating countries report using the media to distribute winter maintenance data to road users. The media can be either radio, television, telephone or fax or else all of them. Also, most of the countries have developed their own systems involving web-based solutions.

The biggest differences are in the manner data is collected and presented on road weather information systems. Both web-based systems and other transfer methods are used. Denmark passes information by file transfer to user’s PCs. In
Finland the winter maintenance operational centre has network access to the weather bureau server, internet based service. There are also fixed line, telephone line and mobile connections and services available. Germany has online connections between the ice detection systems to RWIS centres and regional centres of the German Weather Forecast bureau (Deutscher Wetterdienst).

In Spain, the collected information is sent to a central data bank through the transmission network by telephone line. Sweden uses a password protected web system. And in Norway, the information is sent by satellite to five main locations. It is then transmitted to users via their Intranet and presented in web applications.

Raw sensor data are generally not readable in their initial state mainly because the sensors collect through some specific algorithm. These data are then transferred to either a meteorological institute or a road agency for translation or conversion to a format that is readable and functional for road authorities.

The data transfer protocols used seem to vary between countries and manufacturers. The selection of a suitable protocol involves a compromise between the goals of speed, price and security.

4.2.2.3 RWIS (Road Weather Information System)

The main purpose of RWISs is to provide weather and pavement information to support winter maintenance operations - particularly snow and ice control. The on-line information includes air and road surface temperature, precipitation, road condition, freezing point, wind data and visibility from automated sensors.

The Road Weather Information System is also a tool in the decision making process for icy road driving safety. The object is to maintain satisfactory traffic fluidity and safety on roads during a winter season.

The system highlights icy driving situations before they actually arise, enabling preventive salting before it becomes icy.

All road agencies surveyed collect some weather data from their own weather stations. The number of RWIS stations ranged from 4 in Romania to over 680 stations on the Swedish National Roads. In addition to basic air temperature, humidity, wind and precipitation measurements, most of the stations also include road surface temperature and condition information. Some are equipped to provide data like freezing point and residual salt amount.

Reliability of RWIS information should be considered with a degree of caution.

The interpretation of the sensors measurements in describing the behaviour of physical laws seems to vary from one product to another. Also most of these sensors require ideal conditions for accuracy. These factors are related, which makes accurate measurement difficult. This is especially true concerning road surface parameters such as freezing point, residual salt amount and salt concentration.

Almost all of the data from the road agency weather stations is made available to their meteorological agencies.

The period for provision of RWIS forecasts depends on the climatic zone in Europe. For example the forecasting period is from 1 Oct to 30 April in Switzerland and from 15 Nov. to 15 March in Romania.

Criteria used to locate stations seems to vary between countries. In Romania, the RWIS stations are located at critical spots on mountain, plain and hill roads while in Austria, the stations are set up at the coldest points of the roads and bridges.

In Denmark, the stations are found at the so-called white spots. In Germany, the stations are predominately in the critical parts of a road. Usually RWIS stations are located throughout each country at places where the conditions are known to be difficult, places on the road which first become icy when the temperature approaches freezing point.
The arrangements for monitoring, servicing and calibration of road weather stations is extremely important. In Ireland, station sensors are calibrated pre-season (October) and mid-season (January). The stations and sensors are checked for functionality and accuracy on a continuous basis by a central computer and serviced immediately once a fault is detected.

The frequency or density for placement of RWIS differs between countries. It seems to be a function of the requirements and size of a country. In Finland there are 280 stations with a spacing of 29 km/station. In the Netherlands there are 301 stations with a spacing of 29 km/station. Switzerland has 400 stations, Norway 180, Germany 600 and France 500 RWIS stations. These countries did not mention density.

4.2.2.4 Thermal Mapping

Thermal mapping involves measurement of radiated or reflected heat and it's conversion into real-time pictures or images. A thermal map is an analogue pictorial representation or visualisation of temperature differences. All objects above absolute zero (-273 degrees) emit radiation, some of which is infrared. Depending on temperature and emissivity, most objects in the world can be thermally imaged, including roads.

White spots on the road are the stretches, which first become icy when the temperature approaches freezing point. The white spots are known to some extent from local experience but a more reliable method is by thermographic measurement.

When thermal measurements are used for winter maintenance, the object is to draw a thermal profile of the road and from that to determine the white spots. These are the locations where risk of icy roads is greatest when the temperature drops towards freezing point. It is also here that preventive measures are first initiated. Depending on local practice which seems to vary between countries road side weather stations can also beneficially be located at these cold spots.

The readings are therefore also used for checking and calibrating of the icy road stations, and for data collection for thermal maps (thermal mapping).

Changes in climatic conditions during measuring can have a significant influence on the results, therefore it is recommended that at least three independent measurements be carried out during different conditions, and again every three or four years.

Most countries utilise this technology simply to find the white spots which are the places where the temperatures are lowest and/or have winter maintenance problems.

However in countries like Ireland and the U.K the thermal mapping is a fundamental element of the forecasting software. Thermal mapping surveys define relative surface temperature differences along highways at night in different weather conditions. This data is used in the RWIS forecasting software to provide forecast maps for up to 24 hours ahead, of road surface temperature across the complete highway network. The software tells the decision maker not only which sections of road will freeze during the coming night, but also the timing of the process.

In some countries like Ireland, there is concern about the number of repeats of thermal mapping surveys required. Frequent repeat surveys are required when pavements are resurfaced with e.g. porous material which have different thermal properties to the original material. Thermal mapping is done in winter while resurfacing occurs in summer time.

There are few countries where thermal mapping has low relevance like in Germany, Switzerland, Hungary and Slovenia and there are yet other countries that apparently do not use the technology at all.

The area of climatic domains in km² and the frequency of thermal mapping repeat surveys varies between territories, varies with the needs and requirements of countries. For instance, thermal mapping is not carried out regularly in Sweden and only to locate white spots where RWIS stations are placed. In Denmark on the other hand, thermal mapping is at 5 year intervals and does not occur systematically. In Spain it happens at irregular intervals.
4.2.2.5 Systems of control posts and patrols

A system of control posts and patrols is employed when needed or as a daily task in most participating countries. For instance, in France, where patrols are an important part of adverse condition detection they take place daily in the early morning if there is a risk of frost. In Romania a daily patrolling occurs between 3:00 – 5:00 a.m. and 3:00 – 5:00 p.m., when it is necessary depending on meteorological conditions. In Norway and Sweden the operators on duty are out on road inspections more frequently when slippery conditions are expected.

In the Czech Republic it happens only when weather conditions are critical. This is also the situation in Switzerland, The Netherlands and Denmark and Austria.

Most RWIS systems are in continuous use on-line. These systems can also give visual and acoustic alarms. The alarms are activated by weather and road sensors. While an RWIS is an advanced system it has its limitations. The system is able to alert when frost or sleet occurs, but has its limits when drift or snowing appears especially if it happens locally. While RWIS stations can identify different types of precipitation, patrolling is sometimes necessary to check precipitation conditions at locations distant from the stations. This enables authorities make correct decisions. However there is no doubt that the availability of RWIS technology has reduced the extent that control posts and patrols are needed.

According to our survey it appears that no countries use an expert system to take the intervention decisions or decide other actions (give an alert or send a patrol...)

4.2.3 Methods

4.2.3.1 Preparative programme for winter activities

The duration of the winter maintenance season varies between climatic regions. No general rule can be established. In the Alpine and mountainous regions, the winter maintenance service generally lasts from 15 October to 15 April and in severe winter regions, from 1 October till 30 April Some mountain passes at high altitude may be opened by end of May only or even later (Switzerland). In the Atlantic region, severe weather conditions are probable from December until February. The period is longer in the north.

The preparative activities however, start much earlier, as they have to be completed before operations start.

It has to be noted that a missing or incomplete winter maintenance plan is organisational neglect in the legal sense and may therefore have consequences of liability.

Preparations differ slightly from one country to the other, according to organisational and other circumstances. Details are given in the respective country reports.

They generally include:

- Contracting out (CH, DK, H, N, S, UK,...)
  - assignment of contractors
  - duration of contracts (e.g. 3 years)
  - compensation
  - management system
  - quality control

- Preparations on the road adjacent plot of land.
  - snow fences, parapets. Accessibility to the
  - check up of the ice detection systems
• marker posts for snow clearing
• special signalisation for the winter period
• preparation of snow deposits
• check of water outlets and drains
• check of roadside trees, cutting of loose branches

→ Route planning
(Ch, D, DK,
NL, RO, SF...)
• road categories
• priority levels
• service levels, type of treatment
• detailed ploughing and salting schedules

→ Stand by organisation
• planning of regular crew stand by (24 hrs or reduced), presence in the maintenance centre or duty on call at home
• emergency planning
• providing accommodation

→ Weather forecast
• organisation, contracts
• warnings in case of special events
• dissemination to all interested parties

→ Operation
• winter administration system
• information of road users and institutions like police, public transport, hospitals, fire brigades, etc.
• alternative route planning (closures)
• inspection, quality control
• documentation, statistics, reports

→ Equipment
• availability of the necessary equipment
• equipment check incl. spare parts (checklists)
• workshop availability

→ Material
• procurement and stocking up of spreading materials, fuel and lubricants

→ Crew instruction
• tasks in winter maintenance
• general organisation, turnouts
• vehicles and engines
• stand-by organisation
• instruction on tools
• weather forecast systems and ice warnings
• preparation of group leaders
• instruction on route planning, service levels and priority levels
• dosage of salt according to RWIS-forecast and residual salt
• ploughing in teams
• what has to be done in case of accidents
• reporting
• test drives and training of new operators
At the end of the winter period, usually not before end of March:

- removing of winter road signs
- removing of snow fences
- repair of all damaged material
- cleaning of depots;
- cleaning, repair and storage of all winter equipment.

4.2.3.2 Route optimisation

Route optimisation is based on:

- priority levels,
- road categories
- service levels, type of treatment
- available equipment

The speed of loaded vehicles and duration allowed for the task determine the optimal route. Drives with empty spreaders and turning manoeuvres should be avoided.

For every route a map document with all the indications and the necessary equipment is established. The drivers, whether permanent or private, operate according to the route document. (Denmark, Finland, Germany, Netherlands, Romania, Switzerland...)

GPS is used in Denmark to locate operating vehicles and to supervise clearing and spreading operations. Such equipment also allows communication between headquarters and drivers. When GPS is used, headquarters can follow the state of operations and issue information to the road users on actual road surface conditions.

Service objectives vary between countries and, of course, according to road class and priority levels.

For main traffic arteries, such as multilane motorways, national trunk roads, main urban thoroughfares, access roads to police and fire brigade stations, a period of 1.5 hours (Netherlands) or 2 hours (Germany, Switzerland...) for one treatment is standard.

Service objectives are fixed in standards and contracts.

4.2.3.3 Prevention

Strictly speaking there is no way to prevent snow. However snow fences enable the amount of accumulated snow to be reduced considerably in certain conditions. Prerequisites are optimal shape and dimension of the fence taking account of wind speed and direction and of course the optimal choice of location.

Availability of suitable sites has to be considered. Planting of vegetation may also help to prevent snowdrifts.

Preventive treatment against slipperiness of the road surface gives good results. Accurate road weather forecasts coupled with a reliable ice detection system is indispensable to avoid an excessive consumption of thawing agents. Furthermore, a well-organised stand by service around the clock has to be provided.

Preventive treatment is normally done with prewetted salt.

Against avalanches there exist several possibilities:

- snow sheds
- earthworks
- wide road ditches
- supporting structures, nets
- road bridges

- all types of avalanches and terrain
- diverting and collecting earth dams. Earth mounds. Gentle terrain and small and medium-size avalanches
- small avalanches only
- for small snow avalanches, falling rock and ice
- small and medium sized avalanches where roads cross ravines
• relocation of roads mainly in gentle sloping terrain where the relocation may be limited in length
• blasting several types of blasting techniques, radio and cable-controlled detonation of pre-planted charges and use of cableways
• detection of avalanches avalanches are detected by geophones which can switch on red lights at the roadside
• tunnels all types of avalanches

Traffic controls are sometimes necessary to protect roads which are sensitive to freezing-thaw cycles during the winter thawing period. They consist of a timely restricted weight limit for heavy traffic. They usually require an order or decision by the local administration (France, Romania...).

4.2.4 Equipment
4.2.4.1 Number of operation centres
Winter maintenance is administered by surveillance centres (also called operation centres) which maintain a certain length of road network or a section highway and branches of junction belonging to it. The number of surveillance centres and the maintained road length are given in the country reports and practices differ. For example, there are 18 surveillance centres in Iceland and more than 800 in Germany.

It is the winter maintenance administration that defines the crew and equipment of the surveillance centre. It also depends on the levels of service of the roads for the centre is in charge.

In some countries, motorways surveillance centres are independent of the surveillance centres of the other roads (Belgium, France, Germany, Hungary, and Romania). In other countries, the area of the surveillance centre can be responsible for all types of roads. In this case, the limit of action is generally political (in Switzerland the limits of intervention are generally defined by canton borders). In another country (Sweden) the maintained road network is divided in contract areas. There are about 140 maintenance contract areas in Sweden. The maintenance contract areas comprise between 600 and 1,000 kilometres of road.

Apart from Sweden, the maintained road length of surveillance centres are typically the following:
- For motorways: from 45-55 km to 70-75 km
- For other roads: from 200 to 350 km

It is not possible to define the optimum number of surveillance centres because it depends on many factors:
- the severity of winter, type of meteorological events faced
- type of road network and traffic (number of lanes...)
- road levels of service
- country standards and political organisation (state or contractor)

4.2.4.2 Number of machines
The number of vehicles per 100 km of road depends on:
- the length by service category of the roads maintained by the surveillance centres, i.e. the deadline within which the first round of the action must be carried out,
- the actual performance of trucks,
- the climatic zone (=> different type of intervention).

Reported machinery per surveillance centre are as follows:
In Iceland, 1 vehicle per 50 - 120 km is given depending on the service category of the roads.

For the countries where vehicles are rented from private companies, data is available only about the numbers of snowploughs and demountable salt-spreaders owned by the roads authorities.
In another country (U.K) the Highways Agency’s operational vehicles are for routine use on motorways only. In these cases the number of needed vehicles depends on the local practice at the operational centres i.e. “maintenance agencies are notified each year of the operational vehicles based with them, from which compounds they should operate and on which roads they should be used. “

In Sweden e.g., a total of 820 kilometres of road (cycle and pedestrian paths not included) is maintained by a vehicle fleet consisting of the following: 5 own trucks, 12 contracted trucks, 1 road graders, and 14 contracted tractors.

4.2.4.3 Manning of equipment

One man operation is the norm for salting and snow clearing simultaneously. But for hard snow and use of large snowploughs, there is usually a driver’s assistant (Czech Republic, Iceland, Hungary...)

With winter maintenance equipment mounted trucks, it is the rule on motorways to always act in a fleet or group. However, in Ireland the overtime issues can be problematic, under severe conditions 2 or 3 shifts could be organised for all equipment by the operation centres, as well.

4.2.4.4 Other equipment

- Spreaders:
Spreaders are categorised everywhere by the performance and automation-level.

**Types of spreaders:** Most are demountable, for spreading of dry salt (these type of spreaders are used for gritting, as well), wet (pre-wetted) salt (= dry salt + brine) or brine.

**Main technical parameters of spreaders:** the volume of the hopper is 4 to 6 m³ for dry salt + 2 m³ brine. Spreaders can be up to 7 or 9 cubic meter capacity depending on the truck, too. Spreading width is 4-12 meters. Modern spreaders in general spread at a rate 5 - 40 g/m² of salt or pre-wetted salt or 250- 350 g/m² abrasive proportional to the road width. Rate and width of spread are often fully controlled from the cab by the driver.

**Performance of spreaders:** According to practice in the Czech Republic one spreader covers 33 km of carriageways in average (sand spreader less, salt spreader more km). Length of a two lane roads for a circuit of a spreader could be 15 to 40 km depending on the importance of the road, the service level, the rate and width of spreading (see country reports). In some countries the number of equipment units recommended depends of the road’s levels of service (France).

- Snow ploughs

Snowploughs are in use for snow removal from the road surface.

The types of ploughs are one wing (angle blade) or two wings (V blade) superstructures.

**V blade** are used less on motorways. V blades are very useful and used instead of snow-cutters in light snow, or in snow-drift of 30 – 70 cm. They are in use in several countries, especially in the mountains mounted on a truck with 240 kW (or more) motor performance.

There are also side-mounted snowploughs which enlarge the working width. Blades of ploughs are protected against collision, and the windshield against swirling snow. Truck mounted blades (on one or two wings ploughs, too) made from plastic or steel are commonly used for clearing up to 50 cm of height of light snow.

**Working width** of snowploughs range between 3 – 6 m according to the width of road to be cleared. There are no significant differences among the practice of the countries.

- Plastic tips are fitted to protect blades from damage. They can be changed when necessary.
- Steel blades are generally used when the pavement is very regular (typically on motorways).

**Self-propelled snow cutters or attachments** are used for heavy snow (snowdrift with a height of more than 50 cm). There are graders to handle ice ridges, if it occurs, snow loading equipment, and rotary blowers used on stretches of rural road. On urban roads where the snow can not be removed to the side blowers are necessary to load the snow on to lorries. There is also loading – unloading equipment i.e. pay-loaders or conveyor belts.
However, the extent to which these accessories are used depends on the climatic characteristic of the country in question, e.g. where strong wind occurs causing snow-drift, more snow-cutters are necessary.

- **Storing of salt:**
  According to the general practice salt is stored under roof.
  It can be stored either in barns (up to 4000 tons) or in silos (200 tons per silo) made of non-corroding materials. The advantage of the silos is the short time needed for loading (2 - 3 minutes), which can be done by the driver alone. Indeed with good disposition of the silos, 2 - 3 spreaders can be loaded at the same time. Gritting materials are stored in great covered buildings or on asphalt platforms, where water discharge is ensured.
  In France and the NL, there are national guidelines for correct storage of salt.
  For the environmental reasons, it is very important to collect the water coming from salt depots. In some countries, the collected water is used to make brine.

- **Standards for devices for fastening equipment to lorries**
  Lorries are equipped with standard clamping devices (plate and hydraulic) produced by the manufacturer of snowploughs. Spreader attachments are fixed on lorries with retaining devices produced by the manufacturer of spreaders. In practice the German and Norwegian standards are mostly used. France has its own standard.
  More information is given in section 1.2: Standards.

- **De-icer spraying installations, road heating**
  **Only a few automatic de-icer brine-spraying** installations are in operation.
  Automatic de-icer spraying installations are in operation in Switzerland, Austria, NL, Denmark... on specific stretches with a particular microclimate or which are particularly exposed and/or far away from winter maintenance centres. A couple of installations are on high bridges, or on a stretch with heavy traffic (80'000 vehicles per day) and particular microclimate. De-icer spraying installations are used on urban roads, as well. For example, two short sections of urban roads in Prague (100 meters each) are equipped with automatic brine spraying from stationary facilities. These automatic de-icer brine-spraying installations are still very expensive, and are more generally used on airports.

  **Road heating** is not used in general. There is however on a particularly exposed bridge a solar energy pilot application in operation since 1995 in Switzerland. A heat exchange tube system embedded in the asphalt layer of a bridge, covering a surface of 1300 m², collects heat during summer and utilises it during frost periods in winter, to heat the bridge surface, thus preventing the formation of ice. The liquid is stored in an underground heat store.

  An additive mixed into the asphalt pavement can delay ice formation. These pavements additives are used on a few stretches in Switzerland for example. The product is not a substitute for winter maintenance, but can delay the formation of ice on particularly exposed stretches.

4.2.5 **Materials**

Classes of material are spread to mitigate the effects of ice & snow in Europe.

- **Chemical de-icing materials** are substances which modify the properties of snow and ice by physical and/or chemical means.
- **Abrasive materials** are substances capable of mechanically increasing the friction coefficient of icy or compacted snow layers on the road surface.

4.2.5.1 **Description of chemical de-icers**

- **Principles of chemical de-icers.**
  Chemical de-icers prevent ice formation or melt snow by the depression of freezing point of water to well below 0°C. The freezing point of a solution drops as the amount of solute in the solution increases. However, this drop is not infinite. The lowest temperature to which freezing can be lowered is determined by a point on the phase diagram of any given solution known as the “eutectic point” (-21°C for sodium chloride and – 52°C for calcium chloride) Any further addition of solute at this point will only result in precipitation, as the solution is saturated.
When chemical de-icers are spread on roads covered with ice or snow, some de-icer dissolves and melts the ice or snow to produce a solution (e.g. brine). If ice is in excess, all the de-icer will dissolve and the solution will continue to melt ice until there is equilibrium with the remaining ice at the system temperature.

There is a common misunderstanding that de-icers should melt all ice and snow on the road. To do this would require large quantities of de-icer which would be economically ineffective and possibly harmful for the environment. The key function of the de-icer is to break the bond between the road surface and the overlying ice. Passing traffic then breaks up the loosened ice or snow and disperses it from the trafficked area of the road. An even more efficient use of de-icers is to apply it preventively, so that the ice/pavement bond does not form. In marginal climates, such precautionary work can significantly reduce the amount of de-icer needed to keep roads free of ice and snow.

It should be noted that in de-icing situations, the effectiveness of all chemical de-icers will reduce well above the eutectic point, as the rate of solution slows considerably.

**- Properties of chemical de-icers.**

The substances used for road winter maintenance today are sodium chloride, calcium chloride, magnesium chloride, urea, alcohols, glycols and C.M.A. (calcium magnesium acetate) and other magnesium acetates.

**Sodium Chloride (NaCl).**

NaCl is the most widely used de-icer in Europe. It is extracted from salt mines (rock salt) or obtained through evaporation (solar or vacuum salt), remaining effective to about –15°C depending on the particle size (eutectic point -21.2°C). It is used as a dry solid, a damp solid (prewetted) or brine depending on local conditions and operating procedures.

The particle size distribution of salt used across Europe differs from country, depending on local practice. The range varies, the widest specified range being 0-10mm. Particle size distribution is important, as fine particles start to act more quickly, but coarser material gives a wider spread. There is insufficient evidence to indicate the optimum size, but it is vital that vehicles are calibrated to the material in use.

The product is usually supplied in bulk, to an agreed specification. An anti-caking agent is needed to ensure that the salt remains free flowing in storage. The anti-caking agent used is usually a hexacyanoferrate (II) salt, either the potassium or sodium salt.

In some areas prewetted salt is used. The prewetting fluid is commonly sodium chloride brine, though calcium chloride or magnesium chloride brines are also used.

Sodium Chloride needs humidity to form a solution, and the process of dissolving is endothermic, i.e., some energy is taken from the surroundings causing slight further cooling of the road surface. Factors such as dry conditions, wind chill, low traffic density, cloud cover, and ambient temperature can, therefore, affect the melting capacity of this salt. In practice, sodium chloride is efficient down to around –8 deg C, and becomes ineffective at - 15 deg C. At low temperatures, calcium chloride or magnesium chloride are sometimes used in conjunction with sodium chloride brine as prewetting agents, due to their exothermic effects. The price difference between those products is also a determining factor in decision making.

Whilst having low toxicity, and being cheap and effective, salt has the potential to corrode metals and be harmful to vegetation and ground water. These adverse effects can be minimised by careful spreading and road design.

**Calcium Chloride (CaCl2).**

This substance is a by-product of soda manufacturing. It is hygroscopic but very efficient at low temperatures, down to -35°C (eutectic point -55°C). It is used in solid state or brine with CaCl2 concentration varying between 15 % and 32 %, according to the conditions. The most commonly used solution is a 26 % brine. As the price is currently about 6 times that of common salt, it is usually only used as prewetting agent for sodium chloride.
It is supplied as flakes with a thickness of approximately 1.25 mm and maximum size of 20 mm. Its calcium chloride content is typically 77 – 80%. It is supplied in 50 kg sacks, tightly sealed to avoid storage problems due to its hygroscopicity. If exposed to moisture eg through sack damage, calcium chloride hexahydrate is formed, rendering the product useless for winter road maintenance. Therefore, the product must be handled with care, bearing in mind its high cost.

Unlike sodium chloride, dissolving calcium chloride is exothermic. In other words, it gives off heat that helps to melt ice or snow. Also, its great hygroscopicity allows it to absorb the humidity from the air and ice. However, the hygroscopicity causes the road surface to remain wet for considerably longer than when sodium chloride alone is applied.

Swedish research into calcium chloride has shown the chemical to be associated with concrete damage. It has also a harmful effect on the vegetation. In Sweden it is therefore not allowed for use in winter maintenance.

**Magnesium Chloride (MgCl₂)**

This substance is mainly a by-product of potash manufacturing and is used in a solution form. It is a very hygroscopic substance mainly used for de-icing operations. It is used at temperatures lower than -9°C (eutectic point -33.5°C). The product comes direct from the factory as a brine solution.

Like CaCl₂, MgCl₂ can result in wet slippery roads through moisture absorption. MgCl₂ has also been associated with reduced brake efficiency in some motor vehicles. As NaCl, this salt has the potential to corrode metals and be harmful to vegetation and ground water.

**Urea [CO(NH₂)₂]**

This is a crystalline substance supplied in granular form of 1 – 2 mm diam. It is not corrosive but is very light and easily blown by the wind, and needs a carrier such as water or sand to be efficiently applied. Its price is very high, eight times more than that of common salt. For this reason, its application is reserved for special cases such as airports and structures particularly susceptible to corrosion.

In addition, the nitrogen content can cause problems with over-fertilisation of verges and in extreme cases eutrophication of nearby water sources and harmful effect to the fish nutrients.

**Potassium carbonate (K₂CO₃)**

The City of Vienna is using this de-icing material between 0° and -8°C in a mixture with grit. The ratio K₂CO₃ : grit is normally 1:10. Potassium carbonate is containing no chloride, whereby contamination of the soil with chloride is avoided.

Potassium carbonate is hygroscopic and clumps in connection with water and grit, thus the transport equipment within the spreader are very often blocked.

On the other hand the price is more than 8 times higher than the costs of salt. Another problem is the excessive corrosion at spreaders and winter maintenance vehicles.

**Alcohol and Glycol.**

These products are very expensive and are mainly used in airports, applied by spreading machines capable of covering 16 m width. They are practically never used in winter road maintenance.

**C.M.A. [CaMg(CH₃COO)₂] and other magnesium acetates**

In several countries including USA trials have been carried out with Calcium Magnesium Acetate (CMA) with the following results:

- The product has a low density and is very fine, causing some problems in handling and spreading (dust accumulation).
- The eutectic point of C.M.A. is -5°C.
Some workers were affected by tracheal problems and dermatological conditions on hands. Operators have to wear gloves and nose and mouth protection masks.

C.M.A. has a low durability and has little effect on soil and vegetation, compared to NaCl or CaCl₂. It seems that in general C.M.A. could be less harmful than normal salts. However, large-scale tests have still to be run. C.M.A. does not melt ice or packed snow as quickly as salt. To obtain a comparable level of efficiency 2 – 3 kilos of C.M.A. would be needed for every kilo of salt. The de-icing action of C.M.A. can be accelerated by mixing it with sand at rate of 2:1.

The price is very high and the product can only be economically used on structures that don't tolerate chlorides. Therefore, in the short term, the widespread use of CMA cannot be considered, since the all-round advantages of chlorides are greater.

Other magnesium acetates such as potassium magnesium acetates are used occasionally in sensitive areas such as bridges, but are more usually used on airfields.

- General evaluation of chemical de-icers.

From the above analysis, we can conclude that the most recommended de-icers for winter road maintenance are Sodium Chloride and Calcium Chloride (attention! - CaCl₂ has negative effects to the concrete), while Urea, Alcohol's and Glycol's can only be used under certain circumstances due to their prohibitive prices. From this point of view, we will therefore concentrate on de-icers recommended for winter road maintenance; i.e., Sodium Chloride. These may be used in a granular form, separate or mixed, in a solution (brine), or in mixture of salt and brine (pre-wetted).

According to the characteristics of the snow or ice, one or another system should be put into practice (see chapter 4.3.3).

4.2.5.2 Description of abrasives

The use of abrasive grits is the oldest winter maintenance method. The types of gritting material generally used are the following:

- natural aggregate - exploited (e.g. graded aggregate/gravel)
- crushed (various grading of angular chippings)
- synthetic aggregate (e.g. granulated blast furnace slag)
- waste material (e.g. cinder from fossil fuel).

The following chemical and physical conditions are assumed:

- the material is not allowed to contain toxic or other harmful substances (the maximum limits of such substances are generally defined)
- adequate grading of material is required, usually between 0,5 and 8 mm, sometimes between 0,3 and 16 mm.
- particles shall be sharp edged (rounded material is entirely unsuitable)
- one dimensional edge of particle shall not be excessive (flat particles are not suitable)
- the material shall not contain clay.

4.2.5.3 Spread materials practice in Europe

The evaluation of de-icing agents has been widely discussed throughout Europe for many years, with a greater or lesser scientific basis. Heated debate has focused particularly on the relative merits of abrasives versus chemical de-icers, with salt being banned in some areas at times. Today it is widely recognised that it is unrealistic to exclude salting from winter maintenance on environmental grounds. Extensive research (e.g. in Germany and Switzerland) has shown that treatment of winter roads with abrasives alone is not an alternative to salt application on grounds of cost effectiveness and environment. Salt is essential for maximising traffic safety.

Analysis of national reports (see tables in 4.3.3) has shown that the most used spread material is salt, the ordinary Sodium Chloride NaCl. The NaCl salt has been chosen as it balances advantages and disadvantages better than the other types of salt. Over the last 20 years, many countries searched and tested substitutes but no suitable alternative has...
been found. The tested substances were either too expensive or did not give the required results. That is why nearly all European countries use Sodium Chloride (NaCl) for winter maintenance on roads of higher service level, which logically have higher traffic densities. Except in unusual circumstances, all motorways are spread with salt alone.

In practice the spreading of other types of material is highly heterogeneous. Calcium chloride (CaCl₂) and also magnesium chloride (MgCl₂) are sometimes used with sodium chloride. Urea, glycols and alcohols are occasionally used, particularly on bridges and footpaths.

Abrasive materials, eg sands or grits, are predominantly used within various technologies of spreading. In some countries, also various kinds of slag or cinder are occasionally used (see tables in chapter 3.3). The abrasive materials should not contain toxic or otherwise harmful substances. The materials should not contain clay.

The recommended grading curve ranges is within 0,5-8 mm. For black ice spreading, fine-grained material (grain size < 2 mm, typically sand) is more suitable. On the other way, a material of higher content of rough fractions (grain size > 4 mm) is used for spreading non-icy packed-down snow layers on the road surface and therefore, mostly various fractions and different kinds of rubbles are applied. As for cross-town links, use of materials with grain size > 8 mm is not recommended. Nevertheless, in view of vehicle windscreen damage, a maximal grain size up to 4 mm is recommended.

Gritting materials are more used for secondary road network and/or communal roads. In fact, gritting is predominantly used on roads with small traffic density and mostly in higher topographic locations. The gritting is usually applied on sections of great transport significance or on spots, where traffic conditions and technical state of road call for it (crossings, steep upgrades, sharp curves, stops of bus lines, etc.).

Practical experiences point out a series of defaults and problems with use of gritting materials in winter road management: increased dustiness of the environment occur as well as relatively low effectiveness in time for use of the materials—after passage of a higher number of vehicles, an intensive cast away from the pavement surface occur so that frequent repeated spread is needed and all that is to considerably increase financial demands of winter maintenance, accompanying process of that is also excessive sewage clogging, problems with scrap and removal or recycling of used material, etc.

For increasing the effectiveness of gritting materials use, it is recommended to apply these materials in frame of new technologies as mixtures with salt and salt. Recently, very favourable results of tests have been also shown for sand wetted with hot water (Norway and Sweden).

4.2.6 Manpower, training and privatisation

4.2.6.1 Specific jobs

Winter maintenance activities require special skills, know-how and staff functions. The staff functions are identified in some of the country reports.

In Switzerland, staff of a maintenance centre usually consists of

• road master, responsible of the centre
• administrator, responsible for accountancy and administration
• 2 – 3 group leaders
• crews, drivers and other profession categories
• 2 – 3 vehicle mechanics
• 1 – 4 electricians, depending on the electro-mechanical installations along the highway

The group leaders are responsible for operational tasks. They decide on interventions based on the RWIS-system.

In France four specific jobs are defined for specific tasks.

• Meteorological watcher: he centralises all the meteorological information: predictions and actual weather (with weather stations or RWIS)
• Duty Officer: he takes the decision on a winter maintenance action and follows it’s development
• Patrol: he monitors the state of the road while driving, looks for frost, evaluates traffic conditions and eventually organises road cleaning . . .
• Vehicle driver: he operates a spreader/plough and submits a return on the activity on a memorandum slip
The Belgian local surveillance centres are organised in different functions:

- The centre manager is responsible for the daily operations on the road network
- The coordinators check all data on the road surface conditions and weather forecasts and decide when to treat the road - The staff members are in charge of the network inspection and turnout control
- The operators execute the winter activities (truck drivers, salt loader operators)

In Germany, the staff of a surveillance centre usually consists of a road master (manager of the surveillance centre), administrators and a crew leader who is responsible for quality control of operatives. There are also roadmen, mechanics and technicians.

4.2.6.2 Training and education

All staff should be properly and demonstrably trained. This obligation also relates to those carrying out the winter maintenance under contract.

In Germany, regular training and education of crews before winter is very important. Existing knowledge is reviewed and new information disseminated. Staff should be made sensitive to their responsibilities, which includes the provision of a fast, economical and ecological winter maintenance service.

Crew training, manager training, training centres etc.

According to the country reports, training contains in general some of the topics below (among others in Denmark, France, Germany, Ireland, Belgium):

- **Winter maintenance**
  - Winter events to be mastered
  - Tasks in winter maintenance,
  - Instruction on route planning,
  - Service levels and priority levels,
  - Developments in winter maintenance.

- **Organisation**
  - Organisation of turnouts,
  - Organisation of personnel and stand-by,
  - Preparation of readiness for action, reporting
  - Special measures in case of accident
  - Experience of the last winter (statistics, summary, etc.)
  - Changes for the next winter (new equipment, plans, rules, etc.)

- **Information Provision**
  - Weather forecast and meteorological observations, connection between weather and winter maintenance
  - Use of RWIS

- **Equipment**
  - Vehicles and engines,
  - Vehicles and equipment, operating instructions and practical training

- **Material**
  - Dosage of salt according to RWIS-forecast and residual salt,
  - Use of gritting materials
  - Ploughing in teams
  - Measures for low use of salt

Training is provided by the road authority itself or by professional contractors under the control of the road authority. The venues could be at specialised training centres (if available) or at the surveillance centres.
Training of the (truck) drivers

Truck drivers having the acceptable driving license do not attend special courses in general. In some countries (Hungary, Spain...) new drivers travel with the more experienced drivers, learning under real circumstances, until they have acquired enough knowledge and know-how in spreading and ploughing.

In other countries (Denmark, Norway) special training is given to drivers on snowploughs and gritting. Training of machine drivers take place within the local authorities themselves or organised in professional training centres.

4.2.6.3 Privatisation

A table at the end of the chapter presents current practices of the different countries concerning privatisation. Since winter maintenance is a seasonal phenomenon, the tendency is to increase the privatisation but it is not necessarily less expensive at the end.

There can be different levels of privatisation

- The execution => Trucks, drivers...
- The coordination => Surveillance and control centres
- The management => Responsibility

The management of winter maintenance is seldom privatised in Europe.

Private companies (contractors) / non governmental organisations

Surveillance centres are usually owned by the government road administrations (RA) in European countries. Winter maintenance standards and quality are also specified by Ras.

The special winter weather forecast system is also under control of the RA. The relationship between the RAs or surveillance centres and the private sector is contractual. Important aspects of this are the contract conditions and the quality of the completed work. The involvement of the private sector varies between countries but it could be up to 50% of the total costs of winter maintenance (see Table in Appendix).

Total privatisation

With total privatisation a private contractor may have full responsibility for maintenance over a district or along stretches of roadway (as is the case with some motorways in France). The contractor has to comply with standards or guidelines. He has to report regularly. His plans have to be approved and his performance monitored by the road owner. If he is not able to meet the demand or correct discrepancies within a time limit, there can be a financial penalty. In the Netherlands all the necessary trucks for the demountable spreaders and snowploughs are rented from commercial companies. By contrast, in other countries little winter maintenance is done under contract.

However interest in private sector participation in winter maintenance is increasing. In almost every jurisdiction there is a wish to allocate winter maintenance to private contractors. This could be delayed from happening though where there is a lack of experienced contractors or a moderate climate.

Partial privatisation

Partial privatisation is where private companies are only helping the staff of the surveillance centre. In a typical case the private companies provide drivers and vehicles, in general with equipment of the surveillance centre and work with the crew of the surveillance centre. In general there are three main types of contract with variations of the service delivered by the contractor:

- The contractor is in charge of a stretch of road for snow ploughing and ice control. He works with his own trucks. The maintenance centre provide ploughs and spreaders. The call-out is in most cases given by the maintenance centre.
- The contractor provides vehicles and drivers, who work together with the crews of the maintenance centre. Sometimes drivers of the hired trucks are registered by the RA.
- The contractor provides vehicles for the winter season.
Relationships between private companies and the contract manager

Practice is characterised by random inspections by the client. General rules could not be established for the relations between contractor and the contract engineer. Some of the practices are the following:

- There are meetings every month between the contractor and the road owner where results, problems and achievements are discussed in Norway.
- The contractor has to have a quality assurance system with regular inspections and a copy of the inspection reports sent to the owner. If non-compliance with specification is discovered a work order should be issued with a copy to the owner. The work order has to be signed and returned when the job is finished. A copy of the result and work orders are sent to the contractor. The contracts are normally for several years and the contractor gets a stand-by allowance in the winter period in the Netherlands.

In Sweden, different systems are used and their advantages and disadvantages given:

The SNRA "Construction and Maintenance" is the contract manager for 69% 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.

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. 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 efficiency 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 performance data 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 being 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 Swedish National Road Administration system for road weather information, RWIS. Through using special definitions, the data is translated into eight weather situations at hourly intervals.

The hour-by-hour weather descriptions are then summarised into clearly defined weather periods, for instance drifting snow for 6 hours or a snowfall lasting 20 hours to a depth 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 deemed representative for the maintenance area. Starting from each weather period the number of weather outcomes is calculated, this being the basis of compensation. In this manner, the connection is made between weather and the need to take measures.
<table>
<thead>
<tr>
<th>Country</th>
<th>PRIVATE JOBS</th>
<th>CONTRACTS</th>
<th>RATIO</th>
<th>TENDENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) AUSTRIA</td>
<td>Private companies can be commissioned to execute winter maintenance activities when the service is cheaper than the public service. The quality level may not be influenced negatively. The road administration (road master) decides and monitors all activities.</td>
<td>A public tender is necessary to award contracts to private companies</td>
<td>When the work quality is satisfactory the contract can be extended yearly.</td>
<td></td>
</tr>
<tr>
<td>(B) BELGIUM</td>
<td>The road and traffic organisation hires the services of many private companies (truck and drivers).</td>
<td>Private contractors execute the winter service. Local officials decide [??, rules, gives logistic support and controls??] in the Flemish region. In the Brussels area, winter maintenance is performed both by the local administration and by private contractors. In both cases the local administration staff decide, give logistic support and monitors the execution of winter activities.</td>
<td>As far as possible, the contracts are renewed each year with the same private companies.</td>
<td></td>
</tr>
<tr>
<td>(CH) SWITZERLAND</td>
<td>Snow ploughing and ice control.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CZ) CZECH REPUBLIC</td>
<td>Focused on snow removal and partly on road spreading.</td>
<td>Private sector is predominantly focused on the snow removal sphere (coupling the carriers to snow ploughs, V-blade, etc.) and partly on road spreading (lease of truck chassis for demountable spreaders).</td>
<td>Approximately 8% of the total road network</td>
<td>Private sector participation in winter maintenance is continuing to increase.</td>
</tr>
<tr>
<td>(D) GERMANY</td>
<td>Private companies only assist the work of the surveillance centre.</td>
<td>Several activities such as repair to safety barriers are in charge of private companies. Only in Thuringia, a state in the eastern part of Germany, are all activities like repair, mowing, rubbish collection etc. in charge of private companies. The private companies provide drivers and vehicles for snow and ice activities.</td>
<td></td>
<td>The question of which parts of road maintenance should be in charge of private companies is under discussion for some years.</td>
</tr>
<tr>
<td>(DK) DENMARK</td>
<td>Winter maintenance, snow clearing and maintenance of salt spreaders is by contract.</td>
<td>All the machinery aspects of winter maintenance (driving salt spreaders, snowploughs, trucks or other vehicles) are subjected to private tender in accordance with EU’s service directives. Maintenance of salt spreaders also includes a part of EU’s purchase directive.</td>
<td>Occurs on entire national roads network and most county roads.</td>
<td>This procedure is also being followed for most municipal roads.</td>
</tr>
<tr>
<td>(E) SPAIN</td>
<td>The reasons behind these contracts are: greater agility in negotiation, machinery acquisition and use of manpower.</td>
<td></td>
<td>Approximately one half of winter road maintenance is carried out through contracts with private enterprises.</td>
<td>??? These operations normally make up the development of the integrated conservation contracts. ???</td>
</tr>
<tr>
<td>Country</td>
<td>PRIVATE JOBS</td>
<td>CONTRACTS</td>
<td>RATIO</td>
<td>TENDENCY</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FRANCE</td>
<td></td>
<td>Generally there is some winter maintenance by private companies (men and vehicles). But for motorways, the toll companies undertake all of the winter maintenance responsibilities including surveillance and quality control.</td>
<td>A number of private companies do all the winter maintenance. The contract is based on result objectives (for example, the road must be black within two hours). Other companies are paid according to the number of turnouts or the quality of salt used. Sometimes an administrative agent must be in the private vehicle.</td>
<td></td>
</tr>
<tr>
<td>FINLAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNITED KINGDOM</td>
<td></td>
<td>The Highways Agency owns the operational and reserve spreading/snowploughing vehicles and snow blowers used for motorway winter maintenance in England. Maintenance areas are notified each year of the operational vehicles that are to be based with them, from which compounds they should operate and on which roads they should be used. They are also told the compounds where reserve vehicles and snow blowers are kept. During emergencies, reserve vehicles can be made available. The procedure for obtaining them is set out in the Regional “Winter Arrangements” publication. For maximum flexibility in severe weather conditions, however, it is considered advantageous for all operatives to be able to use the Highways Agency’s vehicles.</td>
<td>Private companies under contract maintain about 1600 km of public roads in winter.</td>
<td></td>
</tr>
<tr>
<td>HUNGARY</td>
<td>Hired trucks with drivers ; Certain stretches are contracted out completely.</td>
<td>Whole winter maintenance is done under “public utility contracts” Public utility contracts by state owned companies of public utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRELAND</td>
<td>Local authorities hire trucks and equipment in severe winter weather conditions</td>
<td>Currently little winter maintenance is done under contract.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICELAND</td>
<td></td>
<td></td>
<td>Private companies are involved in winter maintenance about up to 45%.</td>
<td></td>
</tr>
<tr>
<td>NETHERLANDS</td>
<td>Spreading and ploughing is done by contractors.</td>
<td>Trucks for the demountable spreaders are rented from commercial companies. These agreements are laid down in a contract for mostly covering several years. Most local surveillance centres have contracted several agents.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORWAY</td>
<td></td>
<td></td>
<td>There are 1700 i.e. 85 % private trucks that have a contract for snow clearing and 120 units i.e. 20% for gritting. Each contract is for approximately 50 km of road.</td>
<td></td>
</tr>
<tr>
<td>ROMANIA</td>
<td>Snow removal</td>
<td>The state (maintenance centres) owns most operational and reserve spreading and snow removal equipment necessary for normal conditions. In situations where they do not have sufficient equipment, it can be hired from other sources.</td>
<td>Snow removal is performed by private companies on about 10% of the road network.</td>
<td>SNRA has about 70 % subcontracts (men and trucks) in their maintenance contract areas while the private contractors have almost 100 % subcontracts.</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>Whole winter maintenance</td>
<td>In 1991, the Swedish Government decided that design and construction of new roads, all road operations and maintenance works within the state road transportation network, were to be contracted through competitive bidding.</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>SLOVENIA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Operational Organisation of Winter Maintenance

4.3.1 Getting information

During winter, it is important to deal with ice and snow problems in real time and quickly. The objective of this section is to understand how the European countries get their information and how they take their intervention decision. The details of the country organisations are in the country reports.

4.3.1.1 Meteorological forecast

In all European countries, meteorological products and forecasts are available in the operational centres. There are usually weekly and daily forecasts. At least twice a day, there is an update of the forecasts with meteorological warnings when necessary. In some countries meteorological radar information is available at the intervention centre (usually via Internet).

Generally all the forecasts are made by a governmental meteorological administration. There are two types of forecast specific to winter maintenance:

- Road weather bulletins giving 24 hours forecasts. It is a product of the general forecast models taking into account radar information on small-scale climatic regions (about 30 km wide for example).
- In some countries, RWIS information is used and specific forecasts are made for the RWIS (it can be for all the RWIS of a country or for some of them).

Usually the meteorological product is sent by fax or by Internet. There is always the possibility to make a phone call to the meteorological office.

There is always an arrangement for warning to be provided in case of extreme meteorological conditions.

4.3.1.2 RWIS

Road Weather Information Systems (RWIS) involve electronic weather monitoring outposts located throughout the road system. RWISs can provide data on wind speed, air, ground and road surface temperatures and rainfall. RWIS comprise sensors, outstations, installations and masterstations.

It seems that users have most confidence in RWIS systems which have centralisation of data collection. When there is a doubt or a problem, it is the job of the man on duty to fill the gap and a patrol is generally made.

In Ireland meteorologists manually fine tune the RWIS forecasts.

3.1.3 Patrols

For the countries equipped with RWIS and in particular the countries that have centralisation of the RWIS information:

- They make no or scarce patrols.
- There is a person on duty at a central level that activates a local organisation and the local organisation takes the decision of a patrol.
- The tendency is to make preventive salting when there is doubt.

In some climatic regions (mountain for example), patrols are less necessary because the intervention is generally due to precipitation.

Countries that make more patrols generally have less RWIS. They usually have patrols turnout with specific observation points and a formalisation of the observations.

Some countries also use information coming from police patrols.
4.3.1.4 Position of man in the decision process
When there is a centralisation of information (a RWIS network for example), the local level is activated by the central level.

When there is no centralisation there is a man on duty at a local level when necessary (it depends on meteorological forecast and local RWIS measures (and eventually forecasts)).

Excepting extreme meteorological conditions, the intervention decisions are always taken at a local level. The availability of information is as follows at local intervention levels:

<table>
<thead>
<tr>
<th>Information</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>meteorological information and forecasts</td>
<td>always</td>
</tr>
<tr>
<td>radar and satellite imagery</td>
<td>in a few countries</td>
</tr>
<tr>
<td>specific road weather forecast using RWIS info</td>
<td>not always</td>
</tr>
<tr>
<td>RWIS measurements and sometimes forecast</td>
<td>not always with centralisation of data</td>
</tr>
<tr>
<td>thermal mapping</td>
<td>in a few countries</td>
</tr>
<tr>
<td>patrols</td>
<td>not in every county and never systematically</td>
</tr>
<tr>
<td>knowledge of the roads and of the local peculiarities</td>
<td></td>
</tr>
</tbody>
</table>

It is difficult to classify the relative importance of each information in the intervention decision. It depends the countries and the quality of the information.

It is always the person on duty at the local level that takes the intervention decision.

4.3.2 Methods, equipment and materials for snow control
This chapter describes the differences in the European countries in relation to snow control.

4.3.2.1 Snow removal
Methods, techniques and equipment for snow removal on European roads depend on various circumstances. A general differentiation is usually made according to the following parameters:

- climatic region (Nordic region, Atlantic region, Alpine region, Central European region, Mediterranean region)
- altitude (mountain roads, flatland roads)
- traffic volume (motorways, trunk roads, secondary roads, etc.)
- location (roads in urban areas, supra-regional roads)

In the standards for snow removal, distinction is made between:

- road classes
- service levels
- priority levels

As a general rule, in most countries, snow clearance is done by mechanical means only. Thawing agents are not spread on a snow covered road, before a plough has cleared snow from the surface as completely as possible.

Under certain weather conditions (snow forecast on undercooled road surfaces) preventive salting, mainly prewetted salt, is generally applied. It prevents the snow from sticking to the surface. The applied dosage for preventive or precautionary treatment varies from 5 to 25 grams per m².

The necessity to salt after ploughing depends basically on the weather situation and the kind of snow. It is usually recommended, as it greatly reduces the danger of slipperiness due to snow compaction or ice formation when the temperature drops. Dry salt dosage varies from 10 to 40 grams per m², wet salt from 5 to 30 grams per m². In some countries pre-wetted salt is normally used for this purpose.

The equipment used for snow clearance are trucks equipped with ploughs. The ploughs used are of the type which can be moved to a diagonal position. According to the local situation, side ploughs are used additionally. Graders are used before or after the passage of ploughs in some countries.
The tips of blades (cutting edges) are either steel, synthetic material or a combination of both. The "soft" tips are used for removing slush, whereas packed snow requires "hard" tips. When using steel tipped blades, care must be taken to avoid damage to the road surface.

On narrow mountain roads, for pass openings and on certain difficult stretches, V shaped ploughs are still in use.

For cycle and pedestrian paths lighter and small size equipment is used, usually diagonal ploughs.

The technique of rotating brooms or brushes (initially developed for airports) used in combination with ploughs or as single equipment is not yet common on European roads. It is likely though to become a more widespread and more important piece of equipment in the future, as it promises better results in snow clearing and thus permits a reduction of salt consumption.

Heavier snow removal equipment like snow blowers, snow cutters or bulldozers, are used for special interventions (pass openings, blizzards, snowdrifts), mainly in mountainous regions. Snow blowers are also used to load snow ploughed to windrows onto trucks, especially on long bridges or on stretches without shoulders.

To obtain a guideline for the number of ploughs necessary to carry out snow clearing in a particular sector, the following formula (Spain) can be used:

\[ N = \frac{(L \times C)}{(V \times T)} \]

where

- \( N \) = number of snowploughs
- \( L \) = lane length in kilometres
- \( C \) = number of lanes
- \( V \) = average speed of the ploughs in kilometres per hour
- \( T \) = time in hours in which a stretch of road must be treated

The methods used for snow ploughing depend on the type of road (number of lanes), on the traffic volume and on the existing equipment. The ploughs operate either separately (clearance by lane) or in echelon ploughing (2 or more vehicles moving in the same direction, one behind the other, in different lanes).

In prolonged, heavy snowfall the priority will be to maintain a single lane open.

An example (United Kingdom) for a 3 lane carriageway with hardshoulders, particularly suited to echelon ploughing (2 or more vehicles moving in the same direction, one behind the other, in different lanes), is clearance in the following sequence:

1. First: plough lane 2 snow to lane 1;
2. Second: plough lane 1 to hardshoulder;
3. Third: plough lane 3 snow to central reserve;
4. Fourth: plough hardshoulder snow to verge.

More than 2 lanes ploughed onto the central reserve could be hazardous to traffic by inviting drifting and melt water problems later on. When clearing 4 lane carriageways consideration should be given to abandoning lane 4 rather than creating problems of excess snow on the central reserve.

Lanes should be completely cleared, and the windrows of snow remaining should form a smooth and continuous line without sudden encroachments into the cleared path as they may tempt drivers to squeeze into the cleared lane. On motorways, windrows can be left on hardshoulders, but there should be intermittent clearings to provide refuge for broken down or abandoned vehicles. Windrows at the side of the road should not reduce the visibility for safe conducting.

Special attention is to be given to windrows on the higher side of the road, as during daytime the snow may melt and cause slipperiness on the road surface when the temperature falls.

The beginning of the snow clearing operation depends on several factors (weather forecast, traffic density, rush hour, standards, etc.). As a rule, snow clearing starts with 3-8 cm of snow on the road surface.
Snow dumps can be a problem, especially in urban areas. In some countries, laws on the environment list the necessary precautions for snow dumps.

4.3.2.2 “White roads”
White roads are defined as roads or road sections, where no thawing agents are used.
Snow clearance is done when necessary, whereby a close covering of snow remains on the road surface.
The concept of white roads is known in countries with heavy snow fall and long periods of frost and in mountainous regions.

White roads are suitable for the following road categories:

- roads in areas, where the temperature remains below 0 °C for longer periods and therefore no thawing occurs.
- roads with small traffic volume
- roads in winter sport stations
- roads in urban and suburban residential areas

To assure a sufficient adhesion for the vehicle tyres, the snow surface has to be regularly roughened with graders.
Alternatively, abrasives are spread on the compacted snow surface.
Usually trucks, trailers and buses, sometimes all vehicles, are obliged to carry chains with them and mount them when indicated.

White roads are generally indicated by appropriate road signs.

4.3.2.3 Special regulation of traffic
Special regulation of traffic during winter is common on European roads.
For the regulation either permanent or dynamic road signs are used. The following signs or information are applied:

- speed reduction
- road closure
- danger of avalanches
- convoy traffic only behind ploughs
- prohibition against overtaking of maintenance vehicles
- traffic diversion
- snow chains mandatory
- only one lane of a multilane road is treated

In Sweden there is a regulation that all passenger cars, lorries and busses with a total weight of less than 3.5 tonnes have to be equipped with special winter tyres during the period December - March. Most tyres are studded.

4.3.3 Methods, equipment and materials for ice control
This section describes de-icing materials, gritting materials and spread rates in the different countries. The objective is to compare practice between the European countries. The information is summarised in Tables 3.3 at the end of this section.
The following techniques are reported by most countries:

- spreading of chemical materials;
- spreading of abrasives;
- combination of both the above (chemical and mechanical).

All countries distinguish between road classes, service and priority levels. The spread rates of materials are based on information coming from research and practice.
The materials used on highways and main traffic road trunks are exclusively NaCl and CaCl₂, according to the surface temperature.
Preventive and curative spreading is practiced when conditions favor glazed frost, dry ice, rime, black ice etc. or when these have been already formed, to grant satisfactory traffic conditions, expressed by friction coefficient as follows:

<table>
<thead>
<tr>
<th>Traffic conditions</th>
<th>Friction coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory</td>
<td>0.25</td>
</tr>
<tr>
<td>Slippery surface</td>
<td>&lt; 0.25</td>
</tr>
<tr>
<td>Very slippery surface</td>
<td>0.15</td>
</tr>
</tbody>
</table>

This friction coefficient is determined with special equipment to assess the condition of road surface, according to specific procedures.

The personnel experience on fighting against frost and ice is specific to these activities because each road sector has its own particular characteristics, related to temperature, lighting, air currents, geometric elements etc.

The traffic and number of vehicles per time unit has an important effect upon the effectiveness of various de-icing materials, namely:

- dry salt tends to be blown away from under the spreading vehicles and generally by traffic, thus not reaching any effectiveness;
- brine requires 30 vehicles/hour minimum to prevent a repeat of freezing and ice at very low temperature (below -10 °C);
- sand alone may be blown away by traffic or pressed into the snow, thus losing its effectiveness;
- sand mixed with salt acts better on packed snow and ice, with a durable effect provided when the optimum percentage of mix is observed (without salt in excess).

### 4.3.3.1 Chemical de-icing materials

The main de-icing material used in all countries is rock, sea, vacuum salt NaCl in dry, pre-wetted or brine condition. Other chloride de-icers like CaCl₂ and MgCl₂ are also used in brine or in granules, depending on the temperature of carriage way surface. A description of the advantages and disadvantages of the different de-icers is made in section 2.5.

#### Dry salt

Rock salt is the material generally used for dry spreading. Vacuum and solar salt are used also in some countries for dry spreading. The proportions of dry NaCl vary depending on the treatment type:

- Precautionary salting (preventive treatment): 5-30 g/m²
- Curative treatment:
  - freezing fog: 5-40 g/m²
  - icing: 5-40 g/m² is used in most countries. The proportions vary depending on the thickness of ice layer, being greater for ice layers with a great thickness;
  - glazed frost ice/freezing rain: 20-50 g/m² (the greatest dry salt proportion)

In most countries the proportion is 20-40 g/m² and it depends on the thickness of glazed frost ice and on road surface temperature.

One may notice that in FIN, N, S, NaCl dry is not used in any situation probably because of the cold and dry climate.

- snow (after clearance): 10-40 g/m²
Pre-wetted salt and brine

Some countries use pre-wetted salt and/or brine for both preventive and curative salting treatment purposes.

- In the case of rain or glazed frost, most countries act preventively with pre-wetted salt to ensure a high level service for traffic. The salt is blown less easily from the carriageway by traffic and wind resulting in reduced salt consumption.

There are two methods for pre-wetting salt. One is to spray brine over the salt at the spreading disk. The other is to add water in the salt container.

Pre-wetting is made with brine (NaCl, CaCl₂ or MgCl₂). The proportions used depend on the condition of the road surface (dry, moist, wet road), on weather condition (stable or changing), on the thickness of ice layer etc.

In case of preventive treatments, proportions vary in the following way:

- Preventive use: 4-25 g/m², varies with the condition of the road surface and on the expected meteorological expectations, as follows:
  - Preventive use on dry/moist pavement surface: 5-10 g/m² or 6-11 g/m²
  - Preventive use on wet pavement surface/before freezing rain: 10-30 g/m² or 8-13 g/m² on wet road surface
  - Preventive use on wet pavement surface/prior to snowfall: 21-25 g/m²

The proportions used differ according to climate area. Minimum proportions of 4-8 g/m² is used for areas with cold maritime climate, and in areas with maritime climate the proportions vary within the range of 7-15 g/m² and 5-25 g/m².

In most of COST member countries, the minimum proportion is 10-15 g/m² and max. 20-25 g/m².

Brine

The advantages of brine are that there is little salt in solution and almost 100% of the quantity distributed remains on the road surface. The brine is usually made up of a NaCl solution, but sometimes of a CaCl₂ solution, which is more efficient at lower temperatures (-20°C) and more expensive.

The quantity of salt (NaCl) in a brine shall be 20-24% maximum by weight, 16-33% by weight for CaCl₂, 16-34% by weight for MgCl₂. If the concentration of salt when mixed with water to obtain the brine becomes too high, more than 24 to 25% hydrates will be established, and the road gets very slippery. It can be obtained from a natural reserve where such exists (salted natural water springs, salted natural lakes) or by manufacturing in specially constructed basins. Two methods are currently used in the production, bath mixing (dissolving salt in a water bath) and continuous/ongoing mixing (water is injected into salt under pressure).

Brine is spread from a tanker with suitable equipment (spray nozzles or a rotating disk). A brine spreader has a capacity of 5-60 g/m², with a distribution width of 3-5 m and a driving speed of 50-60 km/h. The quantity used is decided by the driver and depends on weather conditions.

In the future, adjusted rate of spread should be automatically monitored even with changes of spreader operating speed within the range of 10-40 km/h. Automatic deicer spraying installations are installed on highway networks, at dangerous points like bridges and stationary facilities (e.g. two short sections of urban roads in Prague, each of 100 m).

- Brine is best suited for preventive measures (rime and "black ice") on thin ice or on rime.
- Brine should not be used on thick ice or snow. If brine is spread during a snowfall, a snowplough should be used in front of the spreader.
- Brine is effective immediately after spreading on a damp road (not wet), in very cold weather (< -10°C) and a certain amount of traffic can improves effectiveness.

Automatic deicer spraying systems have a fast reaction (spray de-icing) when the road is slippery or is expected to become slippery.

The countries which use brine are: F, N, RO, S, CH, ISL.
Studies about the effectiveness of pre-wetted salt use showed a cost reduction with 24-44% in case of using pre-wetted salt of type FS 30 (70% NaCl and 30% salt solution: CaCl$_2$, MgCl$_2$, or NaCl) and with 15-20% in case of using pre-wetted salt of type FS 5 (95% NaCl and 5% NaCl solution).

A detailed description of pre-wetted salt and brine consumption spread rates is presented by Sweden depending on road condition, predicted surface temperature for road widths of 4, 2 x 3 and 7 m, meteorological phenomena, thickness of ice layer, etc (see corresponding country report). For the brine the net quantity of salt is 4-7 g/m$^2$.

**Conclusion**

Spread rates depend on pavement temperature, on meteorological forecasts on the thickness of layers to be removed, etc. Spread rate is also a function of level of service and timing of intervention.

Treatments performed with dry, wetted and brine salt (NaCl, which are most often used), have the following advantages:

- reduced cost: reduced expenses for manpower and spreading devices (better work conditions in case of using the brine);
- long and efficient action, uniform distribution on road surface and in case of brine use, salt response time for ice melting is reduced;
- simplicity in application

However, salt treatments present the following disadvantages:

- corrosive action on reinforced and prestressed concrete bridges, and on metal bridge sections.
- rain or snow may dilute the brine, therefore, the melting effect is reduced and more salt concentration should be used;
- the salt affects the environment around the road (corrosion on iron and steel on cars, and road structures and furniture. It reduces driver vision, dirties head lights and wind screens vehicles signs, etc.).

**4.3.3.2 Abrasives**

Sand and grit (crushed stone) are mainly used, slag to a lesser extent. In Sweden the municipalities also use crushed limestone. Some countries do not use abrasive material at all. Different technologies are used: spreading gritting material, pure sand heated, abrasives wetted with brine, abrasives mixed with salt.

**Pure ground sand**

Size (0-8 mm) is used if there is melting at the road surface (slush) and more coarse sand (4-8 mm) on dry ice. Bigger stones can damage windscreens on the vehicles. On roads with speed limit above 70 km/h, the maximum allowed grain size is 4 mm.

Sand is not effective on roads with a lot of traffic (more than 50 vehicles blow the sand away from the road).

**Crushed stone aggregate**

Usually of 2-5 mm fraction has been used for several years mostly in urban areas in Sweden. Crushed stone aggregate, 2-4 mm is used for pedestrian and cycle paths.

The quantity of gritting material distributed depends on the type of slipperiness:

- icing:
  - 40-350 g/m$^2$ (sand) depending on snow depth, topographic situation, class of road;
  - 70-300 g/m$^2$ (grit) and max. 500 g/m$^2$ for local roads (CZ);
  - In CH it is used 200 g/m$^2$ on local roads only.
- glaze ice/ freezing rain:
  - 40-350 g/m$^2$ (sand) in most countries the maximum proportion is 300-320 g/m$^2$;
  - 70-300 g/m$^2$ (grit) and max 500 f/m$^2$ for local uses in CZ;
  - In N, CH (local roads) 200 g/m$^2$ is used.
- snow (after clearance): 70- 350 g/m$^2$ (sand)
Generally, the quantity of sand assigned is greater if fine sand is used, and smaller (towards the lower limit) if sand is coarse. Spreading speed is 30-40 km/h, spreading width is 2-6 m.

Storage of abrasive materials is made in open air, silos or warehouses. Loading of abrasive materials delivered in bulk is performed in a mechanized manner with adequate equipment (conveyor belt, front loader).

Sand use causes the occurrence of a lot of dust, which should be removed from the carriage way in spring. In Austria (Vienna) grit is collected washed and used again in the next winter period.

In some countries, like Switzerland, abrasives are mainly used on mountain roads in winter sport resorts (white roads) and in urban areas on pedestrian paths.

**Heated sand with hot water** (70-160 degrees)

This method gives good friction for a long period. Coarse sand (grading of 4-8mm) retains heat better than fine one. The spreading rates used in various situations of slipperiness are the same with those of pure sand. With this method the sand melts snow or ice a little, and then gets stuck as it freezes again and the traffic doesn't blow the sand away from the road.

**Sand mix with salt or brine**

In order to prevent formation of frost on sand and in order to increase the adherence of sand to the road surface, salt is mixed into the sand. Sand mixed with salt/brine is used for heavy-traffic roads at a low temperature, where the use of salt is not advised. Distribution speed is approx. 30-40 km/h.

The method is most suitable in regions with a stable climate and low temperatures.

Sand mixed with salt shall be stored in a dry and cold place in order to prevent the salt separating from the sand. A sand/salt mixture may be made through spraying brine on sand at its spreading. The advantages of this method are that the sand becomes wet immediately, and that very little salt is used. When a greater quantity of mix is achieved it is very important to strictly observe the dosages, the adequate mixing in order to obtain as homogeneous as possible mixes with a few hours before spreading in order to be sure that we have a better cover of sand particles with salt and therefore a better effectiveness.

It is necessary to mix the ingredients well and to use the mixture after a few hours, in order to ensure a better salt coverage of the grains of sand, and thereby a more effective action. Mixing is generally made in storehouse or just before spreading.

**Combined actions**

In case of alternating temperatures in some countries, fighting against the ice-snow is made by a sequence of chemical treatment and mechanical action followed by chemical treatment.

The combined actions are applied for thickness of 1-10 cm and only when the road surface temperature has increased to at least -3°C/-7°C (this being the temperature at which NaCl salt is effective).

The combined actions develop depending on the nature of the upper layer (snow or ice) as follows:

- if the upper layer is made up of snow, proceed to its mechanical removal followed by chemicals spreading;
- if the upper layer is made up of ice, first perform chemical spreading until melting is achieved, followed by mechanical removal of the snow layer.

Combined actions are performed on road sectors with 300-500 lengths. After cleaning the carriageway, there is a preventive treatment with chemicals. Equipments used are: graders, material spreaders, snow ploughing vehicles.

To remove ice mechanically a special mounted motor grader-cutting blade is mounted under a truck. This works well if the ice is not too hard. On hard ice motor graders have to be used.

Materials: sand, chipping, crushed limestone for municipalities and slag.

Legend for all tables

- : not present (table 1) or not used (table 2-5) in this country
x : present (table 1) or used (table 2-5) in this country
? : no information available
<table>
<thead>
<tr>
<th>Country</th>
<th>Climatic Region</th>
<th>Main de-icer</th>
<th>Source</th>
<th>Technology</th>
<th>Brine solution</th>
<th>Other de-icers (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>centr-europ. Mountain continental</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>MgCl₂</td>
<td>K₂CO₃</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>16-33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>MgCl₂</td>
<td>mix NaCl/ CaCl₂, urea</td>
</tr>
<tr>
<td>(C) Czech Republic</td>
<td>centr-europ. mountain</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>18-21%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>16-33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>16-34%</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>20-22%</td>
</tr>
<tr>
<td></td>
<td>maritime</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>20-22%</td>
</tr>
<tr>
<td></td>
<td>cent-europ. continental</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>MgCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(D) Denmark</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>CMA</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>mediterran. mountain</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(F) France</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>85 : 15 or 70 : 30</td>
<td>22-23%</td>
</tr>
<tr>
<td></td>
<td>mediterran.</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>centro-europ. mountain</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(F) Finland</td>
<td>cold</td>
<td>NaCl</td>
<td>?</td>
<td></td>
<td>x [on wet roads]</td>
<td>10 : 1</td>
</tr>
<tr>
<td></td>
<td>maritim</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>continental</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(G) United Kingdom</td>
<td>?</td>
<td>NaCl</td>
<td>?</td>
<td></td>
<td>x [on wet roads]</td>
<td>10 : 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>24%</td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>centro-europ. mountain</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>centro-europ. mountain</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>cent-europ. continental</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>26-28%</td>
</tr>
<tr>
<td>(HR) Croatia</td>
<td>?</td>
<td>NaCl</td>
<td>?</td>
<td></td>
<td>x [on wet roads]</td>
<td>20 : 22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td>(I) Ireland</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>x [post-salting]</td>
<td>20 : 22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>marine</td>
<td>NaCl</td>
<td>-</td>
<td></td>
<td>x [post-salting]</td>
<td>20 : 22%</td>
</tr>
<tr>
<td></td>
<td>cold</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>maritim</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>northern</td>
<td></td>
<td>-</td>
<td>x</td>
<td>MgCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>continental</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td>(N) Norway</td>
<td>cold</td>
<td>NaCl</td>
<td>-</td>
<td></td>
<td>70 : 30</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>maritim</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>northern</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>mountain</td>
<td></td>
<td>-</td>
<td>x</td>
<td>MgCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>16-33%</td>
</tr>
<tr>
<td>(PL) Poland</td>
<td>?</td>
<td>NaCl</td>
<td>?</td>
<td></td>
<td>x [post-salting]</td>
<td>20 : 22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>maritime</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>90-70:10-30</td>
<td>20-24%</td>
</tr>
<tr>
<td></td>
<td>maritim</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>centro-europ. mountain</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>-</td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>cold</td>
<td>NaCl</td>
<td>x</td>
<td></td>
<td>70 : 30</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>maritim</td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>continental</td>
<td></td>
<td>-</td>
<td>x</td>
<td>CaCl₂</td>
<td>CMA</td>
</tr>
<tr>
<td>(SLO) Slovenia</td>
<td>?</td>
<td>NaCl</td>
<td>?</td>
<td></td>
<td>x [limited]</td>
<td>20 : 22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>x</td>
<td>NaCl</td>
<td>-</td>
</tr>
<tr>
<td>Country</td>
<td>Climatic Region</td>
<td>Gritting materials</td>
<td>Technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>-------------------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>Grit</td>
<td>Slag</td>
<td>Cinders</td>
<td>Heated sand</td>
</tr>
<tr>
<td>(A) Austria</td>
<td>centr-europ. mountain continental</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>centr-europ. mountain</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>x [rare]</td>
</tr>
<tr>
<td>(CZ) Czech Republic</td>
<td>centr-europ.</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>maritime continental</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>mediterran. mountain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(F) France</td>
<td>maritime mediterran.</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>cold maritim continental</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>centr-europ. mountain continental</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>maritime cold maritim northern</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
**Table 3.2 (part 2/2) Information regarding gritting materials (abrasives)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Climatic Region</th>
<th>Gritting materials</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>Grit</td>
</tr>
<tr>
<td>(N) Norway</td>
<td>cold marit. northern mountain</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>continental</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>(NL) Holland</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>maritime</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>mediterran. mountain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>continental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>cold marit. continental</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

*Comment: The sand is mixed with salt primarily to prevent it from freezing during storage at low temperatures and not in order to improve the performance.*
Table 3.3 (part 1/2) Information regarding spread-rates of de-icers

<table>
<thead>
<tr>
<th>Country</th>
<th>Climatic Region</th>
<th>Main de-icer</th>
<th>Expected slipperiness (pre-salting) amount of de-icer (g/m²) (*)</th>
<th>Freezing fog amount of de-icer (g/m²) (*)</th>
<th>Icing amount of de-icer (g/m²) (*)</th>
<th>Glazed frost ice/freezing rain amount of de-icer (g/m²) (*)</th>
<th>Snow (after clearance) amount of de-icer (g/m²) (*)</th>
<th>Other amount of de-icer (g/m²) (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>cent-europ. mountain continental</td>
<td>NaCl</td>
<td>- 10-15 10 15 15-20 10 20-40 15 20 15-20 10-40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>cent-europ. mountain</td>
<td>NaCl</td>
<td>- 7-15 10 7-15 15-30 7-20 20-40 20 20 15-20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>maritime cent-europ. mountain</td>
<td>NaCl</td>
<td>5-30 5-25 5-20 5-15 5-25 5-20 20-50 20-40 15-40 15-30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>maritime</td>
<td>NaCl</td>
<td>- 5-25 - 5-15 - 10-25 - 10-25 15-20 10-25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>mediterr. mountain</td>
<td>NaCl</td>
<td>- 5-10 10 - 10-15 5-10 20-40 15-20 20 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(F) France</td>
<td>maritime cent-europ. mountain</td>
<td>NaCl</td>
<td>10-15 4-8 - 15-20 - 20-25 - 20-30 - 20-40 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>cold maritim. continental</td>
<td>NaCl</td>
<td>? ? ? ? ? ?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(GR) United Kingdom</td>
<td></td>
<td>NaCl</td>
<td>- 5-10 - 5-10 - 5-10 - 10-20 - 5-20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>cent-europ. mountain continental</td>
<td>NaCl + CaCl</td>
<td>&lt;15 15&lt; 10&lt; 10&lt; &lt;30 40max 40max &lt;20 &lt;40 40max</td>
<td>&lt;20 10&lt; 10&lt; 20&lt; &lt;40 40max</td>
<td>&lt;30 30&lt; 30&lt; &lt;40 40max</td>
<td>&lt;30 30&lt; 30&lt; &lt;40 40max</td>
<td>&lt;30 30&lt; 30&lt; &lt;40 40max</td>
<td>&lt;15 15&lt; 15&lt; 15&lt; &lt;15 15&lt; 15&lt;</td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>maritime</td>
<td>NaCl</td>
<td>10 - 10 - 20 - 20-40 - 10 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>maritime cold maritim. northern</td>
<td>NaCl</td>
<td>- - 12 20 12 20 - - -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 3.3 (part 2/2) Information regarding spread-rates of de-icers

<table>
<thead>
<tr>
<th>Country</th>
<th>Climatic Region</th>
<th>Main de-icer</th>
<th>Expected slipperiness (pre-salting) amount of de-icer (g/m²)</th>
<th>Freezing fog amount of de-icer (g/m²)</th>
<th>Icing amount of de-icer (g/m²)</th>
<th>Glazed frost ice/ freezing rain amount of de-icer (g/m²)</th>
<th>Snow amount of de-icer (g/m²)</th>
<th>Other amount of de-icer (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N) Norway</td>
<td>cold marit. northern mountain continental</td>
<td>NaCl</td>
<td>-</td>
<td>6-11</td>
<td>-</td>
<td>11-16</td>
<td>-</td>
<td>23-32</td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>maritime</td>
<td>NaCl</td>
<td>-</td>
<td>7-14</td>
<td>10</td>
<td>7</td>
<td>15-20</td>
<td>7-10</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>maritime mediterran mountain continental</td>
<td>NaCl</td>
<td>-</td>
<td>5-15</td>
<td>-</td>
<td>5-15</td>
<td>5-20</td>
<td>5-20</td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>cold marit. continental</td>
<td>NaCl</td>
<td>-</td>
<td>6-25</td>
<td>-</td>
<td>11-15</td>
<td>-</td>
<td>11-25</td>
</tr>
</tbody>
</table>

(*) : Amount of de-icer (g/m²) means: number of grams of the solution.

For example:
Amount of de-icer (g/m²) is 7 gr/m² pre-wetted salt
This means that the solution is 7 gr/m² (e.g. 70% dry salt and 30% brine; brine is 16% CaCl₂). The actual salt per m² is less: 70%x7 + 30%x7x16% = 5.2 g/m²
<table>
<thead>
<tr>
<th>Country</th>
<th>Climatic Region</th>
<th>Main abrasive</th>
<th>Icing amount of abrasive (g/m²)</th>
<th>glazed frost ice/ freezing rain amount of abrasive (g/m²)</th>
<th>Snow (after clearance) amount of abrasive (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Austria</td>
<td>centr-europ. mountain continental</td>
<td>?</td>
<td>40-320</td>
<td>40-320</td>
<td>70-140</td>
</tr>
<tr>
<td>(B) Belgium</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(CH) Switzerland</td>
<td>centr-europ. mountain</td>
<td>grit</td>
<td>200 (secondary roads only)</td>
<td>200 (secondary roads only)</td>
<td>100-200 (sec. roads only)</td>
</tr>
<tr>
<td>(CZ) Czech Republic</td>
<td>centr-europ.</td>
<td>grit</td>
<td>70-300(500 on dangerous locations)</td>
<td>70-300(500 on dangerous locations)</td>
<td>70-300(500 on dangerous locations)</td>
</tr>
<tr>
<td>(D) Germany</td>
<td>maritime continental</td>
<td>grit</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>(DK) Denmark</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(E) Spain</td>
<td>mediterran. mountain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(F) France</td>
<td>maritime mediterran.</td>
<td>?</td>
<td>5-200 (sand)</td>
<td>-</td>
<td>100-300</td>
</tr>
<tr>
<td>(FIN) Finland</td>
<td>cold maritim continental</td>
<td>?</td>
<td>100-300</td>
<td>100-300</td>
<td>-</td>
</tr>
<tr>
<td>(H) Hungary</td>
<td>centr-europ. mountain</td>
<td>-</td>
<td>250&lt;</td>
<td>&lt;300</td>
<td>&lt;200</td>
</tr>
<tr>
<td>(IRL) Ireland</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(IS) Iceland</td>
<td>maritime</td>
<td>-</td>
<td>150-350</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>(N) Norway</td>
<td>cold marit. mountain</td>
<td>grit</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>(NL) Netherlands</td>
<td>maritime</td>
<td>-</td>
<td>-</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>(RO) Romania</td>
<td>maritime mediterran.</td>
<td>sand</td>
<td>150-350</td>
<td>150-350</td>
<td>150-350</td>
</tr>
<tr>
<td>(S) Sweden</td>
<td>cold marit. continental</td>
<td>sand &amp; grit</td>
<td>± 250 (?)</td>
<td>± 250 (?)</td>
<td>± 250 (??)</td>
</tr>
</tbody>
</table>
4.3.4 Methods, equipment and materials for special problems

3.4.1 Porous asphalt
Porous asphalt is a road surface material with an open structure. Under certain winter conditions porous asphalt requires more attention than conventional road surfaces. This is due to different characteristics in respect to surface temperature, road humidity and the ability to retain salt on the surface.

All European countries with porous (asphalt) overlays treat it differently to dense (non-porous) surfacing material. More de-icing agent is used (spread rate increased by 40% to 100%) and more turnouts are necessary.

In the Netherlands the treatment on porous asphalt is given winter maintenance guidelines. The guidelines describe (among other things) turnouts, spread-patterns (amount of de-icers for different types of slipperiness) and traffic measures on porous asphalt.

In Switzerland porous asphalt is not used above 600 meters altitude because lower temperatures and more severe winter conditions would impair traffic safety (remaining salt disappears in pores; the sucking affect of tyres pumps pore-water to the surface where it might freeze). In Belgium porous asphalt is not used anymore in the south part of the country (variable relief up to 690 m) due to the same difficulties.

4.3.4.2 Bridges
Bridges (especially steel bridges) cool quicker (due to radiation) than the surroundings. Therefore slipperiness can occur quicker. Also bridges experience corrosion from de-icing agents, like salt.

In some countries more or special turnouts are done on "problem" bridges.

On some bridges in Switzerland, Denmark and the Netherlands automatic de-icer spraying installations are installed connected to a RWIS station. This solution is chosen for economic and safety reasons.

In Switzerland two specialities are present: 1) a bridge is equipped with a road heating system and 2) on another bridge asphalt with a de-icing agent (e.g. verglimit asphalt, Mafilon) is used.

Some bridges have restrictions on the use of salt. Here non-corrosive de-icers, like acetate are used.

In France, some steel bridges are treated (including 1.5 km before and after the bridge because of transportation of salt by tires) with non-corrosive de-icers, like acetate.

In Sweden, salt was considered a problem before, but not so much anymore. The quality of concrete has been improved and steel sections are protected.

In Spain and Romania patrols pay extra attention to possible ice formation on bridges and in tunnels. Some countries have RWIS station sensors placed on bridges.

4.3.4.3 Cycle tracks
Special equipment is used in European countries where cycle paths are present. In Norway, Sweden and Switzerland the gritting material on cycle lanes are almost always abrasive. Salt is seldom used. In the Netherlands pre-wetted salt is used.

In Sweden there are special regulations for cycle paths, which describe the maximum snow depth and the minimum friction.

Cycle paths at municipality-level are under different regulations.

In some cities in Sweden road heating systems are used.
4.3.4.4 **Avalanches**
In all mountain regions avalanches are given special attention. The defence systems are active and/or passive. Passive measures include walls/fences. Active systems include controlled avalanche provocation.

In France and Switzerland a special organisation/task force for avalanche prediction is present. In France, the avalanche risk is scaled between 1 and 5. When the avalanche risk is between 3 - 5, special actions are required, like road closure and avalanche provocation.

In Spain, special weather bulletins give avalanche risk in the Pyrenean Region.

In Switzerland, automatic avalanche warning devices are sometimes installed.

4.3.4.5 **Snow drifts**
To reduce the amount of snow blown on the road, in most countries snow-fences are put up where the phenomena regularly occurs. These fences are e.g. plantation (bushes and trees) for snow protection or mobile snow-fences. If it is not feasible to put up fences, some mountain roads are closed during snow drifts.

The machinery used to treat snow drifts are V-blades and snow cutters.

In the northern parts of Sweden some of RWIS stations are positioned to register snowdrift and precipitation.

In Norway special equipment is used to open a road that has been closed during winter. The layer of snow can be 4 meter thick. A special attachment for a snow cutter unit has been developed. It 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 is transferred to a wheel loader for the last layers.

4.3.4.6 **Others**
Thin surface pavements (repaired surfaces etc.) and road markings do not give any special problem in the European countries.

In Switzerland when opening mountain passes, which have been closed during the winter, special equipment (blowers, cutters) is used. The thickness of the snow layer can reach 5 m and more.

In Hungary, in severe weather conditions it is possible to lease machinery from private companies and/or employment of machinery and crew from the army and fire-guard for winter maintenance activities.

In Romania, on road sections with one year old surfacing, snow removal is performed only, with rubber edged snow ploughs.

In Sweden, the studded tyres (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 an ice-free pavement.

4.3.5 **Measurements of efficiency**

3.5.1 **Internal efficiency**
Resources used (salt, abrasives, equipment and manpower) are normally recorded.

In some countries monthly and/or annual reports are compiled and given to the national road administration.

In a few countries (the Netherlands, Denmark, Iceland and to some extent also in Sweden) the gathering of data is more or less automated. The vehicles are equipped with GPS and a data-gathering system to register exactly when, where and which winter road maintenance actions have been carried out.
Just knowing the amount of salt that has been used during the winter season is not enough to say anything about the efficiency of the winter road maintenance. The amount of salt also has to be compared to the severity of the winter.

One approach to this is a so-called salt index. This has been calculated during the last few years by the Swedish National Road Administration (SNRA). The salt index compares actual salt consumption (kg/km) with recommended use (kg/km) for pre-defined weather situations. A value > 1 means more salt used than recommended, and a value < 1 means less salt than recommended.

This of course assumes that a required level of winter maintenance service is achieved. In those countries where there is monitoring of the service achieved this is normally done by the contractor. The monitoring can be by random sample inspections, by special patrols and/or the drivers of the winter maintenance vehicles logging their activity and the achieved road condition.

4.3.5.2 External efficiency
External efficiency can be judged for example through the number of hours per day of road closures or other traffic restrictions such as an obligation to use snow chains, caused by poorly maintained roads (Spain). Also the number of traffic accidents during a winter season might be used to evaluate the efficiency of the winter road maintenance. As far as known this is however not done regularly in any of the European countries.

A measure of efficiency can also be obtained by asking the road users how satisfied they are with the winter road maintenance. Road user surveys are regularly done once or every second year in a few countries, like Hungary, Sweden and Norway.

4.4 Conclusion on Best Practice

Each country member of the COST Action was asked to write a country report to describe their winter maintenance practices. Because recommended practice or expert knowledge sometimes differ from operational and actual practices, both were considered and each country presented recommended and actual practices.

The 16 country reports collected are the first description of winter maintenance practices across Europe and contain a great deal of information.

Their final version will be accessible to the public and available on a CD-ROM.

Each country report is compiled to an identical structure i.e. table of contents and section captions are standardised. The Group referred these topics a Subject List.

Despite this it has been very difficult to extract best practices since there are no indicators of the quality of the results. Almost no country has an effective measurement of efficiency so it has not been possible to compare practices on the same basis and with reliable indicators. Thus, this report describes best and actual practices in Europe, with emphasis on similarities and differences with reasons given when possible. When a country has more knowledge on a topic than others, this is stated so that the reader can learn more by referring to the country report. This international exchange of practice is fundamental to win time and money.

It seems that there are not many differences in winter maintenance service objectives in Europe. The concept of “classification of the roads according to level of winter serviceability” is widespread. There is generally a distinction on:
  • level of service
  • time of return to the reference condition
All countries organise winter maintenance according to the importance of the road, often measured by the network function and the traffic volume.

Practices differ more in relation to the type of salt used (for example, rock salt or wetted salt) in different climatic zones. Rock salt is mostly employed for maritime climatic regions (humidity is significant) and wet salt in drier regions.

Some common problems and concerns have emerged with sometimes no satisfying solution (for example, for the treatment of porous asphalt).

This "best practice" chapter is a base for international winter maintenance needs. It is important to have an international approach since the needs are closely related and independent of borders. One solution found by a country is useful information for other countries.
Appendix 1: COST 344 TG3 Subject List
General Remarks

Best practice should be discussed
- for every point of the subject list
- in the general and special context
- regarding the aspects: safety, environment, traffic flow, cost efficiency

It would be perhaps a good help to have also in mind the 4 actors of winter maintenance
- the owner of the roads called in french “maître d’ouvrage” (state, highway society...)
- the contract manager (in french “maître d’œuvre”) who works for the “maître d’ouvrage”. He has to organise and manage winter maintenance and also to inform users.
- operational people who make the winter maintenance interventions
- road users

According to this classification chapter 2 “Strategic organisation of winter maintenance” relies on the owner of the road and the contract manager.

Chapter 3 concerns contract manager and operational people.
Chapter 4 is then for road users.

A1. Fundamental issues

A1.1. Climatic conditions
- overview of climatic regions in Europe
- which winter events have to be mastered
  - statistics on
    - temperatures, icing conditions (number of days below 0°, number of days with icing conditions)
    - liquid and solid precipitations (amount of snow, number of days with snowfall, number of days with freezing rain) (add: at what depth of snow a day is considered a day with snowfall)
    - wind (correlation with weather condition; snow drift)
- which winter indices are used + their definition
- changes over the years (global warming)

A1.2. Standards
It's important to cite the exact references of all the standards.

A1.2.1. General standards
- Legal obligation to do winter maintenance?
- Classification of the roads according to level of winter serviceability
- service classes
  - desired road condition
  - reaction and service times
- levels of service (who define them? the contract manager or the client authority?)
A1.2.2. Standards on Man Power
- max. driving time (legal base)
- working schedule (application of the european directive)
- e.g. shift working, stand-by organisation, compensation of overtime
- rules on security and hygiene

A1.2.3. Standards on equipment and material
- what are the laws and regulations, are they always followed and how?

A.2. Strategic organisation of winter maintenance

In this chapter all these informations shall be discussed which relate to general decisions (strategic decisions; for one winter period or longer).

Informations relating to the organisation of individual winter maintenance actions (tactical decisions) are discussed in chapter 3.

A.2.1. General
- codes of practice
- overview
- how obligatory

A.2.2. Information provision
- Meteorological information : What is the contract/ practice of the meteorological office?
- technical and organisational systems of data collection and transmission for decision making (determination of the most suitable system of transmission for a given type of information - fixed, mobile phone lines, radio communication, computer netware)
- systems of control posts and patrols
- RWIS-Systems (road sensors and weather forecast systems)
  - Road Ice Prediction Systems (RIPS)
  - Forecast period
  - Density (number per km of national road / treated road / climatic domain)
  - What measurements on each station
  - Ratio of forecast stations (stations where a metereological weather forecast is provided) to observation stations
  - Where are the “forecast stations” (thermal mapping anchor stations) located; in the coldest / warmest / average part of the climatic domain; where are the supplementary (information) station located?
  - Where are the stations located; in the coldest / warmest / average part of the climatic domain?
- Thermal mapping
  - Significance attached to thermal mapping?
  - Average size of climatic domain km²
  - How often is thermal mapping repeated?
  - How are resurfacing changes handled?
  - Expert systems
A.2.3. Methods
- preparative programme for winter activity (dates of activation of the winter service, different states of activation (normal or exceptional situation...))
- establishing of technological procedure (instructions for the measures) for a given climate situation (the instructions with correlation to traffic density)
- prevention, e.g. snow fences; how paying and organizing it
- route optimisation
- schedules for ploughing and gritting
  - how many
  - how detailed
  - which criteria for higher priorities
  - turn out criteria

A.2.4. Equipment
- how many operation centers
- what stationary equipment
- vehicles (trucks) per 100 km
- men per truck
- other general equipment per 100 km e.g. ploughs
- are there normed devices to fasten equipment to the lorries
- de-icer spraying installations, road heating
- use of ice-delaying pavements (e.g., „Verglimit“)

A.2.5. Materials
- Spreading
  - recommended average rate of spread for m² resulting from an average length of a spreader route (independance on the spreader cubature)
  - how much material (e.g. salt) is stored
  - what contracts for material supply do exist (short/long term); does the contractor provide own depots, prizes

A.2.6. Manpower, training and privatisation
A.2.6.1. Are there specific jobs for specific tasks? which ones?
A.2.6.2. Training and education
- crew training, manager training, training centers etc.
- Training of the (truck) drivers

A.2.6.3. Privatization
- private companies (contractors) / non governmental organisations
  - total
  - in parts
  - only for special jobs
- What are the relations / contract between the private companies and the contract manager? Is the contract made with results or means objective?
A.3. Operational organisation of winter maintenance

A.3.1. Getting Information
- warning and detecting of critical situations
  - Meteorological forecast. What kind of information are given? What are the relations with the operational center?
  - Observation of the weather (e.g. probabilistic forecasts or other models, amount of cloud cover)
  - Patrols (what are the information collected …)
- Getting information from Winter Information System, Road Weather Information Systems (RWISs)
- Problem of fiability and reliability of information of RWISs. Sometimes an alarm is made by the RWISs and there is nothing on the road
- Position of man in the decision process. Who takes the decision of an intervention and how?

A.3.2. Methods, equipment and materials for snow control
- snow removal
  - Strategies for clearing multilane-carriageways
  - “white roads”
  - special regulation of traffic (for lorry in the case of snow for exemple)

A.3.3. Methods, equipment and materials for ice control
- chemical deicing
  - amount and spreading width as function of road width and traffic
  - loading of spreading-materials onto the lorries
  - using (rock) salt, wet and prewetted salt, brine, other deicing materials; problems, e.g. corrosion, slipperiness
  - spread rate
  - preventive spreading
  - storage for spreading materials
- gritting
  - amount and spreading width as function of road width and traffic
  - loading of spreading-materials onto the trucks/spreaders
  - using abrasive materials; problems, e.g. recycling, safety, environment, cost, removal
  - using of sand & brine, heated sand, other (e.g. porous) materials
  - spread rate
  - storage for gritting materials
- mechanical ice removing

A.3.4. Methods, equipment and materials for special problems
- special treatment of porous asphalt pavements and porous overlays
- special problems of thin surface pavements (repaired surfaces …) and road markings
- Specialities on bridges (e.g. higher frequencies; other materials; protection of other, lower situated traffic routes)
- Road markings
- cycle tracks
- avalanches (prevention, warning and removal)
A.3.5. Measurements of Efficiency

A.3.5.1. Internal
- Internal reports on activities; how detailed, which regular evaluations, which consequences
  - Salt consumption
  - Man hours
  - Number of interventions (preventive / curative)
  - Number of patrol
- Forecast verification (also feedback to the forecaster)
- Cost of winter maintenance: method of evaluation and calculation

A.3.5.2. External
- Accidents
- Travel time
- Environment
- User satisfaction, user surveys

A.4. Information of Drivers

- Nature of information given (preparatory information, actual information)
- Ways of disseminations
  - Over radio, journals, teletext
  - On the road (message signs)
  - Over phone and internet
- How much information is useful
  - Before winter (about level of service?)
  - During winter events
  - In case of a crisis
Appendix 2: INFORMATION PROVISION
TABLE OF CONTENTS

Preface

1. Meteorological information
2. Technical and organisational systems of data collection
3. RWIS-System (Road Weather Information System)
4. Thermal Mapping
5. Systems

Preface

There are 5 main issues amid Information Provision

1. Meteorological information;
   What is the contract/practices of the meteorological office?
2. Technical and organisational systems of data collection;
   Determination of the most suitable system of transmission of information
3. RWIS-systems
4. Thermal Mapping
5. Systems

All 18 countries have been participating to answer these questions and as the result this document will show the relationship between these five topics.

Meteorological information

What is the contract/practices of the meteorological office?

Most of the countries surveyed have formal arrangements with their national meteorological agencies.
In France, the respondent to the survey was that each local administration must buy the meteorological provision and there is neither a national contract nor centralisation.

In Denmark, the Danish Road has an agreement with Danish Meteorological Institute since 1983. The type of information, data and services are weather stations forecast, five-hour forecast and radar images.

Showing below a table of narrative.
<table>
<thead>
<tr>
<th>Countries</th>
<th>Name of the road service organisation</th>
<th>Name of the Meteorological Institute</th>
<th>National Administration</th>
<th>Local Administration</th>
<th>Weather forecasts</th>
<th>Satellite pictures</th>
<th>Percipitate radar pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Belgium</td>
<td>3 regional Road Administrations</td>
<td>WING (weather section of Belgian Air Force)</td>
<td>x (3 Regions)</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>The Directorate of Roads and Motorways of the Czech Republic</td>
<td>Czech Hydrometeorological Institute</td>
<td>x</td>
<td>x</td>
<td>8 - 10 &amp; 24 - 72 hrs</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>Denmark</td>
<td>The Danish Road Directorate</td>
<td>Danish Meteorological Institute</td>
<td>x</td>
<td>x</td>
<td>x 5 hrs</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Finland</td>
<td>Finnra</td>
<td>Finnish Met Institute and private Weather Service Finland (FORECA)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>France</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>-</td>
<td>German Weather forecast (Deutscher Wetterdienst)</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Great Britain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hungary</td>
<td>The Technical and Information Services on National Roads (AKM1)</td>
<td>The National Meteorological Service (OM SZ)</td>
<td>x</td>
<td>-</td>
<td>x 72hrs for 6 Regions. 30 hrs in 3 hrs for 30 microclima</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Iceland</td>
<td>Public Road Administration (PRA)</td>
<td>Iceland's Meteorological office and Denmark's Meteorological Institute</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>National Road Authority (NRA)</td>
<td>The weather bureau (Meteorological Eireann)</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>The Norwegian Public Roads Administration (NPRA)</td>
<td>Norwegian Meteorological Institute (DNM1)</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Romania</td>
<td>National Administration of Road (NAR)</td>
<td>National Institute of Meteorology and Hydrology (NIMH)</td>
<td>x</td>
<td>-</td>
<td>x 24 hrs, weakly, monthly</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slovenia</td>
<td>The Directorate of the Republic of Slovenia for Roads</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>The Swedish national Road Administration (SNRA)</td>
<td>The Swedish Meteorological and Hydrological Institute (SMHI)</td>
<td>x</td>
<td>-</td>
<td>x 6, 12, 18 and 24 hrs</td>
<td>x 24 hrs</td>
<td>x 24 hrs</td>
</tr>
<tr>
<td>Switzerland</td>
<td>MeteoSwiss</td>
<td>x</td>
<td>x 24 hrs</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>The Ministry of Transport</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
**A.5. Technical and organisational systems of data collection**

**Determination of the most suitable system of transmission of information**

Determination of a suitable system to transmit information is one of the most influential tasks; it is simply to insure that all necessary information is passable to users in exact time and format.

A summary of all countries technical and organisational systems of data collection are described schematic.

### Technical and organisational systems of data collection

<table>
<thead>
<tr>
<th>Countries</th>
<th>Determination of the most suitable system of transmission of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>The measured values are transmitted by leased lines to the road administration. In exceptional cases selecting modems are used.</td>
</tr>
<tr>
<td>Belgium</td>
<td>RWIS are operating in the Flemish and in the Walloon Regions (in the near feature in Brussels-Capital Region). The Central system of the RWIS downloads, validates and archives data from road weather stations every 6 or 10 minutes (measured data, alarms and warning) through computer lines. In Walloon region the central system calculates a mathematical 3-hour forecast of road surface and body temperature. At the end of this validation and calculation step, measured and extrapolated data are transmitted to Local Terminals. WING is also connected to these systems and its long term forecasts are transmitted to each users.</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>&quot;Meteorological Information System&quot; is destined for processing, distribution and visualisation of data concerning actual weather conditions and its expected development system works on state-wide level and contents of information is adapted to requirements of road and motorway winter maintenance in the Czech Republic with concentration to road masters.</td>
</tr>
<tr>
<td>Denmark</td>
<td>Receives information by file transfer to users PCs. The Road Directorate Traffic Information Centre communicates the information. Open 24 hours a day and maintains contact with road authorities, Danish Meteorological Institute, the police, the emergency services etc. The information is also distributed via, radio, teletext, telephone etc.</td>
</tr>
<tr>
<td>Finland</td>
<td>Operational centre has network access to the weather product server, Internet based service, and there are also fixed line, telephone line and mobile connections and services available.</td>
</tr>
<tr>
<td>France</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>Online connection between Ice detection systems to RWIS centres and regional centres of the German Weather Forecast (Deutscher Wetterdienst).</td>
</tr>
<tr>
<td>Great Britain</td>
<td>UK uses TR2020C protocol, but is looking into web-based systems.</td>
</tr>
<tr>
<td>Hungary</td>
<td>During winter periods, road management companies employ personnel that are on duty around the clock. Its tasks include information collection, taking the necessary actions and providing information to the Centre Information Service on Public Roads (UTINFORM) and locally to the road users.</td>
</tr>
<tr>
<td>Iceland</td>
<td>The current information system for PRA (Public Road Administration) uses a common base, data being gathered into a single, central database.</td>
</tr>
<tr>
<td>Ireland</td>
<td>All weather stations in Ireland are used for forecasting i.e. no weather stations are used for information alone or located at critical sites. There is a view that availability of forecast maps on the RWIS removes a need for information weather stations. However some local authorities request information stations despite the availability of the maps.</td>
</tr>
<tr>
<td>Norway</td>
<td>The information is sent by satellite to five main locations, and then transmitted to users via their Intranet and presented in web application.</td>
</tr>
</tbody>
</table>
## Determination of the most suitable system of transmission of information

<table>
<thead>
<tr>
<th>Countries</th>
<th>Determination of the most suitable system of transmission of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romania</td>
<td>The information from NIMH, RWIS, daily patrolling on roads, local authorities, participants in road traffic and police teams are collected and compiled at National Road Administration. The Central Dispatcher Station (open 24 hours a day). An Information System collects data from RWIS and the Meteorological Institute; these data are then elaborated and disseminated among the whole system (11 computers with different functions for this stage). The information is disseminated to the public via radio, TV, telephone, VMP etc.</td>
</tr>
<tr>
<td>Slovenia</td>
<td>The information of the public is carried out through AMZS (Automobile Club of Slovenia), which is authorised for collection of data from all necessary information and it communicates them to radio stations, television etc. The information for more important road routes are communicated also abroad (ERIC 2000), where the information are exchanged.</td>
</tr>
<tr>
<td>Spain</td>
<td>The information collected is sent to a central data bank through the transmission network by telephone line. It is presented to the public by radio, television and Internet.</td>
</tr>
<tr>
<td>Sweden</td>
<td>The information collected at the RWIS measuring stations is sent to a central data bank at the Swedish National Road Administration through the telecommunications network. The maintenance centres and the seven regional Traffic Information Centres (TIC) have access to RWIS via Internet. The maintenance centres also have to report to the TIC every time they start a winter maintenance action or when there is a change in road conditions. Information about road conditions is presented to the public by radio, television and Internet. The public can also call one of the seven regional TICs.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>The forecast is done separately for over 20 areas with different local climates. The information is distributed by phone lines and computer network and arrives directly on the RWIS-computer in the maintenance centre.</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>The measuring station is linked to a central computer (19 central computers in total). For reliability reasons, all central computers have been equipped with a backup computer. The central computer manages the data communication with the measuring stations. When the co-ordinator calls the central computer, the computer is linked automatically to the computer of a weather bureau. The co-ordinator will use the out to make a decision. The application is called GMS-Meteo.</td>
</tr>
</tbody>
</table>

### A.6. RWIS-System (Road Weather Information System)

Determines the most suitable system of transmission of information.

The Road Weather Information System is decision-making tool for icy road driving safety. The object is to maintain a satisfactory traffic ability and level of traffic safety on the roads during a winter season.

The system highlights icy driving situations before they actually arise, enabling preventive salting before it becomes icy.
<table>
<thead>
<tr>
<th>Countries</th>
<th>Road Ice Prediction System</th>
<th>Forecast period</th>
<th>Density km.</th>
<th>Type of measurements</th>
<th>Ratio of forecast</th>
<th>Location of forecasting stations</th>
<th>Location of RWIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Road Ice Prediction System</td>
<td>1. Nov. to 31. March</td>
<td>350 Stations</td>
<td>Air, surface Temperature, relative humidity, precipitation, road condition, freezing temp. after spreading of de-icing material, wind direction and speed, dew point, air pressure.</td>
<td>2-hour forecast, tendency of air- and surface temperature.</td>
<td>Are set up at the coldest points of the roads and bridges.</td>
<td>Are set up at the coldest points of the roads and bridges.</td>
</tr>
<tr>
<td>Belgium</td>
<td>RWIS</td>
<td>From mid of Oct. to end of Apr.</td>
<td>97 Stations (distributed between major weather stations and secondary weather stations)</td>
<td>Major weather stations: air, subsurface temperature, humidity, wind speed and direction, precipitation, radiation, road condition and dew point. Secondary weather stations are smaller and measure neither wind parameters or road subsurface temperature.</td>
<td>24-hour forecast of road surface temperature of each major weather station (and 3-hour forecast of road surface based on last 24-hour measured data in Walloon region).</td>
<td>At representative points within some climate areas. Along main Highways (motorways and regional roads).</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>RWIS-Systems</td>
<td>1. Nov. to 30. Apr.</td>
<td>Every 50 km on motorways, as for road network, installation is made by steps</td>
<td>Cloudiness, temperature, wind, precipitation, dangerous phenomena.</td>
<td>Forecast for regions (4 times a day), motorways and climatic zones.</td>
<td>Predominantly in the critical points</td>
<td>Predominantly in the critical points.</td>
</tr>
<tr>
<td></td>
<td>Icy Road Warning System</td>
<td>From 1 Oct. to 30 Apr.</td>
<td>45 km/stations. 290 stations.</td>
<td>Road, dew point and air temp. and conductivity, air humidity, wind speed and direction.</td>
<td>3-hours Individual stations + 5 hours corresponding forecast.</td>
<td>These stations are found at coldest climatic spots.</td>
<td>The stations are found at the so-called white spots.</td>
</tr>
<tr>
<td>Finland</td>
<td>Road Ice Prediction Systems (RIPS)</td>
<td>1 Oct. to 30 April</td>
<td>29k/stations. 280 stations. The out stations density in southern part of the country significantly higher than in the north.</td>
<td>Air, road surface, road body (-5 cm) temperatures, Wind speed and direction, humidity and dew point, precipitation, visibility, road conditions.</td>
<td>18-hour, possible to get for every outstations (4 times per day)</td>
<td>In southern part of country.</td>
<td>Both coldest and average.</td>
</tr>
<tr>
<td>France</td>
<td>RWIS</td>
<td>From 15 Nov. to 15 March.</td>
<td>500 RWIS stations</td>
<td>Air, Road, Freezing temp., Humidity or dew point. state of road, precipitation's</td>
<td>Depending of the station</td>
<td>-</td>
<td>Basis on Thermal mapping on motorways, expert and operational knowledge on the other roads. Its spots is on coldest point.</td>
</tr>
<tr>
<td>Germany</td>
<td>Ice Detection System</td>
<td>01. Nov. to 31. March</td>
<td>about 600 stations</td>
<td>Air, Road surface, Road body and freezing temperature, humidity, dew point, road condition, wind velocity and direction, precipitation, thickness of the Snow covering, grip (Fahrbahnglätte), concentration of the de-icer.</td>
<td>Weather, road surface and road conditions forecasts several times a day. Highway surveillance gets 2 hours forecast from their ice detecting systems.</td>
<td>see &quot;locations of RWIS&quot;</td>
<td>Predominately in the critical parts of a track. The forecast stations are also connected with telematic installations on the track to adapt the traffic to the weather conditions.</td>
</tr>
<tr>
<td>Countries</td>
<td>Road Ice Prediction</td>
<td>Forecast period</td>
<td>Density km./stations</td>
<td>Type of measurements</td>
<td>Ratio of forecast</td>
<td>Location of forecasting stations</td>
<td>Location of RWIS</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Great Britain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hungary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Road surface forecast model</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iceland</td>
<td>Traffic monitoring and control</td>
<td>15 Oct. to 30 Apr.</td>
<td>50 km/stations, 60 stations</td>
<td>Air, road temp., humidity, wind force, direction, precipitation and traffic counting.</td>
<td>6 days weather forecast from 50 stations. 5 hours specific forecast from 10 stations.</td>
<td>-</td>
<td>Critical spots and on mountain roads.</td>
</tr>
<tr>
<td>Ireland</td>
<td>RWIS system</td>
<td>1 Nov. to 30 Apr.</td>
<td>48 road weather stations, 56 km/stations</td>
<td>Air, road surfaces and sub-soil temp., precipitation, humidity, surface condition, presence of frost, ice, snow, salt.</td>
<td>24 hrs. forecast of entire road network. Radar images.</td>
<td>At average (515 km²) not critical locations within the 2 domains.</td>
<td>At critical locations as cold spots.</td>
</tr>
<tr>
<td>Norway</td>
<td>RWIS</td>
<td>15 Oct. to 15 Apr.</td>
<td>180 stations</td>
<td>Air and road temperature, humidity and precipitation some stations have in addition wind speed and direction, road surface condition, video and long wave emission.</td>
<td>There exists two different models in their system (IceCast), one has a forecasting period of 3 hours the other 24 hours, only a few stations has such a forecasting.</td>
<td>Throughout the country at places where the conditions are known to be difficult, determined with the help of thermal maps.</td>
<td>At critical locations as cold spots.</td>
</tr>
<tr>
<td>Romania</td>
<td>RWIS systems</td>
<td>15 Nov. to 15 March</td>
<td>36km/station, 4 stations</td>
<td>Air, road, temperature, humidity, amount and type of precipitation, snow height, wind speed, wind direction, solar radiation.</td>
<td>24 hrs. forecast.</td>
<td>At representative points within the microclimate, with the possibility of connecting to the electricity network and GSM.</td>
<td>Critical spots on mountain, plain and hill roads.</td>
</tr>
<tr>
<td>Slovenia</td>
<td>ERIC 2000</td>
<td>1 Oct to 15 Nov.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spain</td>
<td>RWIS systems</td>
<td>From Oct. 15 to April 15.</td>
<td>-</td>
<td>Wind speed and direction, temp. and humidity, atmospheric pressure, solar radiation, precipitation, visibility and ice on the road.</td>
<td>The system gathers information every 10 minutes and makes a forecast for the following 6 hours.</td>
<td>Located at representative points within the microclimate, with the possibility of connecting to the electricity network</td>
<td>Critical spots, shaded areas, bridge decks, etc.</td>
</tr>
<tr>
<td>Countries</td>
<td>Road Ice Prediction</td>
<td>Forecast period</td>
<td>Density km.</td>
<td>Type of measurements</td>
<td>Ratio of forecast</td>
<td>Location of forecasting stations</td>
<td>Location of RWIS</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>--------------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Sweden</td>
<td>RWIS</td>
<td>From 1. Oct. to 30 Apr.</td>
<td>680 stations. 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.</td>
<td>Air, road, dew point temp., humidity, amount and type of precipitation, wind speed and wind direction.</td>
<td>adar and satellite information 24 hrs. a day weather forecast twice a day. 2 hour forecasts for air, road and dew point temperature are calculated and presented every half hour for each station in the RWIS</td>
<td>All stations are forecast stations</td>
<td>Laces most prone to slipperiness. 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.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>RWIS</td>
<td>1 Oct to 30 April</td>
<td>400 road sensors.</td>
<td>Air temperature 2 m above ground, surface, freezing temp., humidity, dew point, precipitation, wind direction and intensity, state of the road, residual salt.</td>
<td>24 hrs. Road weather forecast. Meteorological forecasts “Meteotel”</td>
<td>Usually the most dangerous spots, on bridges and on shady stretches.</td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>RWIS</td>
<td>301 measuring stations. 15 km/ stations.</td>
<td>Air temperature, relative air humidity, road surface temp, sub-soil temperature, precipitation, surface condition (dry, presence of moist and/or salty). Calculated dew point.</td>
<td>Short and long term's road surface forecasts. 4 and 20 hrs. a head.</td>
<td>Decided base on combination of moist and low temp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### A.7. Thermal Mapping

White spots on the road are the stretches, which first become icy when the temperature approaches freezing point. The white spots are known to some extent from local experience but a more reliable method is thermographic measurements.

When thermal measurements are used in connection with winter maintenance, the object is to draw a thermal profile of the road and from this to determine the white spots, where the risk of icy roads is greatest when the temperature drops towards freezing point. It is generally to these localities that icy road warning stations can be set up to greatest benefit. It is also here that preventive measures are first initiated.

The readings are therefore also used for checking and calibrating of the icy road stations, and for data collection for thermal maps (Thermal mapping).

Thermographic reading on the road surface can also be used to provide other information on the road surface, e.g. whether there is poor adhesion between the top layer and the underlaying layers in the road.
This type of measurement is used by several members of COST 344 and mentioned below framework describes their importance attached to thermal mapping together with the average size of climatic domain and ratio of using thermal mapping.

**Thermal Mapping**

<table>
<thead>
<tr>
<th>Countries</th>
<th>Significance attached to thermal mapping</th>
<th>Average size of climatic domain km²</th>
<th>Ratio of thermal mapping</th>
<th>Handling resurfacing changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>No experience</td>
</tr>
<tr>
<td>Belgium</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>The measurements are done by night characteristic of three weather types, (clear and calm, Clear and windy or overcast and calm, overcast and windy). These measurements are done by means of an infrared thermometer placed near the ground in a moving vehicle.</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>No experience</td>
</tr>
<tr>
<td>Denmark</td>
<td>x</td>
<td>-</td>
<td>Not Systematic, but each 5 year.</td>
<td>No different treatment.</td>
</tr>
<tr>
<td>Finland</td>
<td>x</td>
<td>Covers about 500</td>
<td>Only once</td>
<td>No different treatment</td>
</tr>
<tr>
<td>France</td>
<td>Thermal mapping is used to locate the coldest point on motorways.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>Thermal mapping has low relevance in Germany.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Great Britain</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hungary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iceland</td>
<td>-</td>
<td>x</td>
<td>11 climatic domain, 10,000 km² each.</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>No special attention to resurfacing, as resurfacing is done during the warm season and is not supposed to be more slippery than the old surface that is replaced.</td>
</tr>
<tr>
<td>Romania</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>Summertime with hot days when it is possible to appear the exudation phenomenon, these places are treated by specific methods(by paying a special attention to sensor area).</td>
</tr>
<tr>
<td>Slovenia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spain</td>
<td>Will be used on a regular basis to determine the situation of the weather stations</td>
<td>No study has been carried out of climatic domain size</td>
<td>There is no systematic periodicity. Thermal mapping has been used only at irregular intervals.</td>
<td>No experience has been acquired.</td>
</tr>
<tr>
<td>Sweden</td>
<td>x</td>
<td>-</td>
<td>Not regularly, but in cases to locate white spots.</td>
<td>No special attention to resurfacing</td>
</tr>
<tr>
<td>Switzerland</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Countries</td>
<td>Systems of control posts and patrols</td>
<td>Expert system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>Happens in needful situations.</td>
<td>No special expert systems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>Patrols are an important part of adverse condition detection. Occurs mainly in the early morning if there is a risk of frost.</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Only in case of disaster [critical state]</td>
<td>Any applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>Happens in needful situations</td>
<td>Does not exist.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>Control patrols are used only when system gives some indication of the need of maintenance.</td>
<td>Not used so far.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Patrols are an important part of adverse condition detection. Occurs daily in the early morning if there is a risk of frost.</td>
<td>No expert system is in existence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Some kind of ice detecting systems. Experience is also an important point for deciding and working in road maintenance</td>
<td>Does not exist.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Britain</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>Operators on duty are out on the road inspecting the condition, more frequent, when slippery conditions are expected.</td>
<td>The managers on duty get information from different areas, by telephone, video picture and satellite pictures of weather movements. They will inform and instruct the operators.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>Daily patrolling between 3:00 - 5:00 a.m. and 3:00 - 5:00 p.m., when it is necessary depending on meteorological condition.</td>
<td>Ongoing elaboration.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Patrols are an important part of adverse condition detection, carried out daily in mountainous areas with higher risks of ice formation.</td>
<td>No expert system is in existence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>The foreman on duty can patrol the roads if he feels it is necessary in order to obtain information on the road condition</td>
<td>No expert system exists today. A prototype is being developed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Occurs only in exceptional circumstances.</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Happens in needful situations</td>
<td>Not existing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“WINTER MAINTENANCE MANAGEMENT SYSTEM”

Final Draft of TG5

Dr. Christian Holldorb, Germany
Dr. Anita Ihs, Sweden
Ljiljana Herga-Luis, Slovenia
Manfred Skerlan, Austria
Xavier Cocu, Belgium
5. Introduction - Objectives of TG 5

The objectives of TG 5 “Winter Maintenance Management Systems” in COST Action 344 were:

- To give an overview about Winter Maintenance Management Systems (WMMS), their use in Europe and different aspects of their use. During the processing it became clear, that at present opinions and experiences about other aspects of the operation of WMMS are seldom published except those about financial aspects. So no further statements can be given in relation to Quality Aspects, Legal Aspects and Social Aspects.

- To give an overview about the links and interfaces to other Management Systems
- To give recommendations about implementation of WMMS
- To give recommendations about the integration of WMMS in an Integrated Road Management System.

The work of TG 5 is dealing only with computer-based WMMS. TG 6 of COST 344 has discussed in detail the assembly of information about wintry road conditions, winter maintenance etc for road users and population using different media of communication and is therefore not subject of WMMS and the work of TG 5. Main focus of TG 5 is the internal information processing within the road authorities. The recommendations in chapter 6.4 mainly base on the experiences of the members of COST 344 and some other experts, which are working in the field of Winter Maintenance and its management.

TG 5 commenced its operations after the 5th meeting (October 19, 2000) of the Management Committee of the COST 344 action. The task group held six meetings:

1. Brussels, Belgium October 20, 2000
2. Brussels, Belgium January 30, 2001
4. Darmstadt, Germany October 17, 2001
5. Brussels, Belgium December 10, 2001
6. Helsinki, Finland March 16, 2002

Christian Holldorb (Germany) was the chairman of the task group. The other persons participating in the task group were Anita Ihs (Sweden), Xavier Cocu (Belgium), Ljiljana Herga-Luis (Slovenia) and Manfred Skerlan (Austria).

In particular we would like to thank Mr Freddy Knudsen, whose report of Danish Experiences of implementation of WMMS flew into the Report of TG 5.
5.1. Overview on Winter Maintenance Management Systems (WMMS) and their operation in Europe

In this chapter the different parts of a management system for winter road maintenance are discussed.

There are two levels of a Winter Management System (WMMS) that might be considered. There is the strategic level where the socio-economic consequences of a chosen winter maintenance strategy are calculated. The other level is the so-called day-to-day level used for the management of the winter maintenance activities.

5.1.1 WMMS for the strategic level

State road management is responsible to public to optimise its operations and to achieve maximum possible output with limited available resources or to achieve set output with minimum spending of resources, respectively.

The strategic (or network) analysis deals with different levels of spending for maintenance and the effects on current and future network condition. The aim is to reach a long-term optimal road network condition, where the total cost of usage and maintenance of infrastructure are the least.

Figure 6.1: Long-term optimal road network condition
On a strategic level we face the reciprocity of road user and road administration cost. That holds also for winter maintenance.

Maintenance activities during the winter influence user costs:
- accident costs (an example: more accidents because of insufficient black ice treatment),
- fuel consumption and wear cost of vehicles,
- journey time costs,

as well as road administration cost:
- cost for winter services (equipment, energy, labour, materials, other services) and
- environmental costs (for example: the damage arising from use of salt).

To calculate the costs for winter services in some countries, for example in Switzerland, the maintenance centres have a cost accounting system. Therefore the total cost of winter maintenance, as well as the cost factors personnel, vehicles and engines, materials, etc. are exactly known.

Based on this cost accounting efficiency measurements are made after every winter. Benchmarking projects covering all maintenance activities are currently running. The objectives are
- increased efficiency
- institutionalised learning programs
- cost reduction.

In an ideal world the road administration would have performed strategic analysis to find out the minimum of total transportation cost (sum of cost for maintaining infrastructure and cost for using infrastructure) and then allocate the resources needed to attain this optimum. But in the real world governments face budget constraints and are perhaps not in the position to reach that optimum. In that case it is a government responsibility to decide what level of service is sustainable and how much resources can be allocated and to the lowest possible socio-economic cost.
Figure 6.2 Description of a WMMS for the strategic level (by the Swedish National Road and Transport Research Institute)

The flow chart in Figure 6.2 gives an example of a WMMS on the strategic level. Models describing the road administrator costs for winter road maintenance as well as the road user and environmental costs are included in the WMMS.

To our knowledge there does not exist any complete WMMS on this level. Knowledge about some of the arrows in the flow chart has however been achieved through various studies over the past years. As an example the influence of various road conditions on vehicle speed and fuel consumption can be mentioned. Recently an extensive research program has been initiated in Sweden to develop a complete WMMS, or winter model as it is called. A large research program in this area has also recently been carried out in Norway (Veggreppssprojektet).

5.1.2 WMMS on the day-to-day-level

A WMMS on the day-to-day level may consist of several parts/systems such as:
- Administrative information
- Route planning
- Road Weather Information System
- Call-out system
- Reporting and documentation of actions
- Information to road users
- Follow-up of actions
A more detailed description of the parts will be given in the sections below.

There are some European countries having WMMS that include many of the parts mentioned above. Many European countries have a separate Road Weather Information System and some also one or more of the other parts as separate systems.

**Administrative Information Systems**

This part of the WMMS would contain information such as the following:

- Personnel (Addresses and phone numbers)
- Duty schedules
- Material depots (account of material)
- Equipment
- Information on vehicles (type, capacities, time of calibration etc.)
- Action plans (in connection with call-outs to support the duty officer)

**Road Weather Information Systems**

A Road Weather Information System contains several parts

Measuring stations which measure:

- Road temperature
- Air temperature
- Humidity
- Wind speed and direction
- Type and amount of precipitation
- Freezing point

Meteorological information:

- Weather forecasts
- Weather radar images
- Satellite images
- Icy road warning system

Usually based on the information from the measuring stations and the meteorological office and various model calculations.

**Route Planning Systems**

Route planning is the essential element of operational planning in winter maintenance, in which the road sections maintained are related to the winter maintenance vehicles. The route planning is done in several steps:

- Fixing of requirements on winter maintenance (maximum cycle time, spread rate etc.)
- Definition of the road network maintained out of road sections and junctions by assigning sectional parameters (length, spread width, priority because of road category, traffic volume, gradients, special traffic etc.)
Vehicle management (number, location, capacity, operating speed etc.)
Manual drawing up of tours and routes or automated tour planning with optimisation of driving without service, operating times or priorities
Adaptation of automated tour planning to further operational or organisational requirements

It is useful to make route planning for several operational cases that occur more often, e.g. for spreading, for combined snow clearing and spreading, for parts of the network of altitudes etc. The route plans will normally be drawn up before the beginning season of winter maintenance. But they are also basis of contracts with private companies for winter maintenance.

In municipalities it can be additionally useful to do winter maintenance on bicycle routes, footpaths and pedestrian crossings systematically with help of databased planning programs, but here optimisation of winter maintenance is not so central as a systematic and complete maintenance of all areas.

Due to the large amount of data it is more proper for a systematic operational planning to put up computer-based route and tour plans. Here there exists the possibility to optimise operational planning, to actualise them on the basis of changes in the road net and to evaluate different strategies of operation. The use of Geographic Information Systems for tour planning is described in more detail in chapter 6.3.4. Data processing systems for the optimisation of winter maintenance, for instance, are implemented in the Road Authorities of some German Federal States.

Call-out Systems

A call-out system is used in connection with implementation, carrying out and follow-ups on the activities involved in a call-out for salting or snow clearance. The system makes phone calls and/or sends faxes. It may also monitor the individual activities to see that actions are started within the prescribed time limits.

Reporting and Documentation of Activities

In this part of a WMMS all information on winter maintenance activities are gathered automatically. With a GPS the exact position of a vehicle can be monitored at any time. This is done to provide the traffic information centres with information (see section below) but also to keep a running account on all expenses involved in winter maintenance.

- Driver
- Vehicle
- Route/ Road section
- Method (ploughing; combined ploughing and salting; dry salt, prewetted salt or brine; sanding)
- At what time the action was started and completed
- Amount of salt used

Follow-up of Winter Maintenance Actions (Salt Consumption, Costs, ...)

The follow-up of winter maintenance actions can be done both on the strategic and the operational level.

On the operational level the follow-up can be used to keep a record on the salt consumption and the stocks in the salt depots. The follow-up of actions can also for example be used for an invoicing system based on the registrations of individual activities and the price lists for the different activities.
For the strategic level it is important to keep a record on the total salt consumption during a winter season, and to compare the salt consumption from one winter season to another. In this context it can be useful to calculate a winter (or weather) index as well as a salt index. This is done for example in Sweden since a few years back. The weather index describes the severity of the winter seasons and is used to compare the number of occasions with slippery conditions (4 different situations), snowfall (3 situations) and drifting snow (4 situations). The calculations of the weather indices are based on data from the RWIS-stations. The salt index compares the recommended salt application rate for the various weather situations with the actual application rates used. The calculations are done every month for each county in Sweden.

Apart from being dependant on the severity of the winter, the salt consumption can also be expected to depend on the choice of strategy for winter maintenance.

**Payment Controlling Systems for Private Contractors**

When using private contractors for winter maintenance, control of the operations made is essential. Therefore WMMS bases in the main on reports and documentation of winter maintenance. Apart from the automatically capture of operational data with help of GPS in vehicles and the automated classification of the data captured of defined routes plausibility audits on the basis of weather data, the extend of the contract as well as the frequency of the undertaken operation are necessary for paying the enterprises.

If penalties for breach of contract are agreed with the enterprises when differences occur to the designed services of winter maintenance in a contract these penalties could be considered automatically. Furthermore differences between services charged for by the enterprise and services realised should be detected automatically. Control of agreed quality standard is central in a functional description of services, in which the enterprise is responsible for keeping of the agreed level of standards.
### 5.1.3 The use of computer based WMMS in Europe

An overview about the use of computer-based WMMS in different European countries is shown in Figure 6.1 and Figure 6.2. As WMMS is modularly built the information refers to the operation of the unique components that are only partly linked together. The components are explained in chapter 6.2.2. The information bases on data of the COST-Members and therefore it cannot lay claim to completeness.

<table>
<thead>
<tr>
<th>Component \ Country</th>
<th>A</th>
<th>B</th>
<th>CH</th>
<th>CZ</th>
<th>D</th>
<th>DK</th>
<th>E</th>
<th>FIN</th>
<th>F</th>
<th>GB</th>
<th>H</th>
<th>IS</th>
<th>IRL</th>
<th>N</th>
<th>NL</th>
<th>R</th>
<th>S</th>
<th>SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems for administrative information</td>
<td>2</td>
<td>0</td>
<td>2/1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>/</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Road Weather Information Systems</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>/</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Field Stations</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>/</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Meteorological Information</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>/</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Route Planning Systems</td>
<td>2</td>
<td>2/1</td>
<td>2/1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>/</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>/</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reporting and documentation of activities</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>/</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>/</td>
<td>2</td>
</tr>
<tr>
<td>Call-out systems</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>/</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>/</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Follow-up of winter Maintenance Actions</td>
<td>3</td>
<td>1</td>
<td>2/1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>/</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>/</td>
<td>2/1</td>
</tr>
<tr>
<td>Controlling of Accounting of Private contractors</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>/</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>/</td>
<td>2/1</td>
<td>2</td>
</tr>
</tbody>
</table>

3 = common in use  
2 = partly in use  
1 = in developing  
0 = not in use  
/ = no information  
1) by Auto Club  
2) at surveillance centres  
3) on Motorways  

Figure 6.3: Use of computer-based WMMS in Europe on Highways (Motorways, National Roads, Trunk Roads, Regional Roads, County Roads)
<table>
<thead>
<tr>
<th>Component \ Country</th>
<th>A</th>
<th>B</th>
<th>CH</th>
<th>CZ</th>
<th>D</th>
<th>DK</th>
<th>E</th>
<th>FIN</th>
<th>F</th>
<th>GB</th>
<th>H</th>
<th>I</th>
<th>IRL</th>
<th>N*</th>
<th>NL</th>
<th>R</th>
<th>S</th>
<th>SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems for administrative information</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>2</td>
</tr>
<tr>
<td>Road Weather Information Systems</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>/</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Field Stations</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>/</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Meteorological Information</td>
<td>/</td>
<td>/</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
<td>3</td>
<td>3</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Route Planning Systems</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>/</td>
<td>/</td>
<td>3</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Reporting and documentation of activities</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>/</td>
<td>2</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>2</td>
</tr>
<tr>
<td>Call-out systems</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>/</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>0</td>
<td>/</td>
<td>/</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>/</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Follow-up of winter Maintenance Actions</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>/</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>/</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Controlling of Accounting of Private contractors</td>
<td>/</td>
<td>/</td>
<td>1</td>
<td>/</td>
<td>1</td>
<td>2</td>
<td>/</td>
<td>/</td>
<td>0</td>
<td>/</td>
<td>/</td>
<td>0</td>
<td>3</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

3 = common in use  
2 = partly in use  
1 = in developing  
0 = not in use  
/ = no information  
1) by Auto Club  
N*: only representative for the biggest municipalities in Norway

Figure 6.2.4: Use of computer-based WMMS in Europe in urban areas

5.1.4 Financial Aspects

When using WMMS financial aspects are of most interest. These are not only economic improvement for the road administration but also the economic benefit on the road user’s part. The operational and economical benefit however faces business management costs when implementing and using WMMS that are to be borne by the road administration. In Figure 6.1 the essential benefit and costs are compiled for the WMMS explained in chapter 6.2.2. There is no possibility to make general statements concerning the level of benefit and costs of WMMS; they depend on a variety of specific marginal conditions e.g. postulated functionality of WMMS, existing technical equipment, existing database, level of the staff’s training and so on, so that a detailed cost benefit analysis is necessary when implementing WMMS.
### Benefits and Costs

<table>
<thead>
<tr>
<th>Benefits and Costs</th>
<th>Administrative Information Systems</th>
<th>Road Weather Information Systems</th>
<th>Route Planning Systems</th>
<th>Reporting and Documentation of Activities</th>
<th>Call Out Systems</th>
<th>Follow-Up Winter Maintenance Actions</th>
<th>Controlling of Cost and Accounting of private contractors and public administrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of efforts in planning and administration</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Reduction of consumption of spreading material</td>
<td>0</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Reduction of operation time</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Reduction of operation frequency</td>
<td>0</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Improvement of winter maintenance documentation</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Simplification of accounting</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Reduction of accident costs</td>
<td>0</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reduction of traffic obstructions</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Costs of technical equipment</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Costs of system implementing</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Costs of data procuring</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Costs of data maintenance</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

++ = very important,  
+ = important,  
o = no influence

Figure 6.5: Benefits and Costs of the use of different components of WMMS

### 5.2. Integration of WMMS in Road Management Systems

WMMS makes use of some information that is created and stored in other road management components (see Figure 6.1). In order to avoid doubling of information (costs and problems that arise because of that) it is necessary to establish a proper relation between the components.

In the next section an overview is given about different management systems in an Integrated Road Management System as well as their links to WMMS. Traffic Management Systems are discussed in more detail in the report of TG 6.
5.2.1 Interface to Pavement Management Systems (PMS)

General
Planning and building of traffic facilities requires considerable public investments. The preservation of roads is also very cost-intensive; therefore diverse programs are developed, whereby the annual expenditure for preservation works becomes determinable. Pavement Management Systems (PMS) form the base for the cost estimation of the road conservation. The preservation of the structural substance must be ensured, thus the road administration contributes its section to the road safety. The different kinds of PMS offer the possibility to prevent pavement problems, which are caused for all by the traffic volume and the influences of the weather. The reduced financial resources, which are available for the road conservation, must be used in such a way that the purpose of its use is economical and essentially comprehensible.

A PMS is used to find the “optimum” strategy for maintaining the road. i.e. to find the “minimum” socio-economic costs as described in chapter 6.2.1. Important parts of a PMS are therefore models for calculating the road user and road administrator costs, but also for example models for predicting/describing the deterioration of roads.

Structure of a PMS
Basis of each PMS is the entry, collection and sequential administration of the constructional status of a traffic surface. The quality of a road database is depending on type and range of the available data. Important facts are thereby the road category, the average daily traffic volume, the proportion of heavy vehicles like trucks or buses, the average driving speed and so on. The probable point in time and scope of road construction can be better judged by inclusion of this information. The resulting costs are assessable and can be documented at an earlier moment. The evaluation of the road condition takes place among other things through visual inspection, structural testing, digitally cameras, imagine processing systems and so on.
The Pavement Management System is completed by data of diverse type, which concerns certain road elements. Some examples:

- Plans of cross section, front view and ground floor
- Type, range and point in time of executed repairs
- Type and position of installations (e.g. road drainage or conduction)
- Measured data such as for example rut depth, roughness, texture, cross fall, gradation

A good roadway quality, which is attainable by PMS, brings also advantages to economical type. Positive aspects arise for the drivers and improve the customers (road users) satisfaction with the travel quality.

Links to WMMS

WMMS and PMS are needs a lot of same information of the road database, for example length, width and number of lanes of the road section or type of road surface. On the other side they are associated through a number of common factors. One of the substantial factors of PMS is budgetary planning. The costs that will be incurred by future winter maintenance activities must be pre-determined with as great a precision as possible. Clearly, an unknown issue is the precipitation intensity during the forthcoming winter period. Weather conditions determine the consumption of spreading materials, the number of control activities, personnel and fuel costs within the context of winter maintenance operations.

The mechanical clearing of snow from the pavement causes wear and tear on the road surface. Damage to landmarks, ramp lanes, and roadsides cannot be prevented. The choice of spreading materials depends on the kind of road to be treated. Important factors are the traffic volume, altitude and camber of the road as well as environmental criteria. De-icing agents can damage pavement surfaces, wing units of bridges and verges through chemical reactions. The costs of damage repairs must be considered during the PMS budget preparation.

Due to their close interrelationship, PMS also affect the cost structure of WMMS. Apart from the factors already mentioned, the selection of a winter maintenance category depends on the type, quality and performance of the road surface. When purchasing a road maintenance vehicle, it is essential to select one that offers the possibility of also buying a number of add-on modules. The objective is an all-season use of the vehicle. Summer-season activities, which can be assigned to the PMS, are carried out. For example the truck can be used as a feeder unit during road construction works or road cleaning activities. In the majority of cases winter activities form a part of WMMS. The kind of add-on modules has changed. Spreaders, snow ploughs and snow cutters have replaced other types of equipment. Therefore, there is a flowing transition between the PMS and the WMMS, which cannot be separated.
5.2.2 Interface to Bridge Management Systems (BMS)

Overview BMS

Bridge Management includes all activities, which occur in connection with planning, construction, conservation, maintenance and operating of bridges. Herewith the road administration as well as third parties e.g. engineers and executing companies are considered. The aim of BMS is to achieve the highest degree of benefit with the lowest possible costs. In addition of road bridges further construction in connection with roads e.g. retaining walls can be included in an increased Construction Management System.

Essential element of BMS is a database that includes all information of the construction, its condition, its traffic loading, the accident occurrence and the costs concerning history, presence and future. In addition to the database BMS can include modules for the presentation of information, modules for planning and documentation of inspection measures as well as forecasts and planning of future projects depending on complexity and target.

In order to plan and optimize inspection (service) and maintenance procedures of all bridges in the road network according to the same valuation standards a complex Bridge Rehabilitation Management System is necessary. Herewith maintenance projects are determined in view of the predicted condition of the construction which base on the actual condition (state), the future traffic loading (heavy vehicle traffic) and further influence quantities as well as the budget available in future. In addition to the technical economical optimisation of projects another aim is to show clearly the worsening of the condition when the budget is not sufficient.

Link to WMMS

BMS and WMMS are not in a close connection together because there is no direct interaction between them. Both systems however call partly up the same data like other management systems referring to roads.

For WMMS data of bridges construction are first of importance because the construction can influence the wintry reaction of the pavement surface on the bridge. Bridges cool down quicker than the road itself. The present structural condition however has no direct influence of the strategy of winter maintenance provided that the bridge is completely available to the traffic. Data of bridges can also be required for planning of ice detection systems that are often installed on exposed road sections.

Information on winter maintenance planning and its realisation are of no importance for BMS. Because salt can damage bridges made of steel and concrete, the documented total amount of salt, spread during winter periods, could be a useful information for a BMS.
5.2.3 Interface to Road Equipment Management Systems (REMS)

Essential elements of the road equipment are traffic signing in order to regulate and to guide as well as marker posts and safety installations. At present there are no managing systems in action which optimize their net wide planning and maintenance according to PMS and BMS. The existing equipment along roads will however be documented in corresponding databases partly in integrated road databases partly in separate systems concerning defined equipment. For example guiding signing in Germany is archived in a central database on the basis of video monitoring of roads.

Following information on regulating traffic signing can be important for winter maintenance especially for its planning: warning of a special risk of slipperiness, heavy sections of ascending and descending grades, traffic regulation in order to use snow chains or (in some countries) studded tyres.

In many European countries electronic controlled variable traffic signs are implemented to inform road users about wintry road conditions, e.g. slipperiness, temperatures, closing of roads to traffic. The control of these traffic signs is made among other things on the basis of Road Weather Information and information about the Winter Maintenance Activities. On the other part those traffic signs can also influence planning and execution of Winter Maintenance Activities so that they must be integrated into WMMS.

The equipment of road sections with stationary de-icer spraying installations is of great importance for WMMS, because through this not only the priority rating of winter maintenance planning but also the individual turnout can be influenced. Furthermore road sections can be analysed out of the evaluation of winter maintenance plans referring to roads which need winter maintenance service more often and so they are interesting for the use of a stationary de-icer spraying installation. In addition to this the use of a stationary de-icer spraying installation depends on further aspects like accident occurrence, traffic loading and road characteristics.

5.2.4 Use of Geographic Information Systems (GIS)

Geographic Information Systems have the purpose of presenting space-referred information, which appears in graphic or tabular format, in a simple and comprehensible manner. There are a large number of diverse data sources within the structure of a GIS usable, from which a uniform database system is used. Data import and export is possible. The co-ordinate system (longitude, latitude and height above mean sea level) can be used as a base. An abundance of technically relevant data (location of groundwater, vegetation, ground condition, road systems, line routes, land development and so on) completes the plan, forming a meaningful overall view. The data packets can be linked together and are callable on the display in coloured representation. The output of the plans can be made by printers, plotters or colour copiers.
One of the simplest forms of the graphic representation is the block structure (s. Figure 6.1), which can be completed with different attributes (e.g. road designations). The input into the system takes place via digitisation, scanner or mouse.

![Block structure (grey) with multipurpose map and road designation](image)

**Use of GIS for Route Planning**

The use of the GIS for winter maintenance planning requires an appropriate volume of data, whereby the road system is representative in any yardstick. Each road is divided into sections, which are limited by nodes. By clicking on the mouse, the individual sections can be activated. A number of marked road segments are the result of an area under maintenance. These segments can be connected together or they can be separated, depending on whether a whole area or only some roads are maintained. The system offers the possibility of marking the desired roads by means of a coloured line or indicating the route process from a starting point to a final point. In Figure 6.2 the starting point is called A and the final point is E. The route is displayed by means of a continuous line with directional markers.
GIS enables information to be inserted, which is important for creating a winter maintenance route. It is also possible to insert land and property registers or the surface plane. In this way administrative efficiency can be determined. The person or organisation responsible for road clearing and winter maintenance in a certain area can be indicated.

GIS supplies an information-packed usable in the same way for the administration, operators (winter maintenance operation centres) and the individual citizen. Each winter maintenance plan can be accessed via Internet or Intranet (reduced circle of users). Winter maintenance vehicle drivers and additional personnel involved in monitoring the condition of the roads, have a paper copy of the related winter maintenance plan. To create a framework that covers clearing and spreading concepts it is important to maintain an overview. Which roads were already taken into account and which were not. This takes into account all surface areas with winter maintenance obligations, within the urban zones or outside the local area. During the planning phase, duplicating the insertion of roads or omitting a road completely must be avoided. GIS offers the opportunity of avoiding this risk, since all road sections that were originally taken into consideration are underlined in colour. Maps with complicated route systems can be added by means of several supplementary windows in order to make details more clearly legible. The data in graphic form can be completed with the data presented in textual format. In a type font, the basic (map number, date of issue, author, responsible road administration) as well as the additional information (north arrow, map legend, yardstick call-sign of the concerned vehicle) is displayed, which had previously been introduced into a database.

Figure 6.8: Winter maintenance plan with attached route process
Winter maintenance maps are constantly being modified. The construction of new roads and the modification of existing road sections, as well as the associated traffic diversions must be considered. For road traffic safety reasons, some roads are narrowed in order to reduce the speed of passing vehicles or to completely prevent access to heavy goods vehicles. Technical traffic measures, such as the regulation of new one-way systems or the modification of existing ones are also a part of winter maintenance organisation.

GIS offers the possibility of rapidly carrying out modifications to plans. The modified plan is available for the respective vehicle within a short time period.

Geographic Information Systems are programs that offer an abundance of basic information. With the assistance of GIS, responsible decisions can be made. Regarding quality improvement, cost consciousness and transparency, this technology is a substantial step forward in improving the supply of information.

5.3 Recommendations

5.3.1 Implementation of WMMS

5.3.1.1 Model approach to implementation

WMMS is a complex system. The main obstacle in implementation of any system is usually the complexity of the system. To maintain the overview and control over process engineering and process execution a system modelling approach is applied. According to this approach system is treated from more views and on more levels, which are described in various models. A model is a simplified picture of reality, which allows for the insight into essential elements of a system without the obstruction of excess details. It is a written record (or description) of some system element, structured according to some set of rules. This diminishes the risk of incorrect translation of user requirements into system requirements and then system design, which in practice accounts for a large proportion of unsuccessful implementations (in other words: it improves the proximity to information technology).

The first concept of complexity reduction is breaking down the whole into a number of separate views. Due to this division, the contents of the individual views can be described by the methods, which are suitable for a certain view without having to pay attention to the numerous relationships and interrelationships with the other views. Afterwards, the relationships between the views are incorporated into the model and are joined to an overall analysis without any redundancies.

A second approach for reducing the complexity is the analysis of different descriptive levels. Following the concept of a lifecycle model the various description methods for information systems are differentiated according to their proximity to information technology. This ensures a consistent description from business management-related problems (user needs) all the way down to their technical implementation. In this text we remain on the level of user requirement definition, which is general enough to capture the majority of possible solutions while still structured in the manner that represents a basis for elaboration of design specifications.
For implementation we recommend the method, described in following chapter. We don't have the ambition to provide a “recipe” for W M M S implementation. We will present the method on simplified case of basic W M M S. It is nevertheless the responsibility of every single road administration to find individual solutions that suit their individual needs.

5.3.1.2 Views and their connections

To describe certain notion in our world people has developed a language, which is a tool for intuitive description. If asked to describe some complex business happening we start to explain, who is involved, what is being done, how are these activities documented, how it starts and how it ends, who does what, with whom and so forth. From such an unstructured description it is the analyst's task to extract the relevant information. This is done easily by organizing all statements in four types of views:

- Organization view,
- Function view,
- Data view and
- Control view.

Organizational entities involved in the system are captured in organization view. Organizational units perform certain activities in the system. In this view unit definitions as well as their relationships and the relevant structures are represented.

The activities that need to be done in the system are called functions. The function view contains the description of the function itself, the enumeration of the individual sub functions that belong to the overall relationship and the (static) positional relationships that exist between the functions.

In data view information entities (or objects), attributes and relationships, which appear in the process, are depicted.

By splitting the original problem into separate views, the complexity of the representation was reduced. Analysis based on three basic views would be inconsistent and static and relationships between elements of the views would not be included. The relationships between individual views are represented in the control view:

- Combination of organization and functions ("who does what");
- Combination of organization and data ("who needs/creates/is responsible for certain data");
- Combination of functions and data ("which activity needs input/has output of certain data");
- Combination of functions, organization and data (a dynamic business process).
5.3.1.3 Processes
In the following processes, which unite organization units, functions and data, are presented. Apart from only merging the different views, the relations between the objects in the model are introduced.

A process is always triggered by some event. This activates some activity or function. This function cannot be performed by itself; it is performed by some organizational unit. There is variety of possible relations between function and organization unit. Function can be performed by a unit, the unit must be informed about/must inform about, can decide upon, etc.

Performing the function may call for some informational inputs or it may create/update some informational outputs.

The process may start or end with an interface from/to another process. Interfaces connect individual process into complex interdependent structure.

As examples of different kinds of processes dealing with WMMS three (sub-) processes are presented:
- Preparatory works,
- Winter service performing and
- Post-winter works
Figure 6.10: Process description for preparatory works of winter maintenance

Preparatory work process needs to be done before winter season. It’s “getting ready” for winter as such.
A call-out system is performed by road directorate dispatching centre. It triggers certain activities, mainly those that need prompt execution. A decision what action, where, when and by whom needs to be taken is based on Winter road maintenance implementation programme and road weather information system. Messages are mediated by phone or fax using the numbers from Winter road maintenance implementation programme.

Figure 6.11: Process description for winter service execution
During the execution of winter works supervision should be on site. By pre-set supervision procedures a quality of service to road user and cost effective maintenance (for road directorate) is assured.

Another crucial activity is data collection and reporting. This should result in relational database containing data about all winter maintenance activities.

Figure 6.3: Process description for post-winter works

5.3.4 System implementation
So far we have discussed the recommendation for implementation at the level of user requirement. In this chapter we give only a short hint on how to proceed into the next, more technical, phases.

Technical implementation is (again) a complex process. A process is a series of actions bringing about a result. The implementation process starts with unsatisfied user desires (expressed as user requirements this level of analysis was presented in previous chapters) and should end with an operating system with properties that satisfy those desires. It consists of eight main stages and three (sub-) processes.
Figure 6.13: Implementation process

Figure 6.13 is presenting the typical V-shaped life cycle for the project of that kind. On the left side is a strategic part of the project, which should produce conceptual documents and designs for the project. On the right we have physical solutions, which are checked against documents and designs.

From the figure three (sub-)processes are evident:

- Process of implementation as such moving from stage to stage (represented with black line);
- Process of verification the comparison of the output of each individual phase of the development with the output of the previous phase, the objective being to ensure that the output from the new phase fulfills the requirements specified in the outputs of the previous phase. Verification always requires a comparison to be made;
- Process of validation the demonstration that a product satisfies its requirements. Validation requires a decision to be made based on the results of the verification processes and reviews, as well as of the tests performed on the system as it is being integrated.

It is worth saying that the implementation is not a straightforward process. Verification and validation may reveal inconsistencies, which require iterative corrections of outputs of previous phases. This kind of work is worth to be done. The problems that are discovered during the late phases of the project are much more costly to remove than those that are discovered during the early phases.
5.3.1.5 Danish Experiences with Implementing

A winter administrations system is not that simple to implement. If the implementation is to become a success, there are a number of factors to consider:

- The users must be identified. It is important to determine every user's role and by whom and where data will be gathered.
- Users must be involved in the implementation procedure, simply to secure that their situation is considered, while it'll take off the acknowledgement of the system. Especially the duty personnel, who shall input the data into a pressure situation thereby they have a reasonably demands at joint and have influence for the procedures.
- Use of map. Map is evidently useful in a system as a presentation of the current situation, however, simultaneous it contributes to increasing the technical demands for the system. Even without utilisation of GPS and on-line data collection, a map is an essential tool to give an overview and thereby improving the quality of contribution. A "forgotten" route is easily discovered on a map, while it is more difficult to find in a file.
- Spreaders and ploughs can be equipped with GPS and on-line data collection. Principally it is profitable to use this way to gather data, because it saves the need for manual input device and provides a far more detailed documentation of actions.
- An IT site should be determined and established. The users are normally located at different geographical spots and frequently need to be connected through a network. By known design of IT architecture, we must also consider the appropriate technique of management and services for equipment's and databases, simply to obtain a high operating performance for the collected system.
- Information, education and follow-up. It is important to provide an education of inexperienced users as close to the reality as possible. It is also essential to constantly inform about the improvements of the implementation process. Additionally, after introduction of the system, it is essential to collect the information on problems, faults and suggestions of modifications.

The actual system can be developing by its own or based on a standard system. Whatever the method of development is, it is important to divide the implementation to in several phases. Separation of phases can only be effected by introduce parties of the system and simultaneous be satisfied with. The system should only be introduced to a few spots the first time. Thus it is possible to solve some of the difficulties before they spread.

5.4. Requirements on the integration of WMMS in an Integrated Road Management System

As shown in Chapter 0 main focus of the integration of WMMS in an Integrated Road Management System is to manage standardised bases of data, especially for the road net. Hereby however WMMS refer primarily to road data. Modifications in common road data are seldom made in WMMS because of the only of inferior interest of this information for other specific applications. A further essential link is the transfer of operating data on systems for the documentation and evaluation of operating data as well as controlling systems. TG 6 will discuss the link to road user information systems.
Well-defined and clear system architecture is essential for all-inclusive integration of WMMS in overall management and information systems like for the implementation of single components of WMMS, too.

In order to avoid mistakes in the databases all data necessary for different managing systems should not filed repeatedly due to the fact that this complicates data administration considerably. Data can be deposited in a central database, on which several system components access. Decentralised databases are also possible in which the required data can be accessed by cross-reference. Hereby however, heightened demands on the data administration are made.

WMMS as far as possible should base on the same user interfaces as other RMS in order to make handling WMMS easier to the users. It is assumed that the staff of the road administration is not occupied exclusively and the whole year with WMMS so that like in integrated office software solutions, too, standardised user screens and definitions are reasonable. Implementation and use is for example easier if the same GIS-system is used as graphical user interface for all RMS.

The quality of the data necessary for WMMS and provided from other databases must be described precisely. Duration and actuality of data are primarily counted among the accuracy of measurement. For example demands on the accuracy of road lengths are only of less importance in a tour-planning program, however, for a thermal mapping system very high demands on the information about pavement structure can be made. It must be defined similarly, which quality and actuality data must have provided by WMMS.

To avoid incorrect data, rights for data administration are to be defined clearly. In the case of rights given you can access on mutual databases from different systems. Through this it must also be guaranteed that data belonging to persons or other sensitive data e.g. for winter maintenance activities done are secured but common information, however, are available.
Future Research Topics

Final Report of Task Group 4

Dr. Risto Kulmala

Editor: Risto Kulmala
VTT Building and Transport
Box 1902
FIN-02044 VTT

Contributors: Andreas Bark (DE)
Jon Berg (NO)
Marilyn Burtwell (UK)
Yrjö Pllii-Sihvola (FI)
Gudrun Öberg (SE)
The report describes the work of the Task Group 4 “Future research” of the COST Action 344 “Improvement of Ice and Snow Control on European Roads and Bridges”. The objective of Task Group 4 was to identify the most important topics for future research activities in the domain of COST Action 344.

The Task Group carried out the work in three phases:

- identification of topics for future research;
- prioritisation of future research topics; and
- selection and elaboration of the most important topics for future research.

The topics for future research were collected via an e-mail survey sent to the COST Action 344 Management Committee and other international experts. About 90 respondents from 16 different countries sent proposals for research topics. The Task Group analysed the list of 200 different topics received, and produced a final topic list by merging a list of 93 research topics for prioritisation. This topic list was used as a basis for an Internet survey, where experts from different countries and representing different organisation types (road administration, industry, research or academia) were asked to prioritise the research topics. In all, 57 experts from 17 different countries filled in the survey.

A number of topics were regarded as very important or important. The Task Group identified the most important research topics out of the important ones on the basis of analyses of the survey results. The analyses included weighted means of priority scores, histograms, and comparison to current research and finally, combined expert judgement of the Task Group members. The Task Group also produced tentative research task descriptions for these six topics. In addition, another COST 344 Task Group identified a seventh topic. The seven most important future short-term research topics are:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.
7. New methods of winter maintenance management through the use of the latest technologies for data management, communication and positioning.

The topics identified should also be used as input when developing the contents of future European and national R&D Programmes, e.g. the 6th Framework Programme or a possible COST action as a follow-up to COST Action 344. The Task Group also identified a number of long-term research topics in the domain.
Foreword

Task Group 4 “Future Research” of the COST Action 344 “Improvement of Ice and Snow Control on European Roads and Bridges” commenced its operations after the 5th meeting (October 19, 2000) of the Management Committee of the COST Action 344. The Task Group on future research was one of the seven Task Groups of the action.

The Task Group held five meetings:
1. Brussels, Belgium October 20, 2000
2. Brussels January 29, 2001
5. Darmstadt, Germany October 15, 2001

Risto Kulmala (FI) was the chairman of the Task Group. The other persons participating in the Task Group were Andreas Bark (DE), Jon Berg (NO), Marilyn Burtwell (UK), Valérie Muzet (FR), Yrjö Pilli-Sihvola (FI) and Gudrun Öberg (SE). Pekka Kulmala and Arja Wuolijoki from VTT participated in the setting up and analysis of the Internet surveys for this Task Group.

Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
<tr>
<td>Climatology</td>
<td>Study of climate e.g. the basic components (solar radiation, temperature, moisture, and atmospheric circulation) that create the climate system, the regional characteristics and differences in climate, and the changes in climate</td>
</tr>
<tr>
<td>COST</td>
<td>An inter-governmental framework for European Co-operation in the field of Scientific and Technical Research, allowing the co-ordination of nationally funded research on a European level</td>
</tr>
<tr>
<td>FAST</td>
<td>Fixed Automated Spray Technology</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information system - mapping software that links information about location with information about the item and its characteristics</td>
</tr>
<tr>
<td>Nowcasting</td>
<td>Forecasting the status of conditions in the very near future (0 to 2 hours)</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RWIS</td>
<td>Road Weather Information System</td>
</tr>
<tr>
<td>TERN</td>
<td>Trans-European Road Network</td>
</tr>
<tr>
<td>TG</td>
<td>Task Group</td>
</tr>
<tr>
<td>Topoclimatology</td>
<td>Study of the relationships between climate and regional and local characteristics</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Message Sign</td>
</tr>
<tr>
<td>WMMS</td>
<td>Winter Maintenance Management System</td>
</tr>
</tbody>
</table>
6. Introduction

6.1. Objectives and structure of the COST Action 344

The primary objective of the COST Action 344 is “to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states.” (COST 1999)

According to the COST Action 344 Memorandum of Understanding (COST 1999), the main objective of the COST Action 344 is to establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across the EU and other COST member states. This work will provide national governments with the best materials, techniques and procedures required to meet the changing demands of the European road networks (including structures). The conclusions from the project will also contribute to the minimisation of harmful effects on highway features and the environment and improve value for money.

Quantifiable and reliable information on this topic will enable national governments and the EU to consider the policies, which will result in a more cost-effective response to severe low-temperature climatic conditions. This provides for reduced impact on the environment, the recovery or distribution of any additional costs or benefits arising from the changes in winter maintenance operations, and any necessary harmonisation of safety and environmental standards. A significant contribution will thereby be provided to the stated goals of the Trans-European Road Network (TERN), as established by Decision No 1692/96/EC of the European Parliament and of the Council of 23rd July 1996 (COST 1999).

In addition, as a result of the study of management and operational practices employed at national level, the project will assess the effectiveness of these within the various situations and conditions encountered. These assessments are expected to result in objective criteria and benchmarks being developed for the various facets and impacts of snow and ice control in participating countries. (COST 1999).

In all, 19 countries (Finland, Germany, Spain, Sweden, Switzerland, Poland, United Kingdom, Romania, Hungary, Ireland, Austria, Denmark, Belgium, Iceland, France, Czech Republic, the Netherlands, Slovenia and Norway) signed the Memorandum of Understanding of the COST Action 344.

The action is co-ordinated by the COST 344 Management Committee, chaired by Marilyn Burtwell from the United Kingdom. Philippe Stalins, Martin Kemp and Magnus Carle from the Directorate General for Energy and Transport of the European Commission have acted as the secretary of the COST 344 Management Committee.

The work plan structured the work in the following stages: (COST 1999)

1. Review of existing practices involved the following elements:
   - Terminology review.
   - Literature search to establish the state-of-the-art in snow and ice control.
   - Review of current research and development work completed or underway, in both the public and private sectors.
   - Review of current practices by evaluating selected case studies in targeted regions.
   - Creation of an inventory database of snow and ice control methods, equipment, products and materials.
   - Evaluation of the information obtained.

2. Definition of snow and ice control requirements in different European regions.


4. Recommendations for future research.
5. Development of guidelines for the integration of specified snow and ice control methods into network level pavement management and maintenance systems.

6. Recommendations for improvements to driver information and traffic management systems.

7. Reporting.

Most of the work of the COST action 344 was carried out within Task Groups or Task Groups concentrating on the key issues related to the domain of COST 344, and reflecting the aforementioned stages of the work plan. Some of the items of the work plan's stage 1 were carried out in Task Groups 2 and 3. The Task Groups were:

1. Information gathering, literature review and glossary
2. Definition of Requirements
3. Best Practice
4. Future Research
5. Route Management Systems
6. Driver Information Systems
7. Final Report

6.1.2 Purpose and scope of Task Group on future research

The objectives of the Task Group on future research were:
- to identify short-, medium- and long term research issues and topics related to road traffic and infrastructure in the wintertime, and
- to identify those topics with optimum expected benefits.

Task Group 1 produced an earlier list on past and ongoing research in the domain, and this was utilised in the work of Task Group 4. The Task Group decided to limit the scope to the near future, i.e. up to the year 2010. The purpose was to provide issues and topics that should be covered by European and national research projects and programmes. The topics identified should also be used as input when developing the contents of future European and national R&D Programmes, e.g. the 6th Framework Programme.

6.2 Method

6.2.1 Identification of research topics

Firstly, the Task Group agreed a tentative classification to be used in the identification of issues and topics for future research. This classification was then checked against the classification used by TG1 of COST Action 344 (see Appendix 1.2 for the classification).

It was planned to send the classification along with a letter to experts asking them to identify up to five important research topics (in a priority order, if possible) that should be addressed in the national and European R&D programmes in the near future. The letter was sent to all TG4 and Management Committee members, who were asked to send it (possibly after translation) to road authorities, researchers and meteorological offices in their country, and collect the replies. The replies were to contain contact information at least in terms of e-mail addresses. The letter was also sent to industry via the TG4 contacts.

The letter was sent out by e-mail at the end of October 2000 with the deadline of December 15. The letter is enclosed in Appendix 1.
Table 1. Priorities of the research areas as indicated in the survey on identifying future research topics

<table>
<thead>
<tr>
<th>Topic/Research area</th>
<th>Priority of topic/research area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1. Weather and climate</td>
<td></td>
</tr>
<tr>
<td>1.1 Monitoring and data exchange</td>
<td>11</td>
</tr>
<tr>
<td>1.2 Modelling and forecasting</td>
<td>21</td>
</tr>
<tr>
<td>1.3 Effects on traffic (safety, efficiency, ...)</td>
<td>2</td>
</tr>
<tr>
<td>1.4 Implications to infrastructure design</td>
<td>4</td>
</tr>
<tr>
<td>2. Winter maintenance</td>
<td></td>
</tr>
<tr>
<td>2.1 Maintenance management</td>
<td>8</td>
</tr>
<tr>
<td>2.2 Operational practice</td>
<td>2</td>
</tr>
<tr>
<td>2.3 Maintenance equipment</td>
<td>5</td>
</tr>
<tr>
<td>2.4 De-icing products</td>
<td>7</td>
</tr>
<tr>
<td>2.5 Effects on traffic</td>
<td>1</td>
</tr>
<tr>
<td>2.6 Costs and benefits of maintenance</td>
<td>2</td>
</tr>
<tr>
<td>3. Road users</td>
<td></td>
</tr>
<tr>
<td>3.1 Vehicle control and tyres</td>
<td>1</td>
</tr>
<tr>
<td>3.2 Driver information</td>
<td>4</td>
</tr>
<tr>
<td>3.3 Traffic management and control</td>
<td>1</td>
</tr>
<tr>
<td>3.4 User acceptance and requirements</td>
<td>3</td>
</tr>
<tr>
<td>3.5 Education</td>
<td>1</td>
</tr>
<tr>
<td>4. Strategic research</td>
<td></td>
</tr>
<tr>
<td>4.1 Policies and strategies</td>
<td>5</td>
</tr>
<tr>
<td>4.2 Harmonisation of quality levels</td>
<td>1</td>
</tr>
<tr>
<td>4.3 Relations to other domains</td>
<td>1</td>
</tr>
<tr>
<td>4.4 Emerging new technologies</td>
<td>3</td>
</tr>
<tr>
<td>5. Other</td>
<td></td>
</tr>
<tr>
<td>5. Other</td>
<td>3</td>
</tr>
</tbody>
</table>
More than 90 persons replied to this letter after two reminders had been sent. The e-mail addresses of the respondents are shown in Appendix 2. In all, more than 200 topics were proposed as future research topics. After merging by TG4, the list of topics included less than 100 topics.

Some of the respondents did not specify a detailed topic, but instead prioritised the research areas in the classification enclosed in the letter. After classifying the topics accordingly, the research area prioritisation by the survey respondents was established (Table 1).

The most frequently mentioned research areas were modelling and forecasting, de-icing products, maintenance management, monitoring and data exchange, and driver information. These research areas were also most frequently mentioned as the ones with the highest priority.

There was a bias in the replies as very many replies have been received from the same organisation in the same country. This was not a problem as this phase was primarily to identify as many relevant research topics as possible.

6.2.2 Internet survey for prioritisation of topics

After the merging had been completed, the topics were prioritised. The Task Group decided to employ an Internet survey to accomplish this.

The Internet survey (see Appendix 3) was set up on the web site of VTT (Technical Research Centre of Finland), and its address was sent to the persons who had contributed to the first round of topic identification with some exceptions. Firstly, only five respondents were selected from those countries with more than five authorities, research or academic respondents who had responded to the original survey. Secondly, the Internet address was sent to experts known to the Task Group members, who had not participated in the first round, in the countries with less than five respondents. All industry respondents were retained in the list.

The Internet survey respondents were asked to classify each topic in the four priority categories:
1. very important - should be studied as soon as possible,
2. important - should be studied within five years,
3. quite important - should be studied in the future, and
4. not important.

In addition, a fifth category was provided:
5. no priority given (in case the respondent did not feel competent or willing to judge it).

All forms had the fifth category ticked as a default value, enabling the respondents to only classify the topics that they wanted to prioritise. This made the filling of the survey form easier. Subsequent comments from the respondents also confirmed that this had been a well-accepted solution.

The Internet survey was sent out on February 16, 2001 and the deadline for completing the survey was March 2, 2001. After two reminders, 57 respondents had completed the survey at the end of March 2001, when the survey was finally closed. Out of these respondents, one third belonged to the COST Action 344 Management Committee. Most of the respondents were road administration representatives (31). Nine (9) were from industry, fourteen (14) from research institutes and three (3) from the academia. The final respondents came from 17 different countries (Table 2).
<table>
<thead>
<tr>
<th>Country of respondent</th>
<th>Roads Administration</th>
<th>Industry</th>
<th>Research/ Academia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Belgium</td>
<td>6</td>
<td>1</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Denmark</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Finland</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>3</td>
<td></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Iceland</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Ireland</td>
<td>1</td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2</td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Norway</td>
<td>2</td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Romania</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Spain</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sweden</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>United Kingdom</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>9</strong></td>
<td><strong>17</strong></td>
<td><strong>57</strong></td>
</tr>
</tbody>
</table>

Table 2. The respondents of the Internet survey by country and organisation type.

### 6.3. Future research topics

#### 6.3.1 Topics proposed by international experts

As a result of the first e-mail survey, the Task Group received about 200 distinctive research topics. Some of the topics were very similar, and after analysis the Task Group combined some of the topics. The full list of topics as proposed by the experts is evident from Appendices 3 and 4. The number of topics within each research area is shown in Table 3.

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Number of topics within area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Weather and climate</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Monitoring and data exchange</td>
<td>6</td>
</tr>
<tr>
<td>1.2 Modelling and forecasting</td>
<td>8</td>
</tr>
<tr>
<td>1.3 Effects on traffic (safety, efficiency, …)</td>
<td>4</td>
</tr>
<tr>
<td>1.4 Implications to infrastructure design and construction</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
</tr>
<tr>
<td><strong>2. Winter maintenance</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Maintenance management</td>
<td>8</td>
</tr>
<tr>
<td>2.2 Operational practice</td>
<td>7</td>
</tr>
<tr>
<td>2.3 Maintenance equipment</td>
<td>7</td>
</tr>
<tr>
<td>2.4 De-icing products</td>
<td>8</td>
</tr>
<tr>
<td>2.5 Effects on traffic</td>
<td>1</td>
</tr>
<tr>
<td>2.6 Costs and benefits of maintenance</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38</strong></td>
</tr>
<tr>
<td><strong>3. Road users</strong></td>
<td></td>
</tr>
<tr>
<td>3.1 Vehicle control and tyres</td>
<td>2</td>
</tr>
<tr>
<td>3.2 Driver information</td>
<td>2</td>
</tr>
<tr>
<td>3.3 Traffic management and control</td>
<td>3</td>
</tr>
<tr>
<td>3.4 User acceptance and requirements</td>
<td>2</td>
</tr>
<tr>
<td>3.5 Education</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
</tr>
<tr>
<td><strong>4. Strategic research</strong></td>
<td></td>
</tr>
<tr>
<td>4.1 Policies and strategies</td>
<td>9</td>
</tr>
<tr>
<td>4.2 Harmonisation of quality levels</td>
<td>2</td>
</tr>
<tr>
<td>4.3 Relations to other domains</td>
<td>1</td>
</tr>
<tr>
<td>4.4 Emerging new technologies</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
</tr>
<tr>
<td><strong>5. Other</strong></td>
<td></td>
</tr>
<tr>
<td>5.1 Other</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3. Number of topics proposed for further research in the e-mail survey to international experts by research area
In all, after the analysis by the Task Group, the list included 93 topics. These topics were then used as the list of topics in the Internet survey.

6.3.2 Topics of highest priority

Appendix 4 presents the results of the Internet survey carried out to prioritise the future research topics. The results are presented as a means of priority ranking and are classified according to the organisation type.

The research areas of:

- monitoring and data exchange,
- modelling and forecasting,
- effects of weather on traffic,
- maintenance management, operational practice,
- de-icing products,
- effects of winter maintenance on traffic, and
- driver information as well as traffic management and control

were considered important. This means that these areas contained topics, where the mean priority was at least 2 (1 = very important, 2 = important, 3 = quite important and 4 = not important) in two of the three organisation groups.

The most important topics (means less than 1.7) by the various groups were:

**Roads Administrations**

- Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures.
- Level of services on winter roads.
- Effects of different winter maintenance quality levels on traffic accidents and traffic flow.

**Industry**

- Integration of road and meteorological data and real-time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations).
- Development of real-time information systems via different media (VMS, radio, cellular phone,) to affect driver behaviour (especially speed choice) in low friction conditions, based on user requirements.
- Preventive use of anti-icing materials.

**Research/Academia**

- Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures.
- Development of improved methods (contactless, remote, etc.) for road surface condition measurement (e.g. friction, freezing temperature, water film thickness).
- Integration of road and meteorological data and real-time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations).
- Effects of different winter maintenance quality levels on traffic accidents and traffic flow.
- Development of in-vehicle road surface condition detection system, and its communication to road and maintenance operators.
Effects of the weather and road conditions on traffic and driver behaviour
Impacts of ice warning systems on road safety.

There are clear differences between the priorities assessed by the various organisations, but there are also similarities. The low priorities given to topics relating to strategic research (area 4) were, nevertheless, quite unexpected.

The Task Group analysed the responses, and decided to recommend six priority topics for future research in the short term. These six topics were chosen so as to cover the most important topics as revealed by the Internet survey. The most important and urgent future research topics were:

1. Forecasting, measuring and modelling the road surface condition.
2. Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc).
3. Costs and benefits of operational practice in rural and urban areas.
4. Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour.
6. Weather-related traffic management and information systems optimal for traffic safety and efficiency.

Many Task Group members volunteered to prepare tentative task descriptions on these topics. The detailed tentative task descriptions are given in Appendix 5.

A separate analysis was undertaken to identify the future research topics in the long term. For this purpose, topics with many responses of “3. quite important - should be studied in the future” were selected if not many considered the topic unimportant or the topic was already among the short-term priorities.

There were again large differences between the various organisations. The most important long-term research topics were for the various organisation groups:

**Road Administrations**
- Identification of the maintenance equipment long-term strategy in terms of each department operational organisation and co-operation between different organisations.
- Effects and benefits of unrestricted and free weather data delivery policy on winter road maintenance in Europe.
- Impacts on congestion avoidance on the Trans-European Road Network by preventive de-icing.
- Environmental impact of winter maintenance: impact on ecosystems (hydrological, fauna, flora - roadside and landscape as a whole - what is the actual extent of impact from salt, urea etc).
- Comparison of specialised and multi-purpose maintenance vehicles.
- Development of transnational co-operation in winter maintenance in different levels of integration, based on a continuous level of service and the improvement of operational winter maintenance in border regions.
- Improvement of weather and road surface prediction and observation for local areas.

**Industry**
- Development of modelling and forecasting for the management of rest time for maintenance personnel.
- Development of road weather oriented advanced driver support and vehicle control systems.
- The study of institutional, legal and social issues related to co-ordinated winter road maintenance and driver information systems services.
Research/Academia

- Behaviour of tyre friction in changing winter conditions as a function of amount and type of ice as well as the used de-icer compound.
- Feasibility of using aerial thermal imagery.
- Alternative methods for snow and ice control on porous asphalt.
- The effect of possible climate change in planning long-time strategies for road maintenance (methods and equipment).
- Comparison of de-icing methods and products for specific road surfaces.

The long-term priorities include topics in strategic research such as the identification of maintenance equipment long-term strategies, effects of unrestricted and free weather data delivery policies, effect of possible climate change in winter maintenance, and feasibility of aerial thermal imagery.

6.3.3 Topics related to ongoing research

Task Group 1 of the COST Action 344 gathered information about ongoing projects in all the participating countries and also reports from R&D projects from 1990 until 1999. These state-of-the-art documents can be found and downloaded from the COST Internet homepage: (http://www.trl.co.uk/cost344/cost344.htm).

Table 4 shows the number of all ongoing projects in the different countries during November 2000.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of ongoing projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>3</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>2</td>
</tr>
<tr>
<td>Denmark</td>
<td>5</td>
</tr>
<tr>
<td>Finland</td>
<td>16</td>
</tr>
<tr>
<td>France</td>
<td>11</td>
</tr>
<tr>
<td>Germany</td>
<td>12</td>
</tr>
<tr>
<td>Hungary</td>
<td>1</td>
</tr>
<tr>
<td>Norway</td>
<td>19</td>
</tr>
<tr>
<td>Romania</td>
<td>3</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1</td>
</tr>
<tr>
<td>Spain</td>
<td>14</td>
</tr>
<tr>
<td>Sweden</td>
<td>33</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>129</strong></td>
</tr>
</tbody>
</table>

The topics of highest priority were identified and shown in chapter 3.2. In chapter 4, six priority short-term research areas are identified. Both topics and research areas are compared to ongoing projects as identified by Task Group 1 (Tables 5 and 6). In the comparison between future research topics/areas with high priority and ongoing projects, a match was scored on the basis of identical or at least similar headings. Often the ongoing project deals with just a part of the heading for prioritised topics/areas, but sometimes it fits quite well. One example of that is Future Research Area number 5 “More Cost-effective, efficient and environmentally-friendly friction improvement products” and an ongoing project “Study about new salt and the environmental effects”. The reason to count not only a project, if it fits totally, is that the other projects will also take the knowledge further into that specific topic/area.
Table 5. Number of ongoing projects in each prioritised topic.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
<th>Number of ongoing projects (number of countries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weather and climate</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Monitoring and data exchange</td>
<td></td>
</tr>
<tr>
<td>1.1.2</td>
<td>Integration of road and meteorological data and real time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations)</td>
<td>5 (5)</td>
</tr>
<tr>
<td>1.1.3</td>
<td>Development of improved methods (contactless, remote, etc) for road surface measurement (e.g. friction, freezing temperature, water film thickness)</td>
<td>6 (5)</td>
</tr>
<tr>
<td>1.1.4</td>
<td>Development of in-vehicle road surface condition detection system and its communication to road and maintenance operators</td>
<td>3 (3)</td>
</tr>
<tr>
<td>1.2</td>
<td>Modelling and forecasting</td>
<td></td>
</tr>
<tr>
<td>1.2.4</td>
<td>Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures</td>
<td>3 (3)</td>
</tr>
<tr>
<td>1.3</td>
<td>Effects on traffic (safety, efficiency,...)</td>
<td></td>
</tr>
<tr>
<td>1.3.1</td>
<td>Effects of the weather and road conditions on traffic and driver behaviour</td>
<td>2 (1)</td>
</tr>
<tr>
<td>2</td>
<td>Winter maintenance</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Maintenance management</td>
<td></td>
</tr>
<tr>
<td>2.1.2</td>
<td>Level of services on winter roads</td>
<td>7 (4)</td>
</tr>
<tr>
<td>2.2</td>
<td>Operational practice</td>
<td></td>
</tr>
<tr>
<td>2.2.4</td>
<td>Preventive use of anti-icing materials</td>
<td>1 (1)</td>
</tr>
<tr>
<td>2.5</td>
<td>Effects on traffic</td>
<td></td>
</tr>
<tr>
<td>2.5.1</td>
<td>Effects of different winter road maintenance quality levels on traffic accidents and traffic flow</td>
<td>8 (4)</td>
</tr>
<tr>
<td>2.6</td>
<td>Costs and benefits of maintenance</td>
<td></td>
</tr>
<tr>
<td>2.6.7</td>
<td>Impacts of ice warning systems on road safety</td>
<td>3 (2)</td>
</tr>
<tr>
<td>3</td>
<td>Road users</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Driver information</td>
<td></td>
</tr>
<tr>
<td>3.2.1</td>
<td>Development of real-time information systems via different media (VMS, radio, cellular phone) to affect driver behaviour (especially speed choice) in low friction conditions based on user requirements</td>
<td>4 (4)</td>
</tr>
</tbody>
</table>
Table 6. Number of ongoing projects in each prioritised area

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Number of ongoing projects (number of countries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forecasting, measuring and modelling the road surface condition</td>
<td>10(4)</td>
</tr>
<tr>
<td>2</td>
<td>Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc)</td>
<td>14(8)</td>
</tr>
<tr>
<td>3</td>
<td>Costs and benefits of operational practice in rural and urban areas</td>
<td>6(6)</td>
</tr>
<tr>
<td>4</td>
<td>Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour</td>
<td>11(5)</td>
</tr>
<tr>
<td>5</td>
<td>More cost-effective, efficient and environmentally-friendly friction improvement products</td>
<td>9(7)</td>
</tr>
<tr>
<td>6</td>
<td>Weather-related traffic management and information systems optimal for traffic safety and efficiency</td>
<td>8(5)</td>
</tr>
</tbody>
</table>

The number of ongoing projects differs significantly between different topics and areas and many countries are involved in the research.

6.3.3 Research topics proposed by other Task Groups

The other Task Groups of COST 344 were notified about the results and the priority research topics identified by Task Group 4. Each Task Group was asked to propose new priority topics, if they felt that some important topic had been overlooked in the analysis. Only one research topic proposal was received. Task Group 5 “Winter Maintenance Management Systems” proposed the R&D topic of “New methods of winter maintenance management through the use of the latest technologies for data management, communication and positioning”. The task description of this topic is presented in Appendix 5.7.

6.4. Assessment and recommendations

There are three main categories of research:

1. innovative and fundamental research,
2. implementation-related research with the operational point of view, and
3. strategic research.

The Task Group on future research approached the problem of identifying the most important research topics by asking experts from road administrations, industry, research organisations and academic institutes for their opinions. The topics obtained in the surveys represent all three categories of research. When prioritising the most urgent research topics, however, the topics of highest priority concentrated on implementation-related research from the operational point of view, and to a smaller extent on innovative and fundamental research.
Six priority short-term research areas were identified (see section 3.2). These six research areas include the most essential elements among the often very detailed research topics regarded as very important or important by the survey respondents.

All the six priority short-term research areas have an international, global dimension. European countries and organisations will, however, benefit most from research projects addressing these research areas on the European level. All the research areas require field studies and pilot experiments or demonstrations. These should be undertaken at the national level.

In addition to the short-term research areas, a number of long-term research topics were identified. The long-term priorities include topics in strategic research. The long-term topics also included innovative fundamental R&D (see section 3.2).

The research topics, and especially the results of research on these short- and long-term topics, can be exploited in winter maintenance management as well as in the actual snow and ice control operations. The industry can utilise the results for provision of improved tools and products. The results can also be utilised in the development and operation of a future road management system, which will integrate all management functions of the road operator e.g. winter management, traffic management and information services.

The research topics identified in this COST Action and additional study ideas are needed to solve issues relating to the interaction between client and contractor, quality assurance, the use of modern technology, and specifications and performance standards to describe and measure the target condition(s).

The research work also serves to develop a more focused system of winter maintenance management, to formulate new operational strategies and to improve service delivery.

The COST Action was a useful platform for identifying the most important topics for short- and long-term research. COST Action 344 is one of the few actions involving so many countries in the domain of winter maintenance and road weather. Hence it provided a good network for contacting the relevant experts in Europe, and through them, experts elsewhere.

Because of the positive experience with the COST Action 344 responses, the Task Group proposes a new COST action to continue research on the domain and to build on the achievements of COST Action 344. A COST action is also suited well to these topics, as most of them require active efforts and demonstrations/pilot implementations on the national level and co-ordination and integration between the national inputs.

A future COST action should take on board most of the short-term priority topics identified. Some of the research topics will also fit well in to the 6th R&D Framework Programme of the EU, especially the fundamental and strategic research tasks.
Appendix 11.

COST 344 - Improvement of Ice and Snow Control on European Roads and Bridges - Task Group 4 “Future Research”

Dear Expert,

A European research action COST 344 is currently ongoing with the objective of improving snow and ice control on European roads and bridges. One of the objectives of COST 344 is to identify key issues and topics to be addressed by European and national research projects and programmes in the near future, up to year 2010. The topics identified will probably be used as support when developing the contents of future European and national R&D Programmes, e.g. the 6th Framework Programme.

As an expert in the winter maintenance field, we would appreciate your views as to the key research topics that we should be considering. Please indicate up to five of the most important key topics, in priority order if possible, on the reply form enclosed. To assist you, we have made a preliminary classification of the possible research topics. This classification is included in the reply form.

The replies should be sent by December 15th to the undersigned. The results of this survey will be sent to all respondents, who have provided us with an e-mail address.

Thanking you in advance for your support.

Yours sincerely,

Appendix1.2.

COST 344 Improvement of Ice and Snow Control on European Roads and Bridges Task Group 4 “Future Research”

Contact person: Risto Kulmala, Risto.Kulmala@vtt.fi, fax 09 - 464 850

In my opinion, the most important research topics related to ice and snow control on roads and bridges are (in priority order, if possible):

1. ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

Research area class: _____ (if fitting the classification below)
Contact information: Name: _____________________________
E-mail address: _____________________________

Please send in your reply by December 15 to your COST Action 344 contact person

---

### Research Area Classification

<table>
<thead>
<tr>
<th>1</th>
<th>Weather and climate</th>
<th>3. Road users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Monitoring and data exchange</td>
<td>3.1 Vehicle control and tyres</td>
</tr>
<tr>
<td>1.2</td>
<td>Modelling and forecasting</td>
<td>3.2 Driver information</td>
</tr>
<tr>
<td>1.3</td>
<td>Effects on traffic (safety, efficiency, ... )</td>
<td>3.3 Traffic management and control</td>
</tr>
<tr>
<td>1.4</td>
<td>Implications to infrastructure design and construction</td>
<td>3.4 User acceptance and requirements</td>
</tr>
<tr>
<td>2</td>
<td>Winter maintenance</td>
<td>4. Strategic research</td>
</tr>
<tr>
<td>2.1</td>
<td>Maintenance management</td>
<td>4.1 Policies and strategies</td>
</tr>
<tr>
<td>2.2</td>
<td>Operational practice</td>
<td>4.2 Harmonisation of quality levels</td>
</tr>
<tr>
<td>2.3</td>
<td>Maintenance equipment</td>
<td>4.3 Relations to other domains</td>
</tr>
<tr>
<td>2.4</td>
<td>De-icing products</td>
<td>4.4 Emerging new technologies</td>
</tr>
<tr>
<td>2.5</td>
<td>Effects on traffic</td>
<td>5. Other</td>
</tr>
<tr>
<td>2.6</td>
<td>Costs and benefits of maintenance</td>
<td>5. Other</td>
</tr>
</tbody>
</table>
### Appendix 2

**E-mail addresses of persons proposing research topics**

<table>
<thead>
<tr>
<th>Person</th>
<th>E-mail Address</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="mailto:peter.mader@bstv.bmv.gv.at">peter.mader@bstv.bmv.gv.at</a></td>
<td><a href="mailto:Ljiljana.Herga@gov.si">Ljiljana.Herga@gov.si</a></td>
</tr>
<tr>
<td><a href="mailto:spe@m48.magwien.gv.at">spe@m48.magwien.gv.at</a></td>
<td><a href="mailto:snowtec@libertysurf.fr">snowtec@libertysurf.fr</a></td>
</tr>
<tr>
<td><a href="mailto:ske@m48.magwien.gv.at">ske@m48.magwien.gv.at</a></td>
<td><a href="mailto:info@sterela.fr">info@sterela.fr</a></td>
</tr>
<tr>
<td><a href="mailto:rudolf.schacherl@oeo.gv.at">rudolf.schacherl@oeo.gv.at</a></td>
<td><a href="mailto:mecagil@club-internet.fr">mecagil@club-internet.fr</a></td>
</tr>
<tr>
<td><a href="mailto:rupert.riedl@land-sbg.gv.at">rupert.riedl@land-sbg.gv.at</a></td>
<td><a href="mailto:gerard.queyrel@afr.fr">gerard.queyrel@afr.fr</a></td>
</tr>
<tr>
<td><a href="mailto:aut-wels.1gp-wien@univie.ac.at">aut-wels.1gp-wien@univie.ac.at</a></td>
<td><a href="mailto:chorenkrieg@grandlyon.org">chorenkrieg@grandlyon.org</a></td>
</tr>
<tr>
<td><a href="mailto:Pirkko.Saarikivi@weather.fi">Pirkko.Saarikivi@weather.fi</a></td>
<td><a href="mailto:dde.deux_sevres@equipement.gouv.fr">dde.deux_sevres@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:yrjo.pilli-sihvla@tiehallinto.fi">yrjo.pilli-sihvla@tiehallinto.fi</a></td>
<td><a href="mailto:bertrand.de_rohozinski@equipement.gouv.fr">bertrand.de_rohozinski@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:markku.kangas@fmi.fi">markku.kangas@fmi.fi</a></td>
<td><a href="mailto:rene.julien@equipement.gouv.fr">rene.julien@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:mikko.malmivuo@vtl.fi">mikko.malmivuo@vtl.fi</a></td>
<td><a href="mailto:yves.dupuis@equipement.gouv.fr">yves.dupuis@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:Taisto.Haavasova@vaisala.com">Taisto.Haavasova@vaisala.com</a></td>
<td><a href="mailto:theuriaux@equipement.gouv.fr">theuriaux@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:Risto.kulmala@vtl.fi">Risto.kulmala@vtl.fi</a></td>
<td><a href="mailto:pierre.cabarbaye@equipement.gouv.fr">pierre.cabarbaye@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:Johannes.Dunnwald@nokia.com">Johannes.Dunnwald@nokia.com</a></td>
<td><a href="mailto:ser.dde.basrhin@wanadoo.fr">ser.dde.basrhin@wanadoo.fr</a></td>
</tr>
<tr>
<td><a href="mailto:marcel.boschung_jr@boschung.com">marcel.boschung_jr@boschung.com</a></td>
<td><a href="mailto:xavier.corrihons@equipement.gouv.fr">xavier.corrihons@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:andreas.bark@durth-roos.de">andreas.bark@durth-roos.de</a></td>
<td><a href="mailto:Bureau-Entretien-Routier.dde-ose@equipement.gouv.fr">Bureau-Entretien-Routier.dde-ose@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:sales@irishsaltmining.com">sales@irishsaltmining.com</a></td>
<td><a href="mailto:gregoire.geai@equipement.gouv.fr">gregoire.geai@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:andreas.leckzik@kalisalz.de">andreas.leckzik@kalisalz.de</a></td>
<td><a href="mailto:denis.montpezat@equipement.gouv.fr">denis.montpezat@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:uwe.meissner@schmidt-holding.com">uwe.meissner@schmidt-holding.com</a></td>
<td><a href="mailto:roland.duchamp@equipement.gouv.fr">roland.duchamp@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:klaus.hirzel@lufft.de">klaus.hirzel@lufft.de</a></td>
<td><a href="mailto:daniel.paramo@equipement.gouv.fr">daniel.paramo@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:karel.melcher@brno.rsd.cz">karel.melcher@brno.rsd.cz</a></td>
<td><a href="mailto:p.fabre@saprr.fr">p.fabre@saprr.fr</a></td>
</tr>
<tr>
<td><a href="mailto:fomento@mxmail.co">fomento@mxmail.co</a></td>
<td><a href="mailto:joel.laurent@equipement.gouv.fr">joel.laurent@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:r.j.henny@ddw.rws.minvenw.nl">r.j.henny@ddw.rws.minvenw.nl</a></td>
<td><a href="mailto:Rene.Louarn@equipement.gouv.fr">Rene.Louarn@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:r.a.vdoorn@ddw.rws.minvenw.nl">r.a.vdoorn@ddw.rws.minvenw.nl</a></td>
<td><a href="mailto:parc-pon.dde-25@equipement.gouv.fr">parc-pon.dde-25@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:r.nieuwsma@ddw.rws.minvenw.nl">r.nieuwsma@ddw.rws.minvenw.nl</a></td>
<td><a href="mailto:gerard.fillon@equipement.gouv.fr">gerard.fillon@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:dasplw@wxs.nl">dasplw@wxs.nl</a></td>
<td><a href="mailto:cdes.dde-an@equipement.gouv.fr">cdes.dde-an@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:g.d.pringsd@tbs.rws.minvenw.nl">g.d.pringsd@tbs.rws.minvenw.nl</a></td>
<td><a href="mailto:marie.ros@equipement.gouv.fr">marie.ros@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:fek@vd.dk">fek@vd.dk</a></td>
<td><a href="mailto:jean.livet@equipement.gouv.fr">jean.livet@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:andy.mcdonald@vaisala.com">andy.mcdonald@vaisala.com</a></td>
<td><a href="mailto:legrand@oa.univ-lille1.fr">legrand@oa.univ-lille1.fr</a></td>
</tr>
<tr>
<td><a href="mailto:J.T.Hornes@bham.ac.uk">J.T.Hornes@bham.ac.uk</a></td>
<td><a href="mailto:christian.jacob@equipement.gouv.fr">christian.jacob@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:mburatwella@tfl.co.uk">mburatwella@tfl.co.uk</a></td>
<td><a href="mailto:didier.giloppe@equipement.gouv.fr">didier.giloppe@equipement.gouv.fr</a></td>
</tr>
<tr>
<td>tom.findlay@<a href="mailto:findlay@yvonne.com">findlay@yvonne.com</a></td>
<td><a href="mailto:cariou@equipement.gouv.fr">cariou@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:andrew@econ-eng.co.uk">andrew@econ-eng.co.uk</a></td>
<td><a href="mailto:jacques.busigny@equipement.gouv.fr">jacques.busigny@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:ulrich.schlap@astral.admin.ch">ulrich.schlap@astral.admin.ch</a></td>
<td><a href="mailto:eric.brun@meteo.fr">eric.brun@meteo.fr</a></td>
</tr>
<tr>
<td><a href="mailto:schmid@atmos.unmnnz.ethz.ch">schmid@atmos.unmnnz.ethz.ch</a></td>
<td><a href="mailto:bernard.bourland@equipement.gouv.fr">bernard.bourland@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:mario.gagliardi@ti.ch">mario.gagliardi@ti.ch</a></td>
<td><a href="mailto:Valerie.Muzet@equipement.gouv.fr">Valerie.Muzet@equipement.gouv.fr</a></td>
</tr>
<tr>
<td><a href="mailto:vergulimit@bluewin.ch">vergulimit@bluewin.ch</a></td>
<td><a href="mailto:X.Cocu@brrc.be">X.Cocu@brrc.be</a></td>
</tr>
<tr>
<td><a href="mailto:bjorn.stigberg@vvv.se">bjorn.stigberg@vvv.se</a></td>
<td><a href="mailto:brooke.pearson@vaisala.com">brooke.pearson@vaisala.com</a></td>
</tr>
<tr>
<td><a href="mailto:ingmar.olofsson@telia.com">ingmar.olofsson@telia.com</a></td>
<td><a href="mailto:Liam.Campbell@met.ie">Liam.Campbell@met.ie</a></td>
</tr>
<tr>
<td><a href="mailto:jan.olaander@vvv.se">jan.olaander@vvv.se</a></td>
<td><a href="mailto:mstaunto@nra.ie">mstaunto@nra.ie</a></td>
</tr>
<tr>
<td><a href="mailto:nils-erik.ernarsson@network.vattenfall.se">nils-erik.ernarsson@network.vattenfall.se</a></td>
<td><a href="mailto:konagai@ceri.go.jp">konagai@ceri.go.jp</a></td>
</tr>
<tr>
<td><a href="mailto:christer.mork@danderyd.se">christer.mork@danderyd.se</a></td>
<td><a href="mailto:mori@pwri.go.jp">mori@pwri.go.jp</a></td>
</tr>
<tr>
<td><a href="mailto:jorgen@gvc.gu.se">jorgen@gvc.gu.se</a></td>
<td><a href="mailto:ishimoto@decnet.or.jp">ishimoto@decnet.or.jp</a></td>
</tr>
<tr>
<td><a href="mailto:bengt.olofsson@ncc.se">bengt.olofsson@ncc.se</a></td>
<td><a href="mailto:paul.pisano@fhwa.dot.gov">paul.pisano@fhwa.dot.gov</a></td>
</tr>
</tbody>
</table>
Appendix 3.1. Results of the Internet Survey

Internet survey form - prioritisation of research topics

Appendix 3.2. Results of the Internet Survey

Internet survey form - prioritisation of research topics
## Appendix 4.1. Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Weather and climate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Monitoring and data exchange</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The optimum European wide road weather observation network and database, with harmonised monitoring, minimum and recommended levels of monitoring, and data bases of the monitoring data and maintenance data. Structure, costs and benefits</td>
<td>44</td>
<td>2.43</td>
<td>25</td>
<td>2.20</td>
</tr>
<tr>
<td>Integration of road and meteorological data and real-time information dissemination and exchange networks between various organisations (road operators, rescue authorities, maintenance operators, administrations)</td>
<td>45</td>
<td>2.04</td>
<td>28</td>
<td>2.25</td>
</tr>
<tr>
<td>Development of improved methods (contactless, remote, etc.) for road surface condition measurement (e.g. friction, freezing temperature, water film thickness).</td>
<td>47</td>
<td>1.70</td>
<td>25</td>
<td>1.88</td>
</tr>
<tr>
<td>Development of in-vehicle road surface condition detection system, and its communication to road and maintenance operators.</td>
<td>45</td>
<td>1.93</td>
<td>24</td>
<td>2.00</td>
</tr>
<tr>
<td>Measurement procedure to the concentration of de-icing materials on the pavement surface. Comparison of possible procedures with regard to exactness and costs</td>
<td>44</td>
<td>1.89</td>
<td>24</td>
<td>1.79</td>
</tr>
<tr>
<td>Observation of avalanche flows and installation of road avalanche detectors</td>
<td>26</td>
<td>2.73</td>
<td>13</td>
<td>2.46</td>
</tr>
<tr>
<td><strong>1.2 Modelling and forecasting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvements of models used for weather forecast to the road authorities</td>
<td>41</td>
<td>1.95</td>
<td>20</td>
<td>1.90</td>
</tr>
<tr>
<td>Improved forecasting of freezing rain</td>
<td>43</td>
<td>2.00</td>
<td>23</td>
<td>2.00</td>
</tr>
<tr>
<td>Nowcasting critical weather by combining local measurements with remote sensing data (radar, satellites)</td>
<td>40</td>
<td>2.00</td>
<td>21</td>
<td>1.95</td>
</tr>
<tr>
<td>Improved modelling and forecasting of road surface condition (e.g. 4 hours ahead) for preventive de-icing and other maintenance measures</td>
<td>45</td>
<td>1.56</td>
<td>24</td>
<td>1.50</td>
</tr>
<tr>
<td>Prediction of road surface condition taking into account weather forecast, maintenance operations and traffic. Includes probability distributions for maintenance interval.</td>
<td>41</td>
<td>1.95</td>
<td>22</td>
<td>1.95</td>
</tr>
<tr>
<td>Temporal and spatial extension of surface temperature prediction while taking into account surface and deep pavement temperature; topo-climatology and road temperature</td>
<td>40</td>
<td>2.20</td>
<td>22</td>
<td>2.00</td>
</tr>
<tr>
<td>Improvement of weather and road surface prediction and observation for local areas</td>
<td>41</td>
<td>2.05</td>
<td>24</td>
<td>2.04</td>
</tr>
<tr>
<td>Development of modelling and forecasting for the management of rest time for maintenance personnel</td>
<td>30</td>
<td>2.57</td>
<td>18</td>
<td>2.56</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
## Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Mean</td>
<td>No</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>1.3 Effects on traffic (safety, efficiency...)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects of the weather and road conditions on traffic and driver behaviour</td>
<td>40</td>
<td>2.00</td>
<td>20</td>
<td>2.20</td>
</tr>
<tr>
<td>Relation between accident risk and road surface condition for cars with and without special winter equipment</td>
<td>43</td>
<td>2.23</td>
<td>22</td>
<td>2.32</td>
</tr>
<tr>
<td>Behaviour of tyre friction in changing winter conditions as a function of amount and type of ice as well as the used de-icer compound</td>
<td>39</td>
<td>2.49</td>
<td>20</td>
<td>2.70</td>
</tr>
<tr>
<td>Effects of road surface condition on road capacity</td>
<td>44</td>
<td>2.25</td>
<td>23</td>
<td>2.48</td>
</tr>
<tr>
<td><strong>1.4 Implications to infrastructure design and construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of anti-icing pavements</td>
<td>40</td>
<td>2.60</td>
<td>20</td>
<td>2.50</td>
</tr>
<tr>
<td>Building planning and construction measures to improve environment protection against de-icing products beside roads</td>
<td>41</td>
<td>2.39</td>
<td>23</td>
<td>2.17</td>
</tr>
<tr>
<td>Development of a road climatology and GIS based tool for road planning</td>
<td>36</td>
<td>2.75</td>
<td>18</td>
<td>2.89</td>
</tr>
<tr>
<td><strong>2. Winter maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.1 Maintenance management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of a “perfect” management system as a tool within winter maintenance</td>
<td>42</td>
<td>2.07</td>
<td>23</td>
<td>2.26</td>
</tr>
<tr>
<td>Level of services on winter roads</td>
<td>42</td>
<td><strong>1.86</strong></td>
<td>24</td>
<td><strong>1.67</strong></td>
</tr>
<tr>
<td>Determine criteria for the installation of automatic de-icer spraying systems. Related keywords are: traffic safety, accessibility of particular road stretches, local microclimate, type of road surface, costs, etc.</td>
<td>36</td>
<td>2.72</td>
<td>20</td>
<td>2.70</td>
</tr>
<tr>
<td>Men working hours and rest in regions with mild winter.</td>
<td>27</td>
<td>3.41</td>
<td>15</td>
<td>3.27</td>
</tr>
<tr>
<td>Maintenance management during winter operations by using standardised on-board measuring equipment and automatic registration (with location information) of activities of the winter maintenance contractor</td>
<td>43</td>
<td>2.14</td>
<td>24</td>
<td>2.17</td>
</tr>
<tr>
<td>Development of communications and related interfaces for the data transfer between vehicles of the highway operation and the different organisations</td>
<td>40</td>
<td>2.23</td>
<td>23</td>
<td>2.22</td>
</tr>
<tr>
<td>Harmonise indices of treatment levels which would enable comparisons to be made of performance across local authority boundaries or between countries</td>
<td>41</td>
<td>2.49</td>
<td>22</td>
<td>2.55</td>
</tr>
<tr>
<td>Development of trans-national co-operation in winter maintenance in different levels of integration, based on a continuous level of service and the improvement of operational winter maintenance in border regions</td>
<td>37</td>
<td>2.41</td>
<td>20</td>
<td>2.60</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
### Appendix 4.3. Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Winter maintenance (cont’d from previous page)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 Operational practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis of operational practices depending on climatic areas</td>
<td>35</td>
<td>2.43</td>
<td>19</td>
<td>2.53</td>
</tr>
<tr>
<td>Determine efficient winter maintenance practices (surface treatment) for pedestrian and cycle tracks, taking into account user security, accident rate, costs and impact on the environment. Description of methods for different climatic regions</td>
<td>36</td>
<td>2.39</td>
<td>18</td>
<td>2.33</td>
</tr>
<tr>
<td>Operational practice - winter maintenance in urban areas</td>
<td>36</td>
<td>2.28</td>
<td>20</td>
<td>2.30</td>
</tr>
<tr>
<td>Preventive use of anti-icing materials</td>
<td>43</td>
<td>1.88</td>
<td>24</td>
<td>2.00</td>
</tr>
<tr>
<td>Development of methods for education and training of maintenance personnel</td>
<td>45</td>
<td>2.22</td>
<td>26</td>
<td>2.00</td>
</tr>
<tr>
<td>Development of harmonised European equipment signalling</td>
<td>35</td>
<td>2.54</td>
<td>20</td>
<td>2.50</td>
</tr>
<tr>
<td>Comparison of existing winter maintenance equipment (snow-studded tires or not, chains and ordinary tires) for their road holding while driving and braking and for different snow qualities</td>
<td>33</td>
<td>2.79</td>
<td>19</td>
<td>2.79</td>
</tr>
<tr>
<td><strong>2.3 Maintenance equipment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison of specialised and multipurpose of maintenance vehicles</td>
<td>37</td>
<td>2.73</td>
<td>22</td>
<td>2.86</td>
</tr>
<tr>
<td>Development of more effective winter maintenance equipment</td>
<td>41</td>
<td>2.10</td>
<td>22</td>
<td>2.05</td>
</tr>
<tr>
<td>Technical evaluation of spreaders</td>
<td>39</td>
<td>2.51</td>
<td>22</td>
<td>2.50</td>
</tr>
<tr>
<td>Automatic detection of remaining de-icing products on the road surface by the vehicles equipped with spreaders and automatic adjustment of the dosage</td>
<td>43</td>
<td>2.14</td>
<td>23</td>
<td>2.17</td>
</tr>
<tr>
<td>New materials for snowplough blades, less harmful to pavement surfaces, and obstacle detection devices</td>
<td>40</td>
<td>2.70</td>
<td>23</td>
<td>2.65</td>
</tr>
<tr>
<td>The use of FAST (Fixed Automated Spray Technology) for bridges and roads as well as the integration of this technology into traffic management</td>
<td>30</td>
<td>2.77</td>
<td>15</td>
<td>2.67</td>
</tr>
<tr>
<td>Evaluation of high-speed snow/water removal to reduce use of de-icing chemicals and to increase efficiency of traffic</td>
<td>35</td>
<td>2.69</td>
<td>17</td>
<td>2.59</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
## Appendix 4.4. 
### Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Winter maintenance (cont’d from previous page)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.4 De-icing products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>De-icing products efficiency and their impact on the environment</td>
<td>45</td>
<td>1.93</td>
<td>26</td>
<td>1.88</td>
</tr>
<tr>
<td>Development of new (alternatives to sodium chloride and calcium chloride) de-icing and anti-freezing products which are not corrosive, do not endanger the environment and are not significantly more expensive than salt but are efficient</td>
<td>44</td>
<td>1.95</td>
<td>24</td>
<td>1.75</td>
</tr>
<tr>
<td>Content of harmful substances in used spread materials</td>
<td>37</td>
<td>2.16</td>
<td>20</td>
<td>2.15</td>
</tr>
<tr>
<td>Costs and benefits of different de-icing methods and products</td>
<td>45</td>
<td>1.91</td>
<td>26</td>
<td>1.88</td>
</tr>
<tr>
<td>Comparison of de-icing methods and products for specific road surfaces</td>
<td>43</td>
<td>2.07</td>
<td>23</td>
<td>2.04</td>
</tr>
<tr>
<td>Development of improved surface treatment of bridges</td>
<td>40</td>
<td>2.23</td>
<td>22</td>
<td>2.27</td>
</tr>
<tr>
<td>Review of salt sticking problems in silos and hoppers: Identify conditions which lead to jamming; grades of salt, silo construction, climate, humidity</td>
<td>31</td>
<td>2.61</td>
<td>19</td>
<td>2.63</td>
</tr>
<tr>
<td>Review of salt barn design, details that eliminate corrosion</td>
<td>32</td>
<td>2.94</td>
<td>18</td>
<td>3.00</td>
</tr>
<tr>
<td><strong>2.5 Effects on traffic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects of different winter road maintenance quality levels on traffic accidents and traffic flow</td>
<td>42</td>
<td><strong>1.67</strong></td>
<td>21</td>
<td><strong>1.67</strong></td>
</tr>
<tr>
<td><strong>2.6 Costs and benefits of maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profitability of road winter maintenance in urban and rural surroundings: Cost-benefit analysis including accident costs, loss of time, physical damages, public transport, emergency services, environmental cost, social activity and welfare etc.</td>
<td>41</td>
<td><strong>1.88</strong></td>
<td>20</td>
<td><strong>1.90</strong></td>
</tr>
<tr>
<td>Evaluation of winter maintenance: definition of levels of service and relation between quality asked and necessary means. Is it worth investing in means and number of working men?</td>
<td>39</td>
<td><strong>2.00</strong></td>
<td>23</td>
<td><strong>1.91</strong></td>
</tr>
<tr>
<td>Development of appropriate value indexes of the process, policy and various measures</td>
<td>34</td>
<td>2.44</td>
<td>17</td>
<td>2.76</td>
</tr>
<tr>
<td>Study on winter road maintenance systems and costs in European countries considering various climate change scenarios</td>
<td>38</td>
<td>2.34</td>
<td>20</td>
<td>2.40</td>
</tr>
<tr>
<td>Profitability and efficiency of preventive de-icing in different temperatures</td>
<td>38</td>
<td>2.05</td>
<td>18</td>
<td>2.22</td>
</tr>
<tr>
<td>Environmental impact of winter maintenance: impact on ecosystems (hydrological, fauna, flora - roadside and landscape as a whole - what is the actual extent of impact from salt urea etc)</td>
<td>40</td>
<td>2.23</td>
<td>20</td>
<td>2.35</td>
</tr>
<tr>
<td>Impacts of ice warning systems on road safety</td>
<td>41</td>
<td>2.10</td>
<td>21</td>
<td>2.38</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
## Appendix 4.5.
### Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Mean</td>
<td>No</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>3. Road users</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.1 Vehicle control and tyres</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits and costs of the winter tyres obligation</td>
<td>32</td>
<td>2.75</td>
<td>2.945</td>
<td>2.409</td>
</tr>
<tr>
<td>Development of road weather oriented advanced driver support and vehicle control systems</td>
<td>32</td>
<td>2.56</td>
<td>16</td>
<td>2.75</td>
</tr>
<tr>
<td><strong>3.2 Driver information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of real-time information systems via different media (VMS, radio, cellular phone,) to affect driver behaviour (especially speed choice) in low friction conditions, based on user requirements</td>
<td>41</td>
<td>1.90</td>
<td>20</td>
<td>1.75</td>
</tr>
<tr>
<td>The study of institutional, legal and social issues related to co-ordinated winter road maintenance and driver information services</td>
<td>38</td>
<td>2.24</td>
<td>18</td>
<td>1.94</td>
</tr>
<tr>
<td><strong>3.3 Traffic management and control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of the traffic management and control tools optimal for traffic safety and fluency in varying road weather conditions</td>
<td>37</td>
<td>2.14</td>
<td>20</td>
<td>2.45</td>
</tr>
<tr>
<td>Development of special organisation in the case of important snowfalls including a good anticipation, information to users, stopping and stocking of lorries, indication of other roads and the management of the crisis</td>
<td>35</td>
<td>2.29</td>
<td>20</td>
<td>2.20</td>
</tr>
<tr>
<td>Impacts on congestion avoidance on the Trans-European Road Network by preventive de-icing</td>
<td>36</td>
<td>2.64</td>
<td>19</td>
<td>2.89</td>
</tr>
<tr>
<td><strong>3.4 User acceptance and requirements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis of user needs and requirements for winter maintenance</td>
<td>39</td>
<td>2.26</td>
<td>20</td>
<td>2.30</td>
</tr>
<tr>
<td>Identification of expected user behaviour in different levels of service of winter maintenance</td>
<td>40</td>
<td>2.25</td>
<td>22</td>
<td>2.09</td>
</tr>
<tr>
<td><strong>3.5 Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of methods and tools for education of children, new drivers (with national education system for example) and of drivers (risk taking, respect of the others)</td>
<td>37</td>
<td>2.35</td>
<td>21</td>
<td>2.24</td>
</tr>
<tr>
<td>Development of optimal training methods for driving on slippery roads</td>
<td>34</td>
<td>2.32</td>
<td>18</td>
<td>2.06</td>
</tr>
<tr>
<td>Development of education and information especially for lorry drivers: respect of the driving code when there is ploughing and respect of anticipation measures of lorry stocking</td>
<td>34</td>
<td>2.24</td>
<td>20</td>
<td>1.95</td>
</tr>
<tr>
<td>Development of information to town residents (in term of rights and obligations), information to administrations (advice and help for hospital, school, public transport)</td>
<td>34</td>
<td>2.44</td>
<td>18</td>
<td>2.28</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
## Appendix 4.6. Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4. Strategic research</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Policies and strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulation of new winter road maintenance policies and strategies based on comprehensive socio-economic evaluation of winter maintenance</td>
<td>33</td>
<td>2.21</td>
<td>4</td>
<td>3.00</td>
</tr>
<tr>
<td>Exploration of the possibilities to combine winter maintenance engine driving time, administrative human means and local development in medium mountain</td>
<td>24</td>
<td>3.17</td>
<td>5</td>
<td>3.20</td>
</tr>
<tr>
<td>Identification of the maintenance equipment long-term strategy in term of means for each department operational organisation and co-operation between different organisations</td>
<td>24</td>
<td>2.92</td>
<td>4</td>
<td>3.50</td>
</tr>
<tr>
<td>Harmonisation of winter maintenance policies and strategies on state, county (province) and municipal level</td>
<td>36</td>
<td>2.19</td>
<td>6</td>
<td>2.17</td>
</tr>
<tr>
<td>Effects and benefits of unrestricted and free weather data delivery policy to winter road maintenance in Europe</td>
<td>30</td>
<td>2.37</td>
<td>4</td>
<td>2.00</td>
</tr>
<tr>
<td>Research for harmonisation of rules concerning the liability and responsibilities of the organisations (drivers for equipping the vehicle with winter equipment, road operators for maintaining the road surface friction, etc.)</td>
<td>34</td>
<td>2.44</td>
<td>5</td>
<td>2.60</td>
</tr>
<tr>
<td>The effect of possible climate change in planning long-time strategies for road maintenance (methods and equipment)</td>
<td>37</td>
<td>2.92</td>
<td>6</td>
<td>3.50</td>
</tr>
<tr>
<td>Winter roads for elderly people</td>
<td>28</td>
<td>2.82</td>
<td>3</td>
<td>3.33</td>
</tr>
<tr>
<td>Feasibility of demand responsive winter maintenance (where customers can ask for winter maintenance to clear the roads at such times when needed)</td>
<td>31</td>
<td>2.81</td>
<td>4</td>
<td>2.75</td>
</tr>
<tr>
<td>4.2 Harmonisation of quality levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To define winter maintenance in a European level, based on harmonised levels of service per itinerary with common quality objectives. Elaboration on public service mission between public and private operators, and a European standardisation approach</td>
<td>32</td>
<td>2.25</td>
<td>4</td>
<td>3.25</td>
</tr>
<tr>
<td>Development of a method of standardisation of levels of service so that they could be more understandable for users</td>
<td>39</td>
<td>2.36</td>
<td>4</td>
<td>3.75</td>
</tr>
<tr>
<td>4.3 Relations to other domains</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter road maintenance related to medical, sociological, welfare and educational domains</td>
<td>30</td>
<td>2.97</td>
<td>3</td>
<td>2.67</td>
</tr>
<tr>
<td>4.4 Emerging new technologies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possibility of using aerial thermal imagery</td>
<td>33</td>
<td>2.55</td>
<td>2</td>
<td>3.00</td>
</tr>
<tr>
<td>Pavements that can stock the heat and give it back to avoid frost</td>
<td>37</td>
<td>2.62</td>
<td>4</td>
<td>3.00</td>
</tr>
<tr>
<td>Automatic snow chains</td>
<td>23</td>
<td>3.00</td>
<td>2</td>
<td>2.50</td>
</tr>
<tr>
<td>Institutional etc. issues related to keeping abreast of emerging new technologies while ensuring co-operation with neighbouring &quot;clients&quot; on a county and cross-border basis</td>
<td>27</td>
<td>2.81</td>
<td>4</td>
<td>3.25</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
## Appendix 4.7.
### Results of the Internet Survey

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Total</th>
<th>Authority</th>
<th>Industry</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of solutions to ensure and manage lorry traffic in adverse road weather conditions</td>
<td>25</td>
<td>2.20</td>
<td>14</td>
<td>1.93</td>
</tr>
<tr>
<td>Heating roads (warmth exchange)</td>
<td>30</td>
<td>3.07</td>
<td>17</td>
<td>2.88</td>
</tr>
<tr>
<td>Alternative methods for snow and ice control on porous asphalt</td>
<td>34</td>
<td>2.24</td>
<td>18</td>
<td>1.94</td>
</tr>
<tr>
<td>Organisation of snow dumping, structural design of snow dumping sites</td>
<td>23</td>
<td>3.00</td>
<td>11</td>
<td>2.82</td>
</tr>
<tr>
<td>Research to find effective ways to help users make the most from existing technology, i.e. a lot of useful information exists, but many seem not to be making best use of it</td>
<td>35</td>
<td>2.40</td>
<td>19</td>
<td>2.37</td>
</tr>
</tbody>
</table>

Priority scores of less than or equal to 2.00 are in bold, and those of less than or equal to 1.70 are also underlined. Priority 1 was the highest priority, and 5 the lowest priority.
Research topic: Forecasting, measuring and modelling the road surface condition

Need for research: RWISs (Road Weather Information Systems) have been implemented throughout Europe and we have proof of their many benefits. Methods for cost-efficient contactless measurement of road surface state and in-vehicle road surface condition detection (e.g. surface friction, water film thickness, freezing temperature) over the road network are needed. Research is also needed on improved forecasting and modelling of road surface conditions for winter maintenance and traffic management. Better short-term weather and road condition forecasts have an enormous potential of improving the efficiency of winter maintenance as well as traffic safety and fluency.

Objectives: The objective is to develop measurement and modelling systems which produce the road condition and friction information all along the road network taking into account the short-term hazardous weather phenomena (e.g. freezing drizzle, fog, icing conditions) forecasts as well as the effect of the traffic. An optimising model for different winter maintenance or anti-icing treatment systems will complete the tool for road maintenance operators and traffic information centres.

Exploitation of results: The results will be utilised by European road authorities and operators as well as weather forecasting companies who can implement systems according to the recommendations, and increase the efficiency of their activities. Citizens in Europe will benefit from such systems via better driving conditions and better pre-trip road weather information.

Links: The studies have links to European projects both on winter maintenance and traffic management and also to the development of weather forecasting models and remote sensing by weather radar.

Technical approach: Tentatively, the work could contain the following parts:

1. state of the art of road surface condition and de-icing material monitoring, modelling and forecasting (literature survey)
2. specification of the real-time road and meteorological data needed for the development of models and forecasting of road weather conditions
3. specification of the data exchange networks between various organisations (road operators, administrations and providers of meteorological services)
4. specification of the monitoring methods for the road surface friction and condition measurements, special modelling methods of optimum use of de-icing materials.
5. evaluation of the impacts of improved monitoring, modelling and forecasting methods in pilot implementations under different climate, weather and traffic conditions in Europe
6. socio-economic evaluation and recommendations for cost-effective road surface monitoring, modelling and forecasting systems

International dimension: The study requires the close co-operation of road authorities and operators as well as providers of meteorological services in climatologically different European regions.

Contact information: Head of Traffic Services Yrjö Pilli-Sihvola, Finnish Road Administration
yrjo.pilli-sihvola@tiehallinto.fi
<table>
<thead>
<tr>
<th>Research topic</th>
<th>Winter maintenance and management policies and strategies (service performance, harmonised quality levels etc) (see topics 4.1 and 4.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Need for research</strong></td>
<td>Overall management policies vary from European country to country. Efficiency and effectiveness of service provision and the chosen optimisation process between costs and benefits determines the quality level of service. In order to raise performance standards and harmonise quality levels, the individual components of a management system and the fundamental policy and strategies should be reviewed regularly and updated appropriately.</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>The objective is to develop a framework for the management of winter maintenance such that the best policy is formulated and implemented through effective strategies. In doing so, the expected outcome is a high level of service performance, low accident risk, minimal traffic delays to freight, road users and pedestrians. Harmonisation of treatment indices would also enable comparisons to be made of performance across local boundaries or between countries.</td>
</tr>
<tr>
<td><strong>Exploitation of results</strong></td>
<td>The results will be utilised by European road authorities and operators, who can implement management systems and services according to policy requirements, and thus increase the efficiency of their activities. Citizens and companies in Europe will benefit from the positive impacts of such systems during winter conditions as well as the resulting harmonisation of such services and their quality.</td>
</tr>
<tr>
<td><strong>Links</strong></td>
<td>A number of European countries are operating sound management policies and effective strategies but there are still improvements that can be generated from a re-evaluation of European wide service performance, quality levels and harmonisation of practices.</td>
</tr>
</tbody>
</table>
| **Technical approach** | The study includes the following work packages:  
1. Literature survey on strategic objectives of the winter service, especially its impacts, benefits and costs.  
2. Specification of common evaluation methodology and practices.  
3. Evaluation of impacts as well as benefits and costs of service provision in pilot implementations in European countries.  
4. Synthesis of evaluations, and recommendations for policies and strategies that will produce quality performance and harmonisation of quality levels throughout Europe. |
| **International dimension** | The study should be done as a European study because of its European dimension and the need for harmonisation. It requires the close involvement of major road authorities and operators in various countries so that the management modules can be developed on a European wide basis in order to compare service performance and quality levels in similar climate domains. |
| **Contact information** | Marilyn Burtwell, TRL Limited, Head of Winter Maintenance ResearchM.burtwell@trl.co.uk |
## Appendix 5.3.
### Priority Research Task Descriptions

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Costs and benefits of operational practice in rural and urban areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for research</td>
<td>Many calculations have been made about costs and benefits of winter maintenance. Usually the calculations do not cover all aspects or sometimes just one aspect, for example traffic safety. Hence, a more complete CBA is needed with all effects included. A comprehensive CBA needs to address different climate zones/temperatures and evaluation of winter maintenance, definition of levels of service and the relationship between the quality required and the necessary means. Specific items of interest are the environmental and safety impacts of winter maintenance.</td>
</tr>
<tr>
<td>Objectives</td>
<td>The objectives are to study the effects of different conditions or measures with the help of state of the art surveys and empirical data, in order to estimate the benefits and costs for each item in the CBA, and also to study the utilisation of the CBA in an optimising model for a Winter Maintenance Management System (WMMMS).</td>
</tr>
<tr>
<td>Exploitation of results</td>
<td>The results can be used by road authorities when deciding what is the best winter maintenance on different roads in different climates, and in the development of a “perfect” winter maintenance management system.</td>
</tr>
<tr>
<td>Links</td>
<td>The studies have links to European projects both on winter maintenance, other Road Maintenance Systems and CBA-projects. The study on the effects of weather and winter maintenance (Appendix 5.4) provides valuable input to this task.</td>
</tr>
</tbody>
</table>
| Technical approach | 1. State of the art of effects, appraisement and optimisation models  
2. Empirical studies measuring the effects of various winter management schemes and systems  
3. Develop and utilise methods for estimation of impacts in monetary terms  
4. CBA for specific winter maintenance alternatives  
This ought to continue with:  
5. The development of an optimising model to find the best winter maintenance methods. |
| International dimension | A close co-operation between European countries will progress the parts about CBA and WMMMS. Co-operation between countries of like climate and traffic conditions will cause a quicker result in relation to the effects of different conditions/measures. |
| Contact information | Research Director, Head of Infrastructure Maintenance Gudrun Öberg, VTI gudrun.oberg@vti.se |
## Research topic
Effects of road weather conditions and winter maintenance on traffic flow and safety, capacity and road user behaviour

## Need for research
An efficient road transport system forms a basis for the mobility and economy of the society. The road transport system is expected to function efficiently in all possible weather conditions. The severity of the problems due to adverse weather conditions is well known, but very little reliable information exists about the effects of different road weather conditions and winter maintenance procedures and service levels on traffic flow and safety, expressed in quantitative terms.

## Objectives
The aim of this research project is to determine the effects of road weather conditions and different winter maintenance quality levels on traffic accidents and traffic flow. In addition, driver behaviour and the risk of an accident in winter, are to be examined for various road conditions.

## Exploitation of results
The results will be utilised by European road authorities and operators. The research results will be used to determine strategies and expenditure necessary for winter maintenance for different weather and road conditions.

## Links
The study has links to European projects both on winter maintenance and traffic management in Finland, Germany and Sweden, and provides input to the tasks described in Appendices 5.3 and 5.6.

## Technical approach
The study includes the following work packages:
- A survey of literature on the effects of different road weather conditions on traffic flow and safety
- Analysis of accident occurrence and severity in different weather conditions
- Studies on driver behaviour and traffic flow for different road surface conditions and levels of road maintenance during winter.
- Recommend further use of the results in developing CBA as well as strategies for winter maintenance

## International dimension
This research project is to contribute to improved road maintenance during winter in the different European countries as well as the optimal utilisation of telematics.

## Contact information
Dr.-Ing. Andreas Bark, Durth Roos Consulting GmbH
andreas.bark@durth-roos.de
## Research topic
More cost-effective, efficient and environmentally-friendly friction improvement products (see topic 2.4)

## Need for research
The use of cost-effective, efficient and environmentally-friendly friction improvement products is a sustainable approach to winter maintenance throughout Europe. It protects the environment from damaging chemicals and creates a culture of preservation of natural resources for future generations.

## Objectives
The objective is to search out sustainable friction improvement products that can be proven to be cost-effective, efficient and environmentally friendly through laboratory testing and field validation trials.

## Exploitation of results
The results will be utilised by European road authorities and operators, who can implement treatment regimes that are environmentally friendly, effective and cost effective. Citizens and companies in Europe will benefit from the positive impacts of such treatment systems in adverse conditions as well as the resulting environmental benefits and marketing potential.

## Links
The search for less aggressive de-icer products to replace salt products has been lengthy and is only now beginning to gain support amongst governments and practitioners. Sustainable highway initiatives throughout Europe have prompted a re-think of treatment regimes to combat or control ice and snow. The consensus amongst administrations and practitioners is that our environment should be protected on an international scale.

## Technical approach
European research should be undertaken to find environmentally-friendly de-icers to replace the large quantities of salt products being utilised on the highway network. The efficacy of the potential products should be evaluated by:

1. undertaking an international literature review of de-icer products and chemical inhibitors,
2. undertaking laboratory tests to determine factors such as the freeze/thaw properties, BOD value, corrosion effects on steel and concrete, friction characteristics, dilution factors, spread rates and binder stripping properties of asphalt surfacings when various de-icer products are used,
3. undertaking field trials to validate the efficacy of the candidate de-icer products, their effectiveness at low temperatures and their friction properties under trafficking,
4. assessment of the results from the testing to identify a short-list of possible de-icer products that maintain high friction levels when resident on the road surface.

## International dimension
The study should be done as a European study because of its European dimension. It requires the close involvement of major road authorities and operators in various countries in order to ensure coverage of all types of spreading equipment, products, climates and road weather conditions encountered on European roads.

## Contact information
Marilyn Burtwell, TRL Limited, Head of Winter Maintenance Research Mburtwell@trl.co.uk

### Appendix 5.5
**Priority Research Task Descriptions**
We weather-related traffic management and information systems optimal for traffic safety and efficiency

**Need for research**
New traffic management and information systems and services are being implemented throughout Europe. These have the potential of improving the efficiency, safety and environment-friendliness of transport in all conditions. This also applies to adverse weather and road surface conditions, but so far we have only very limited knowledge of the suitability, impacts and socio-economic feasibility of such systems. It may be that these systems might also e.g. change the strategies and systems for winter maintenance by offering new alternatives for managing transport in adverse conditions.

**Objectives**
The objective is to develop such weather-related traffic management and information systems, which are optimal with regard to safety, efficiency and environment i.e. with regard to their socio-economic benefits and costs. The expected end result is a list of recommendations on how to deploy these systems, and preferably in a form of actual operational specifications for ITS systems.

**Exploitation of results**
The results will be utilised by European road authorities and operators, who can implement systems and services according to the recommendations, and increase the efficiency of their activities. Citizens and companies in Europe will benefit from the positive impacts of such systems in adverse conditions as well as the resulting harmonisation of such services and their quality.

**Links**
Previous studies include European projects CROW and ROSES and studies in Finland (several on E18), Sweden (E22), Germany and the UK. Close links are essential to Euroregional projects VIKING, STREET--WISE, SERTI, CORVETTE, CENTRICO and ARTS implementing traffic management and information systems on the TERN. FP5 projects ADVISORS and PROSPER study in-vehicle systems, where weather-related aspects are among issues considered. This task requires input from the effect evaluation task in Appendix 5.4.

**Technical approach**
The study includes the following work packages: 1) literature survey on weather-related traffic management and information systems, especially their impacts, benefits and costs 2) specification of common evaluation methodology 3) evaluation of impacts as well as benefits and costs of weather-related traffic management and information systems in pilot implementations in European countries 4) synthesis of evaluations, and recommendations for socio-economic optimal weather-related traffic management and information systems.

**International dimension**
The study should be done as a European study due to its European dimension. It requires the close involvement of major road authorities and operators in various countries in order to ensure coverage of all types of climates and road weather conditions encountered on European roads.

**Contact information**
Research Professor Risto Kulmala, VTT Building and Transport risto.kulmala@vtt.fi
<table>
<thead>
<tr>
<th>Research topic</th>
<th>New methods of Winter Maintenance Management through the use of the latest technologies for Data Management, Communication and Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for research</td>
<td>There is a growing demand for economic and effective winter maintenance. On the one hand, a higher traffic volume requires increasing efforts, whilst on the other hand, decreasing budgetary funds are only available to maintain winter maintenance according to the climate in many countries. However, using state-of-the-art technologies (GPS, Galileo, GSM, UTMS) offers new possibilities in Winter Maintenance Management to optimise winter maintenance. To what extent these new technologies can be used sensibly still depends both on their technical applicability and integration into a total system.</td>
</tr>
<tr>
<td>Objectives</td>
<td>The objective is to analyse new technologies for their applicability in Winter Maintenance Management. In this context, different demands are to be considered, differentiated by climatic regions and road networks (Motorways and Trunk Roads, Rural Roads, Urban Roads) to be maintained.</td>
</tr>
<tr>
<td>Exploitation of results</td>
<td>The guideline is to define which technologies are sufficiently advanced to qualify for use in Winter Maintenance Management. The requirements of several components, such as communications or global positioning, need to be established as well as their possible integration into a modular constructed total system. In this respect, legal and social aspects as well as a cost-benefit analysis are taken into consideration.</td>
</tr>
<tr>
<td>Links</td>
<td>The study has links to projects on winter maintenance, road management, communications and positioning technologies, both at a European level, e.g. in FP 5 and FP 6, TREN and on a national level in different countries, e.g. Finland, Denmark, Germany and France.</td>
</tr>
</tbody>
</table>
| Technical approach | The study includes the following work packages:  
1. Survey of state-of-the-art technologies on Winter Maintenance Management in Europe (Literature reviews, surveys amongst Roads Administrations)  
2. Review of existing or emerging technologies applicable to Winter Maintenance Management  
3. Possibilities for improvements in Winter Maintenance Management through the use of new techniques  
4. Use of prototypes and case studies regarding the utilisation of new technologies under different conditions (climatic conditions, traffic conditions, operations by state authorities, municipalities, private contractors)  
5. Analysis of the case studies and recommendations for the use of the new technologies |
| International dimension | The study should be carried out at European level due to its European dimension. It requires the close involvement of different road authorities and operators (state, private, municipalities) from various countries in order to ensure coverage of the different types of winter maintenance management systems. Furthermore, technological developments occur both at national and European level. |
| Contact information | Dr. Christian Holldorb, Durth Roos Consulting GmbH, Head of Road Maintenance and Operation Division, christian.holldorb@durth-roos.de |
BENEFITS OF THE PROJECT TO DIFFERENT USER GROUPS

Gudrun Öberg
Swedish National Road and Transport Research Institute (VTI)
58195 Linköping, Sweden
gudrun.oberg@vti.se
7. Benefits of the Project to different User Groups

General objectives and benefits with COST Action 344 are described below and thereafter benefits for different user groups.

Research objectives
- Establish and improve the content and performance of snow and ice control methods and operations by defining the requirements and specifying best practice across Europe.
- Provide national governments with the best materials, techniques and procedures to meet changing demands.

Benefits
- Improvements in:
  - Programme management
  - Planning
  - Operational practice and techniques
  - Driver information
  - Road user safety
- Efficient road network management
- Technological advances in application and distribution of snow and ice control measures
- Effective service delivery
- Environmental benefits
- Approach to a common standard in winter maintenance activities on the main European axes.

COST Action 344 focuses on winter maintenance. The following categories are possible users of the results from the Action
- Scientific users,
- Professional users
- End users

The scientific users are researchers in the field of winter maintenance – winter traffic – winter climate in the cold part of the whole world. This group of users develops knowledge and prepares tools for the group professional users who are actually working with winter maintenance, active at different levels. The end users of the work are the general public within Europe including road users.

Scientific users
A principal benefit to researchers is the availability of the gathered information as the result of inventory activities. This information helps to further develop winter maintenance technology by making use of the knowledge from other countries. This information comprises.
- Information gathering
  - State-of-the-Art
  - On-going projects
  - Glossary
- Definition of requirements and best practice
- Country Reports
- Ideas how to develop WMMS and ITS and how to use in winter maintenance/traffic (chapter 6 and 7)
- Some case studies compiled during the task groups' works
- Ideas for future research and development (separate document and chapter 8)

**Professional users**

European level policymakers; National Government policymakers; regional planners; local authority engineer and also road and vehicle operators/industry (see MoU Appendix IV)

The professional users are believed to be predominately people managing road networks. They can be active on national, provincial and municipal levels across Europe.

In some countries the overall results of this COST Action will provide a basis for new standards of practice in the field of winter maintenance.

The consultancy profession is expected to derive special benefits from this information, since it brings together the practice of winter maintenance from across Europe and therefore could serve as a reference for working abroad.

**End users**

The end users of the results of COST Action 344 are the general public, and road users in particular. They do not derive benefits directly from the individual chapters but the total Action generates an overall benefit for them. Improved knowledge leads to better winter maintenance and thus to better and safer roads.

Table 9.1 Potential users who could benefit from the technical chapters in this report.

<table>
<thead>
<tr>
<th>Potential Users</th>
<th>Technical Chapters</th>
<th>Classification: + important for the users</th>
<th>+ + very important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Intro &amp; object</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Glossary etc</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Best practice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 WMMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 ITS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Future R&amp;D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policymakers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- European</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- National</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Administration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Regional Planner</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Local Authority Engineer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Winter Maintenance Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- De-icing Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Vehicle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Equipment (chains, ABS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- ITS (telematics, VMS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Researchers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Winter Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- RWIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- ITS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Socio-economics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.2. Publications

To be finished later

7.3. Events

The first international event in the COST Action was in Linköping, Sweden during TRANSPORTFORUM January 12, 2000 where participants from different countries in the COST Action told about winter maintenance in their own country. During the 2-day event TRANSPORTFORUM 2001 and 2002 the Swedish members have told about the progress in the Action. The number of participants are somewhere between 1000 and 1500 each year with about 20 different parallel sessions each day.

In Belgium, since the beginning of the COST 344, work progress and preliminary results are presented by the Belgian Road Research Centre (BRRC; member of the COST action) to the other Belgian experts in Winter maintenance (Administrations, some private companies). These exchanges occur in the framework of some expert's technical committees dealing with the BRRC activities and during the meetings of the permanent Commission about winter viability established by the Walloon road Administration.

In January 27 – 28, 2002 at SIRWEC in Sapporo, Japan two members from the Action had two different speeches that together covered the whole Action. The programme had two parallel sessions and in all about 200 participants.

In January 29 – 31, 2002 at PIARC Winter Road Congress in Sapporo, Japan two members had one speech together that covered the whole project. The programme where divided in six topics and had four parallel sessions. Just over 2000 participants where about 500 came from other countries than Japan.

In March 13-14, 2002 at the 24th Talvitiepäivät - Winter Road Congress arranged by Finnish Road Association in Kuopio, Finland one of the Finnish members had a presentation about the COST Action.

In November 27, 2002 the Swedish members will talk about the COST Action at a Winter Road Seminar at the Swedish National Road Administration. Road authority employees and researchers take part in the seminar.

7.4. Final-of-COST-Action-Seminar

The Final Seminar will take place in Ljubljana, Slovenia during December 9 - 10, 2002 arranged by a working group from Directorate of the Republic of Slovenia for roads and COST 344.