SCR-E/110623/C/SV/RU

Northwest Russia Road Management

Technical Report 3

Development Plan for the Road Weather Information System in Arkhangelsk Region

Final Version

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Form 1.2. REPORT COVER PAGE

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List of Abbreviations

AADT	Annual Average Daily Traffic
ADSL	Asymmetric Digital Subscriber Line
baud	Data transmission speed unit, appr. bit/second
B/C	Benefit/Cost
DRP	Sub-base of a DRSU
DRSU	Road Maintenance Area/ Contractor
EIA	Environmental Impact Assessment
EU	European Union
EUR	The new monetary unit in most EU countries
Finnra	Finnish National Road Administration
FRD	Federal Road Directorate (local representative of RRA)
FRS	Federal Road Service (Earlier Federal road authority)
GIBDD	Road Police
GIS	Geographical Information System
GPS	Global Positioning System
GSM	One type of Cellular phone protocol
GUI	Graphical User Interface
HDM	Highway Development and Maintenance system
IRI	International Roughness Index
IRR	Internal Rate of Return
IS	Information System
IT	Information Technology
LAM	Local area numerical weather prediction model
LAN	Local area network
LED	Light Emitting Diode
LOS	Level of Service
LRC	Leningrad Road Committee
LSDB	Logical Service Data Bank
MIS	Management Information System
NMT	One type of Cellular phone protocol
NPV	Net Present Value
NWA	North West Association
NWRTD	North West Region Transport Development project
PC	Personal Computer
RDS	Radio Data System

RRA	Russian Road Agency (Present Federal road authority)
RUR	Russian rubbles
RWC	Road Weather Camera
RWDC	Road Weather Dispatch Centre
RWIS	Road Weather Information System
RWO	Road Weather Outstation
RWWS	Road Weather Warning System
SES	Sanitary and Epidemiological Institute
SQL	Structured Query Language
TCP/IP	One type of Data transmission protocol
TDO	A monitoring Unit of the Road administration
TEN	Trans-European-Network
TMC	Traffic Monitoring Control
TMS	Traffic Monitoring System
UPS	Uninterrupted Power Supply
USD	United States Dollar
WEMC	Weather and Environmental Monitoring Centre of Leningrad Region
WM	Winter maintenance
WMS	Winter Maintenance System
WWW	World Wide Web (Internet System)
vpd	Vehicles per day
yr.	Year

Executive Summary

Introduction

This report was prepared within the Tacis-funded Northwest Russia Road Management project. The object of the report is to introduce state-of-the-art technology in the field of Road Weather Information System (RWIS) and to produce a development plan for the introduction and extension of RWIS in Arkhangelsk Region.

RWIS Technology

A Road Weather Information System (RWIS) is based on highly automated information system, which detects weather and road conditions and transmits the information to the use of road maintenance organisations and to road user warning systems. The collected data is transmitted to a computer system, which analyses and presents the data in various formats. For the information collection, an advanced RWIS includes components such as:

- Road Weather Outstations (RWO) along the roads measuring e.g. wind, air temperature, road temperature, humidity, visibility and precipitation;
- Road Weather Cameras (RWC) displaying overall situation on the road;
- Weather radar and satellite images and other input from Meteorological Service.

The RWIS is operating throughout a day, and effective and reliable communication network is important for the functioning of the system.

With the assistance of the RWIS, the road maintenance organisation can observe the weather and road conditions and start operations exactly on time and with right equipment and methods.

Road Weather Meteorology

The weather influences the safety of road users, especially in wintertime. Higher risk for accidents arises from slippery roads, poor visibility, strong wind, snow and ice. Weather and road conditions also affect the volume of traffic on the roads.

The meteorological information for road winter maintenance differs somewhat from the standard weather forecasts. The specialised data only available from RWO observations makes it possible to provide road weather forecasts of good quality. Thus, the weather service should have access to the RWIS.

Weather forecasts and other meteorological information from local or regional weather service complement the information obtained from the RWIS. Using both sources the dispatchers in a Road Weather Dispatch Centre (RWDC) can form an idea about the expected road conditions, and alert the maintenance operation groups to take actions such as salting and snow ploughing when necessary.

Planning Factors of the RWIS Development

The Road Weather Information System is planned by taking into consideration such factors as:

- Traffic, roads and accidents;
- Climatic and weather conditions;
- Telecommunication infrastructure;
- Winter maintenance organisation and methods.

The fact is that the most significant sections of road network in Arkhangelsk Region are situated south from the latitude of Arkhangelsk City. The most significant road according to the traffic density and accidents is, of course, the road M8, Moscow - Arkhangelsk. Traffic density on the other roads is relatively low, but there are some short road sections with relatively high traffic density near the big cities like between Arkhangelsk and Severodvinsk and around Kotlas.

General amount of winter road maintenance works as well as amount of appropriate material and financial resources depend on duration of winter road maintenance period. In the northern districts of the Arkhangelsk Region the winter period lasts seven months from November till May. In the southern districts of the Region the period lasts for five and a half months. Winter road maintenance period may be even longer, because de-icing actions may be needed outside that period.

Arkhavtodor is responsible for the maintenance of federal and regional roads as well as an increasing amount of local roads. It agrees on annual contracts with DRSUs, road maintenance organisations, to carry out the road works. In Arkhangelsk Region, there are altogether 20 DRSUs, out of which 6 are federal and 14 regional.

Technical configuration of Arkhangelsk RWIS

Within the scope of this Tacis-project, one of the objectives is to introduce a pilot Road Weather Information System in the area of Primorsk DRSU surrounding Arkhangelsk City. This pilot system will then demonstrate the usability and benefits of RWIS and the System can later be expanded to cover a wider area of Arkhangelsk Region.

The Pilot System will include the following items:

- 3 - 5 Road Weather Outstations;
- Hard- and Software for gathering, delivering, storing and presenting weather related data (Computers, communication devices, etc.);
- Calibration equipment and spare parts.

Experience has proved that such highly developed, large IT systems should be implemented step by step to their completeness to allow the users time to learn to take advantage of all the features of such advanced systems. In this particular case the approach to the System mentioned would be compatible with the Pilot System to be implemented as the first step.

All the planning factors mentioned indicate that when planning the further steps in RWIS development, the additions to the Road Weather Outstation (RWO) and Road Weather Camera (RWC) networks after the Pilot System should be implemented on the road sections located in the southern parts of Arkhangelsk Region. When developing the RWO network step by step the total amount of RWOs together with the Pilot System would rise up to 18 - 20 units during next 10 years. Also RWC network has to be developed in addition to road weather outstations. It has to be taken into account that effective utilisation of cameras will also be adopted step by step only.

Further, satellite and radar images provide valuable information for the Dispatch Centre. They complement substantially the information received from the other sources. In Arkhangelsk, the local Meteorological Service has satellite images available. At present, the meteorological radar in Arkhangelsk is not operational, but there are plans to replace it with modern automated radar, which could become operational during the year 2003.

Radio and TV broadcasting as well as the Internet will be in the near future the most feasible channels to provide information to the road users. At a later stage, it may become feasible even to introduce variable traffic sign technology on road sections with heavy traffic. With relation to the RWIS, the first systems could be just warning signs for slippery roads attached possibly with text signs (e.g. “warning”, “road and air temperature”)

Operation of RWIS

The main function of a RWIS is to support road winter maintenance decision-making. Road Weather Dispatch Centre (RWDC) should be the focal point for all issues related with winter maintenance. The main task of RWDC is to analyse available information about weather and road conditions, and to prepare recommendations for contractors concerning execution of maintenance works. Thus, without well-organised RWDC operation the benefits from the RWIS will not be fully utilised.

The two important factors for effective functioning of a RWDC are:

- Information available;
- Organisation of work.

For effective operation, the RWDC needs information about the present and forecasted meteorological conditions, and about the winter maintenance works being performed on the roads.

Timing is the key factor as far as winter maintenance operations are concerned. The RWDC, situated in Arkhavtodor, monitors the road conditions 24 hours a day facilitating quick responses to the changing weather.

Capable staff is a crucial issue for the functioning of RWDC. It is very important that the personnel working at the dispatch centres are professionally skilled. In the long run, it is recommended that dispatchers have a considerable authority to give strong recommendations or in some instances even orders to the field.

Road masters (maintenance supervisors) in the DRSUs will also need training to be able to adjust their working habits to the opportunities provided by modern RWIS technology.

Weather forecasting is a very demanding task, which requires many kinds of tools and means in addition to RWIS system. The most cost-effective way to solve this problem is to have close co-operation between the road authority and the local (regional) weather service. The weather service has the expertise in meteorology as well as all its own observation networks and has access to world-wide observation data as well as numerical weather forecasts, satellite images, and hopefully in the near future weather radar data. This data is often difficult to understand for non-professionals and has to be processed to a more applicable form of concrete weather forecasts.

Training needs

Implementation of RWIS technology and establishment of RWDC in Arkhangelsk region will require training of specialists responsible for the operation and maintenance of the system as well as the users of the information provided by the RWIS. Two separate groups can be distinguished like technical experts and system users/road maintenance experts.

The exact contents of **the technical staff** training will depend on the type of RWIS to be installed. This training should give the equipment and system experts the required knowledge to run the RWIS satisfactorily. Special attention is to be paid on the understanding of the task of the RWI System and resulting from it requirements to the quality of data produced.

System user group consists of all the users of the information provided by the RWIS. The aim of this training is to provide the basic knowledge about road meteorology, the information provided by RWIS and the utilisation of RWIS for more effective winter maintenance.

Economical analysis

An economic evaluation has been carried out for a full RWI System for the road network in Arkhangelsk Region. The full operational system specification is assumed to include the following:

- Up to 18 - 20 RWOs at varying locations within the Arkhangelsk Region;
- Up to 4 RWCs linked to the File Server, separate from RWI System;
- 5 workstations connected to the RWI System Server (Central Computer) within the Road Weather Dispatch Centre (RWDC).

Following implementation, the RWIS will incur ongoing operating costs on an annual basis like additional staffing, training, system maintenance and communications costs. On the basis of the analysis in Chapter 8, total annual operating costs of the complete RWI System, excluding staff training can be estimated as around 37,000 EUR per annum.

As mentioned the principal purpose of RWIS is to improve the management of winter road conditions so that winter maintenance can be carried out systematically and at the appropriate time. This results in a number of specific quantifiable benefits as follows:

- Accident savings, reduced journeys times and vehicle operating costs as a result of improved winter maintenance and better driver information;
- Potential direct financial savings to the DRSUs in road maintenance costs due to more targeted work effort.

In addition to the benefits identified above, RWIS could potentially have additional uses, e.g. several kind of all-year information for road users

A “Base Case” economic evaluation for RWIS has been undertaken based on the costs and range of benefits as set out above. An assessment period of 10 years and a 12% discount rate has been used, in line with other calculations in this Tacis Project.

The results of the economic evaluation for the Base Case as set out above has been presented in terms of **Net Present Value** (**NPV**) and **Internal Rate of Return** (**IRR**) as follows:

- The NPV is fairly positive at **+ 143,200 EUR** over the ten year assessment period;
- The Internal Rate of Return at **+ 27,1%** is also fairly in excess of the selected discount rate of 12 %;
- For the RWIS implementation period, as specified above, to break-even economically, an accident saving of approximately **77,560 EUR** a year with no index increment is required, broadly equivalent to preventing only two serious accidents per annum.

Given the uncertainties in estimating costs and benefits accurately, it have been undertaken sensitivity testing of the evaluation results based on variations to some of the key input parameters. The results of the test mentioned show that the economic viability of RWIS for the Region is highly sensitive to assumptions made about the extent of forecasted accident savings, the value of accident costs and the discount rate used. Nevertheless, it appears likely that the proposals remain viable under a wide range of circumstances.

After all, the analysis conducted for this Tacis Project demonstrates that the economic case of a full RWIS scheme for the Arkhangelsk Region is fairly justified on the basis of even relatively modest accident savings. It is also possible to justify the investment on the basis of additional non-accident benefits as mentioned in this Report.

1 Introduction

This report was prepared within the Tacis-funded Northwest Russia Road Management project. It was accomplished in co-operation with EU- and local experts with a valuable contribution of the Arkhavtodor as well as the local Hydrometeorological Service. The object of the report is to introduce state-of-the-art technology in the field of Road Weather Information System (RWIS) and to produce a development plan for the introduction and extension of RWIS in Arkhangelsk Region. Planning of the RWIS takes into account various technical, meteorological, economic as well as organisational aspects. RWIS is fairly new technology, and introduction of the system requires training on these issues as well as technical readiness in the environment, such as sufficient reliability of telecommunication infrastructure. However, in order to utilise efficiently this technology, it is necessary to adopt the organisation and staffing for its operation.

A Road Weather Information System (RWIS) is based on highly automated information system, which detects weather and road conditions and transmits the information to the use of road maintenance organisations and to road user warning systems. The detection is carried out basically with Road Weather Outstations (RWO) along the roads, and this information can be supplemented with other sources of information. The data is transmitted via telecommunication or other data communication systems to a computer system, which analyses and presents the data in various formats.

For the information collection, an advanced RWIS includes components such as:

- Road Weather Outstations along the roads measuring wind, air temperature, road temperature, humidity, visibility and precipitation;
- Road Cameras displaying overall situation on the road;
- Weather radar images;
- Weather satellite images;
- Other weather information input from Meteorological Service;

The RWIS is operating throughout a day, and effective and reliable communication network is important for the functioning of the system. Data is transmitted with a few minutes interval from road weather outstations to the database.

Computer system for gathering, analysis and presentation of the data is crucial for the effective utilisation of the system. There are different applications available in the world with different hardware and software solutions.

Goal of the RWIS is to promote smooth and safe road traffic. Primarily, the problems occur in wintertime, when the system is mainly utilised. With the assistance of the RWIS, the road maintenance organisation can observe the weather and road conditions and start operations exactly on time and with right equipment and methods. A common way is to observe the weather conditions in control centres, named often Dispatch Centres, which can take care of the observation with a small number of staff and alert the maintenance operation groups to take actions such as salting and snow ploughing when necessary. Support of meteorologists is important to the operation of RWIS. They make special road weather forecasts and thus, information of RWIS is complemented.

Information provision to road users is another way of utilising the system. Alarms can be made manually or automatically via variable traffic signs. The road users can also be informed via other channels such as radio, TV and the Internet.

The Northwest Russia Road Management project includes a component of Road Weather Information System. Under this component, a pilot RWIS system will be procured and installed, and the operation will be introduced. The Pilot System will consist of 4-5 Road Weather

Outstations and the RWIS software and computer hardware. Budget for the procurement of the RWIS equipment is 94,000 EUR. In addition to the procurement, staff of the Arkhavtodor will be trained in the installation and operation of the hardware and software as well as in interpretation and utilisation of the RWIS. Furthermore, this development plan is prepared under the project component.

Arkhangelsk Region covers an area of 589.9 thousand square kms. The Region consists of Nenetsky National Area, 20 districts (including Solovky islands), 13 cities and towns, 38 urban villages, some 4,000 villages, and the islands of Novaya Zemlya and Frantz-Josef archipelagos. In this plan, we have left out Nenetsky National Area and the islands, because those areas have very scarce population and very limited road network.

The Arkangelsk main land (excluding Nenetsky and the islands) situates between 61 and 66 northern latitude 38 and 50 eastern longitude. In both north-south as well as in east-west direction the length of the area is roughly 700 km. The Region lies in rather northern latitude and in addition the Arctic Ocean causes a rigorous climate. Winters are cold, with temperature down to –26 ^{o}C and often strong winds. Summers are cool with average temperature in July between 14-16 ^{o}C and unsteady weather. Day length ranges from 3.5 hours (22nd December) to 21.7 hours (22nd July).

The population is 1,459,900 people, out of which urban population numbers 1,086,500 (74%). Population density is very low, only 2.5 people / 1 square km. Thus, most people are living in big cities like Arkhangelsk, Severodvinsk, etc. and the rest mostly in the settlements along railroads and the basins of major rivers: Northern Dvina, Vaga, Pinega, Onega and Mezen.

2 RWIS Technology

2.1 The Road Weather Outstation (RWO)

Road Weather Outstation (RWO) is a device, which monitors weather and road surface conditions on the road. Typically, an Outstation consists of a central processing unit (CPU) and different type of sensors explained in this chapter. The structure of station consists normally also of a mast, cabinet for the CPU and a pair of steel beams for fixing some sensors on the mast.

The road sensors are normally located at the level of the road surface and they also wear along with the pavement. The sensors on a pole are usually 5-8 metres above the ground. It is remarkably higher than the sensors at official meteorological observation stations, where the measurements are made two metres above the ground. Earlier, the sensors were put lower, but dirtiness inflicted by traffic caused so much errors and malfunctions that the sensors had to be moved higher on the pole.

Figure 2-1 On the left a Finnish made Outstations (Vaisala) and on the right a Swedish made Outstation (AerotechTelub).

2.1.1 Measuring requirements of RWO

The capable RWO based on generally accepted requirements is supposed to meet high accuracy demands [Perry et al., Highway Meteorology, 1991], [COST-309 Project, EU, 1992]. However, these requirements should be considered only as a target, because it could be impossible to find such equipment, which will meet all the requirements mentioned below.

The Road Weather Outstation should be able to make the following measurements:

- Temperatures, absolute accuracy +-0.2 ºC, resolution 0.1 ºC;
  - *Air, Road surface, Road subsurface;*
- Humidity of the air, absolute accuracy +-3 %, resolution 1 %;
- Wind: direction +-5º, res. 1º, speed +-0.2 m/s, resolution 0.1 m/s;
- Precipitation: intensity, amount and form;
- Estimation of the salt content of the road surface [g/m²].

The measurements listed above are carried out by means of the real physical sensors in Road Weather Outstation, but the RWO can also provide some parameters e.g. "the condition in the road surface" or "the dew point temperature", which are only computational parameters derived from some measured ones.

2.1.2 The most essential sensors of RWO

Road sensors

There are three main types of road sensors: active, passive and non-contact [Perry et al., Highway Meteorology, 1991],.

Active sensors attempt to predict whether ice is likely to form on a road surface by cooling an area on the surface of the sensor by approximately 2 ºC below ambient. A warning is given, if ice or frost is detected. Other developments of active sensors include a heated area to detect dry snow or ice, and a variably cooled area to detect the freezing temperature of any surface moisture.

Passive sensors just sit in the road surface measuring road surface conditions without adding or taking away energy from the system. Both types of sensor mentioned also attempt to measure surface moisture and de-icing salt.

Non-contact sensors include the use of microwave and infrared radiation, using sensors mounted on gantries or poles at the side of the road. More research is required to make them operationally cost-effective.

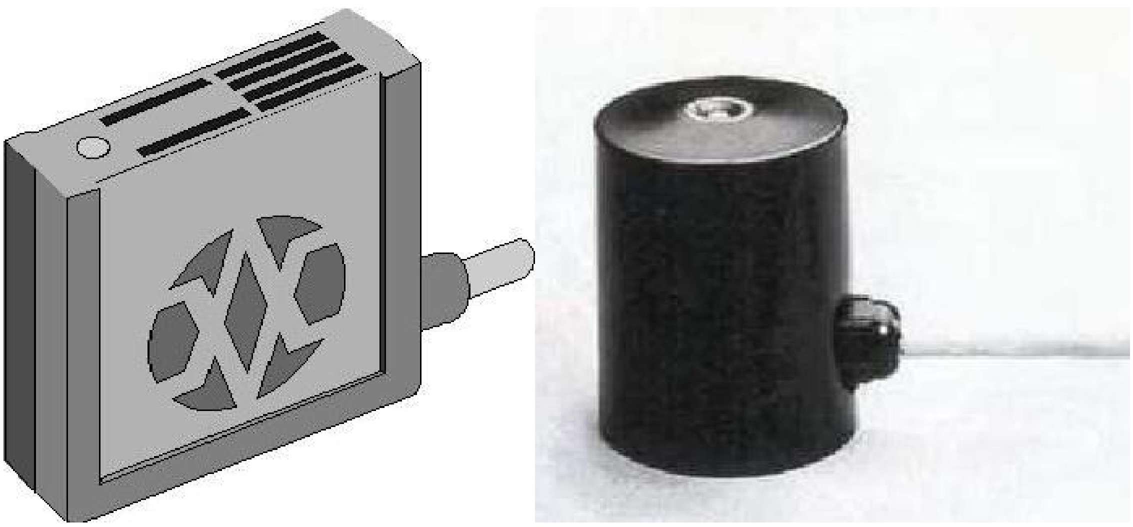


Figure 2-2 On the left one type of the passive road sensors (Vaisala DRS50) and on the right one type of the active road sensors (AerotechTelub Frensor®).

The first two types of road sensors are typically placed in the very close vicinity on the assumed path of the vehicle tyres. The bottom of the path is not a good place for sensors, because even the slightest humidity remains just there. Outside the paths, snow and ice stay longer than on the actual path. The appropriate placement of the sensor is aimed to provide as truthful a view of the driving conditions as possible on the location of each RWOs. That's why it sometimes can be difficult to find the proper place for a sensor on new road segments, where vehicle tyre paths are not yet fixed.

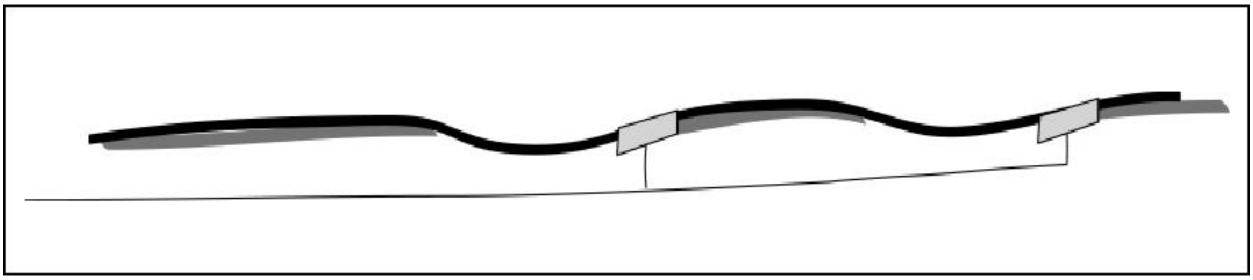


Figure 2-3 Schematic presentation of the correct road sensor placement on the worn pavement

The most sophisticated sensors can measure the following characteristics:

- Electrical conductance;
- Electrical polarisation;
- Black ice detection;
- Surface temperature;
- Ground temperature
- Optical reflection.

By means of the parameters mentioned above can be also derived e.g. the following computational parameters:

- Current road condition like dry, moist, wet, icy, snowy, etc.;
- Estimation of the salt content on the road surface
- Estimation of water/ice/snow layer thickness.

Air temperature and humidity sensor

The sensor monitoring air temperature and relative humidity is always covered from the solar radiation. A polymer sensible to humidity measures relative humidity.

The dew point temperature mentioned earlier is not measured, but it is calculated with the help of air temperature and relative humidity. Thus, the correctness of the calculation result depends totally on the measurement accuracy of air temperature and relative humidity.

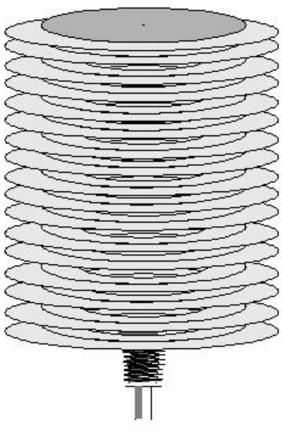
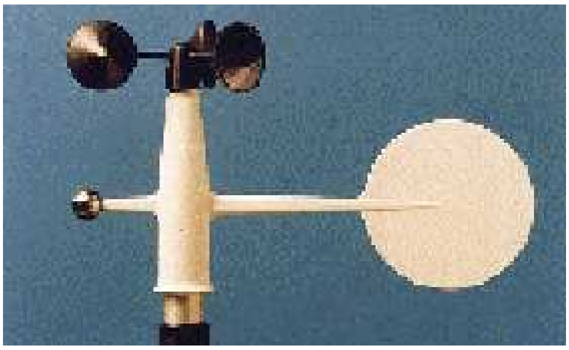


Figure 2-4 Typical air temperature and humidity sensor with solar radiation cover.

Wind sensor



The wind direction and speed are also measured with RWOs. The measurements are normally very reliable, in most cases the possible problems are not caused by the station but by the placement of the RWO.

Figure 2-5 Typical wind sensor observing wind speed and direction

Precipitation sensor

One type of the plain rain sensor has a film that monitors the amount of water on it. The sensor is heated a little to prevent the formation of dew and hoarfrost on it. The heating also melts the snow falling on the sensor thus allowing the amount of it to be measured.

The rain sensor produces two different signals:

1. The sensor reacts to quick changes on the film caused by falling raindrops or snowflakes and "the rain signal" is switched on. The signal returns to the state of "No rain" after five minutes, if no new drops are detected.
2. The second signal indicates the volume of moist on the film. The software estimates the intensity (mm/h), accumulation and class of rain. The intensity of weak rain can be 0.0 mm/h when rounding off and thus the accumulation is also 0, even though the reality may be completely different.

The rain sensor is unable to detect the form of rain; also snow is interpreted as rain after it has melted.

The biggest problem with the rain sensor is that especially in windy weather most of the snowfall drifts pass the sensor. Due to this, the indicator of rain intensity may be rather unreliable. In some cases, the accumulation of rain on a station can be close to the reality and sometimes completely wrong.

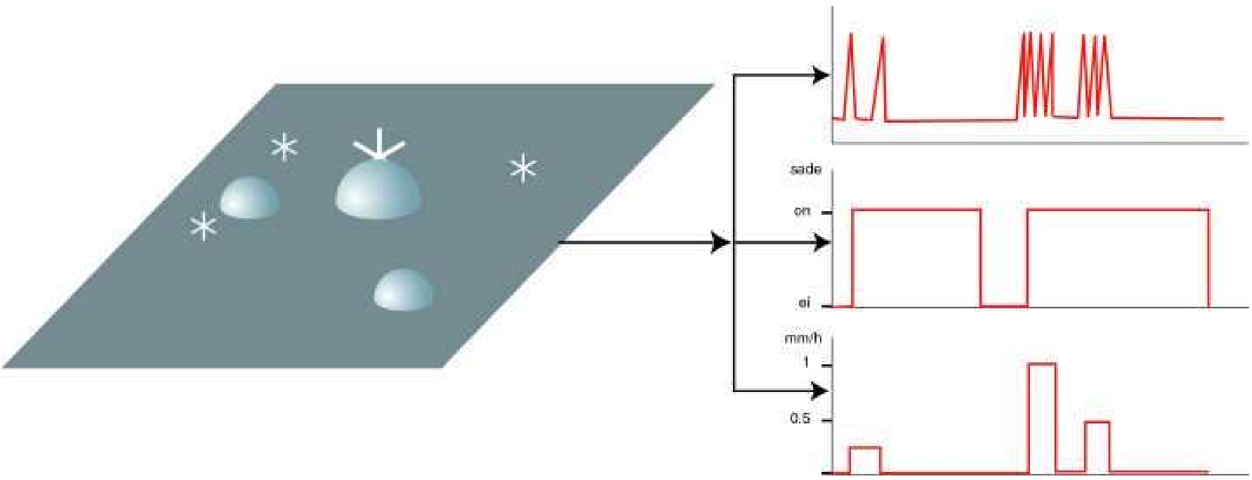


Figure 2-6 Schematic presentation of a rain sensor functioning.

Weather (visibility) sensor

The so-called "weather sensor" is often also a visibility sensor. Generally the intensity, accumulation and form of rain are defined on the basis of measured visibility.

The weather sensor provides much more versatile and reliable information than a simple precipitation sensor, but it is also a more expensive device.

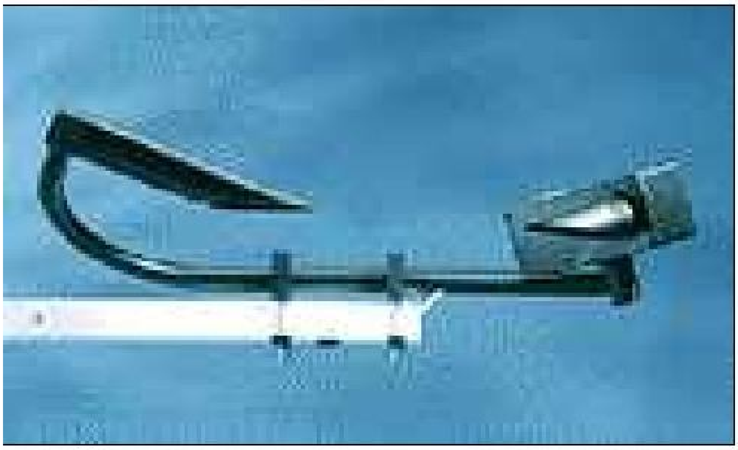


Figure 2-7 On the left Vaisala PWD11 weather sensor and on the right AerotechTelub Optic Eye® weather sensor

2.1.3 Optional sensors

There are some sensor-types, which are used only for some particular places because of the special features of the sensors. Some of such sensors are listed below:

- **Atmospheric pressure**

  Sensor is used mostly for meteorological purposes, but it can also be utilised quite easily in daily road weather monitoring work.

- **Radiation:**
  - Solar (global radiation);
  - Balance of global radiation.

- **Brightness**

  Sensors are used mostly for the research and statistical purposes; sensors give only a little additional value for the road weather monitoring work.

- **Snow depth**

- **Ground frost depth**

  Sensors are useless in daily road weather dispatching work, but give information for research and sometimes for the road maintenance works on springtime.

2.2 Equipment in Road Weather Dispatch Centre

2.2.1 Hard and Software

The Central Computer

The Central Computer collects processes and presents regularly road weather data from the outstations and possible satellite, radar and video images as well as forecasts from meteorological offices. With multiple monitor system, this computer can also be easily used for other purposes like word-processing, etc.

In small scale RWI Systems with only few dozens of RWOs, the Central Computer can be a very effective personal computer (PC), with Windows operating system. In that case, the Central Computer is located usually in the local Road Weather Dispatch Centre because it can be also used as a RWIS Workstation.

In a further developed and large RWI Systems the number of the outstations can be very high, even hundreds, and the quantity and supply frequency of other information is high (satellite, radar and video images, weather forecasts, etc.). In these cases the Central Computer, the Database Server is mainly a powerful main frame computer with an efficient operating system like UNIX or LINUX and has efficient data base program, e.g. Oracle. The data collection and the data base operations have been generally divided to the separate computers so that the malfunctions of some component or process are not disturbing the whole functioning. Also a lot of attention has been paid to the data security technologies in the Database Server. The Central Computers, the Database Server and data collection computers are usually located in the computer rooms of the companies or administrations, where the telecommunication, maintenance and security issues are handled.

The Workstation

A Workstation is a computer, which basically only displays the data collected, processed and archived by the Central Computer. The efficiency requirements for the Workstation are lower than for the Central Computer. The Workstations could also be used in the offices of maintenance units (DRSU). For this purpose a common PC used e.g. in word-processing with suitable connections to the Central Computer is quite appropriate.

Software

The software means the computer program installed in the Central Computer and the Workstations. Its main purpose is to collect and process data from Outstations. In a developed and large system, the software often also has a facility to present satellite, radar and e.g. video images and road weather forecasts, but it is also possible and easy to present images, etc. with another program in the same or in another computer.

The software has to support absolutely automatic, regular connections to all Outstations and it has to be able to handle and present road weather data in different ways and forms as follows:

- Table Views;
- Graphic Views;
- Maps;
- Data exchange;
- Archiving and Presentation of Old Data;
- Printing.

Another very useful addition to the software mentioned or quite separate program in a Road Weather Dispatch Centre (RWDC) can be a Diary Program for recording the discussions between the RWDC personnel and other partners like other RWDCs in the neighbourhood, maintenance personnel, meteorological offices, road police, etc.

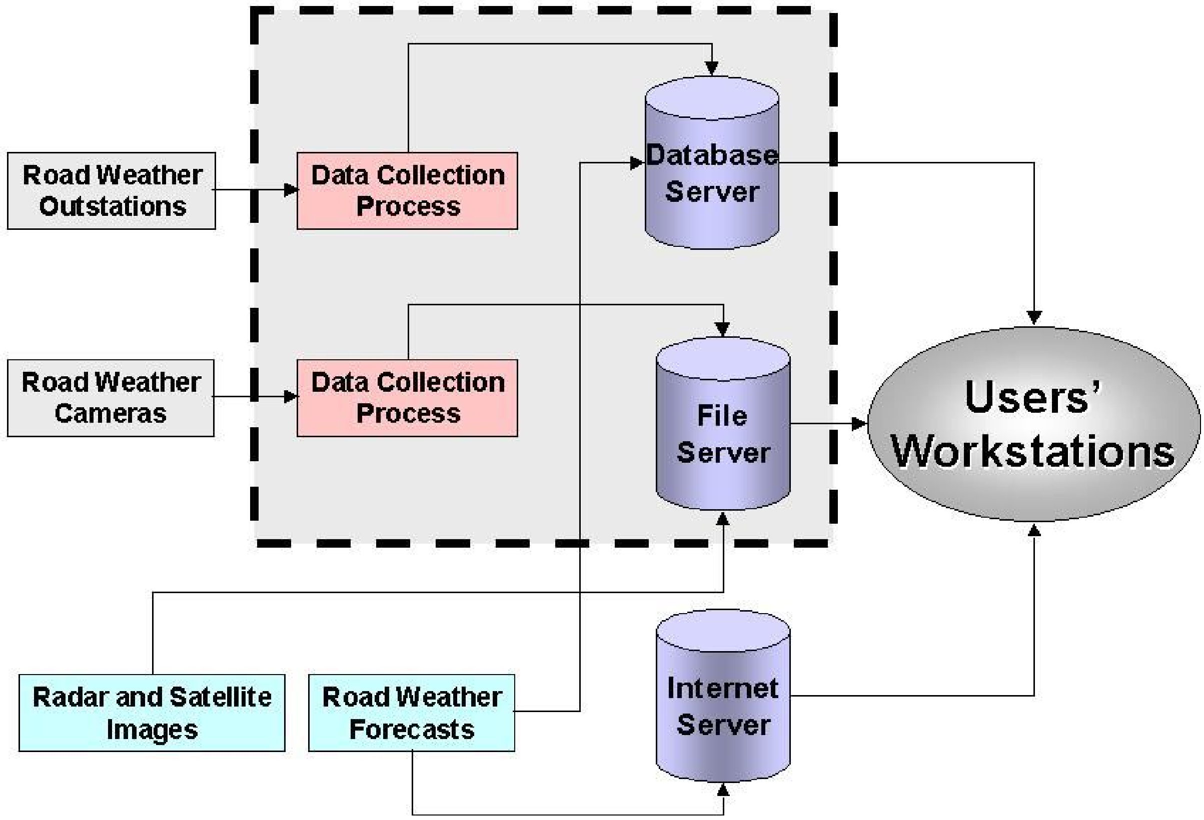


Figure 2-8 Schematic presentation of the Data Flow in large RWI Systems.

2.2.2 Satellites and weather radar

Satellites

In a modern RWIS, information from weather radar and satellites is widely used. The information from these devices is imported as image inputs. The importance of the image input is great for the Rod Weather Dispatch Centre (RWDC), because the images are visualising the follow-up of the prevailing and nearing weather fronts.

The satellite images present weather fronts of very large areas like half Europe. These images sent to the Road Weather Dispatch Centres are nowadays so called multi-channel infrared (IR) images and the images are usually jointed with a schematic map of the area they are presenting. Thus, they are quite comprehensible.

Sometimes the use of IR images can be problematic. In wintertime, the temperature of snow-covered ground can become extremely low making it hard to separate the cold ground from the clouds. Furthermore, thin upper clouds are lying high and they can seem similar to thick rain clouds. However, when looking at them from the ground level, they are almost invisible and they do not cause rain.

The basic purpose of the Weather Satellite images in the Road Weather Dispatch Centres is to present the nearing weather fronts on a large scale. According to the last forecast of the local Meteorological service and the satellite images available the dispatcher in RWDC can follow easily the approaching weather and make the right decisions.

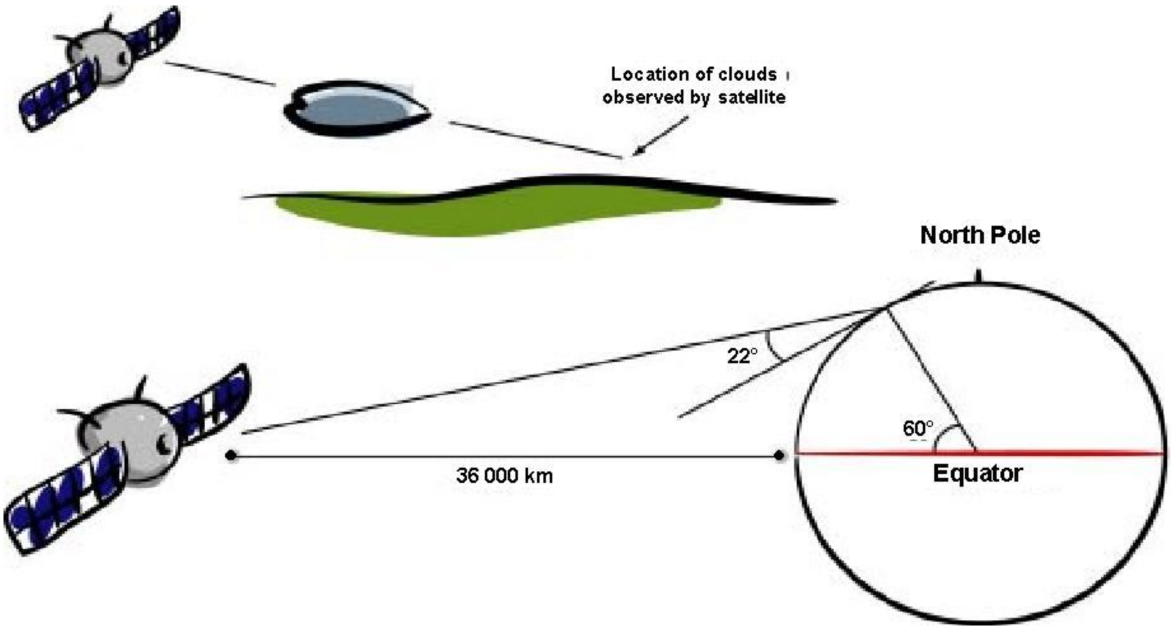


Figure 2-9 Defect of Meteosat satellite on high latitudes.

Depending on different types of weather satellites, geo-stationary (Meteosat Satellite) or polar, whose orbits round from pole to pole (NOAA Satellites), the availability, frequency and the viewpoint of the images are different. Both types have certain advantages and disadvantages depending especially on the frequency of images and on the latitude of the observed area.

It would be considered as a decent situation, if there were at least one image in an hour available. With the frequency mentioned it will make sense to have different time series (animations) of the satellite images to find out e.g. the nearing speed of the weather fronts.

Weather Radar

The radar images present rain clouds within the range of the particular Weather Radar (Max. radius ~ 200 - 250 km). These images may also include a schematic map of the area they are presenting to visualise the locations of rain fronts.

The main purpose of the radar images in the Road Weather Dispatch Centres is to present the nearing rain fronts in the reach of the radar. One type of radar images presents the intensity of the rain in different colours and another type the precipitation in function of time periods. According to the radar images available the dispatcher in RWDC can follow easily movements of the rain fronts (snow fall) and their precipitation regionally.

By means of this information the dispatcher can give relatively precise instructions to the persons in duty in some maintenance region, where and when the precipitation is high enough to start maintenance works.

For the Weather Radar images, too, it could be considered as a decent situation, if there were at least one, preferably several images in an hour available. With the frequency mentioned it will make sense to have different time series (animations) of the radar images to find out e.g. the nearing speed of the rain fronts and the rise of the precipitation in some particular area.

The absolutely greatest benefit could be found by combining simultaneous images of various radars forming a network into one image over very large area. Thus it may be possible to avoid the biggest defect of the radar - the short range, which is presented above in Figure 2-10. As an example of such a wide area radar network it can be mentioned the Scandinavian Nordrad system, which covers Denmark, Sweden, Norway and Finland.

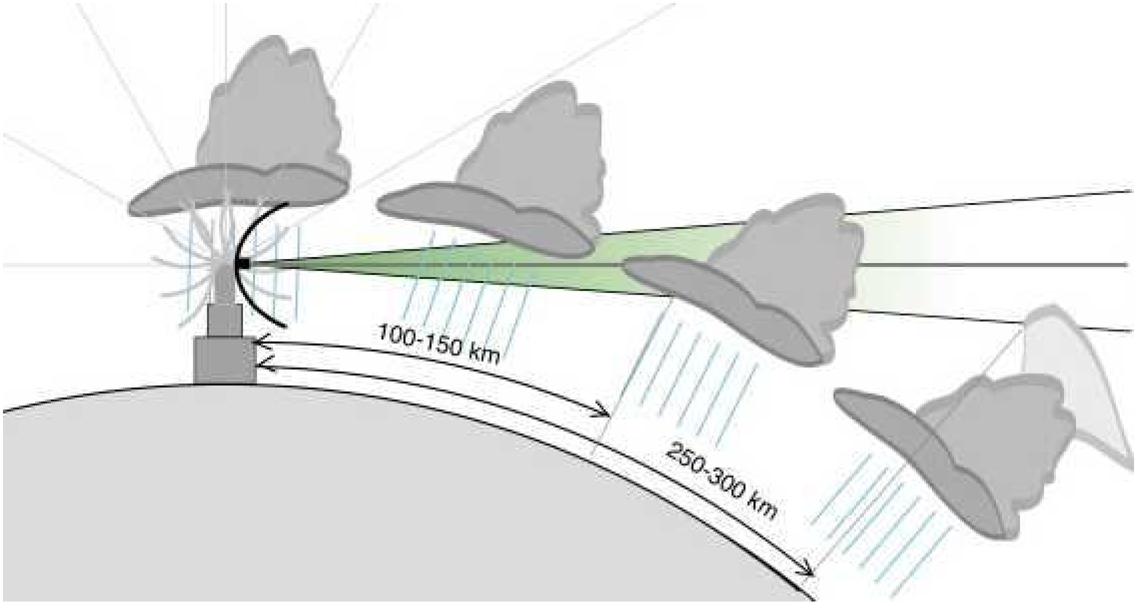


Figure 2-10 Limitation of weather radar

2.2.3 Forecast maps

The forecast maps present schematically the weather fronts in near future (6 - 24h, even more), their situation and the direction, to where they will move. For visualising, these images are also jointed to a map of the area they are presenting. The area and supply frequency of those maps depends always on the agreement between the road authority and the meteorological service.

The main purpose of those maps in RWDC is to clarify how the prevailing weather fronts seen in satellite and radar images are developing and moving in the near future. According to those maps the dispatcher in RWDC can have a first conception of the coming weather in a little bit farther future and give e.g. pre-warnings to the maintenance regions if needed.

For the Forecast Map images, it could be considered as a decent situation, if there were at least one map per day in the morning available and the presented area would be about the area of the Region in question.

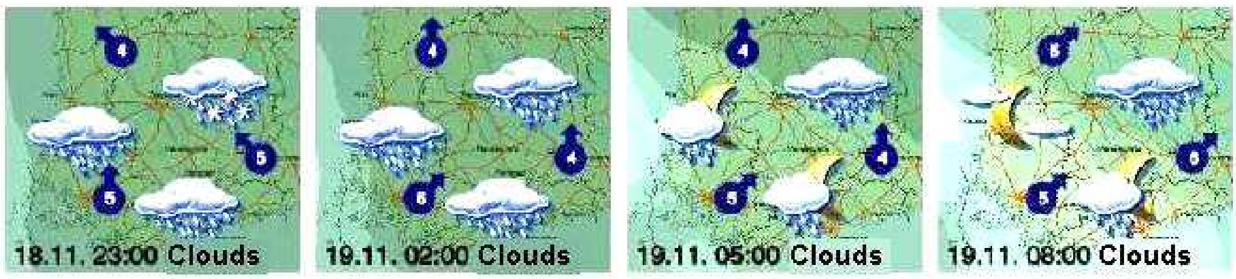


Figure 2-11 One type of forecast products in Finland: Cloud Forecast Map

2.2.4 Useful web pages for satellite image and forecast information

Useful links to Internet www-pages are available in:

- http://prognoza.icm.edu.pl/english/weathfrcst/weatherforecast.html;
- http://www.westwind.ch/an.html?0,http://imkpc3.physik.uni-karlsruhe.de/wz/pics/brack,.gif,a,0,0a,1,1a,2,3,4;
- http://www.westwind.ch/;
- http://www-das.uwyo.edu/upperair/eu.html;
- http://www.uni-koeln.de/math-nat-fak/geomet/meteo/winfos/synNNWWeuropa.gif;
- http://www.algonet.se/~peogan/ponywx.html;
- http://met:pix@www.sat.dundee.ac.uk/abin/browseleaf;
- http://theyr.com.

2.3 The Road Weather Camera (RWC)

Road Weather Cameras (RWC) are actually video cameras, which are located by the side of a road in a mast in the same way as road weather outstations. They are presenting the image of road in their location all the time, but in most cases they will only send still-video pictures.

A typical RWC consists of a common type of video camera and of a Central Processing Unit (CPU) with a video card, a modem and a special program to catch and send video frames from the camera to RWDC. The set-up of the camera station comprises also a mast, box for the CPU and a fixing beam for the video camera on the top of the mast.

The video camera should have the ability to change the mode from colours to black and white and on the contrary according to the prevailing luminance, which improves the quality of the picture resolution at nights. The streetlights have great benefit for the camera images at night, of course, but even without lights, it is possible to have reasonable images during nights by means of the IR-light (Infrared light) connected to the camera system.

Common personal computers with some accessories were used years as CPUs. The accessories were e.g. a video card and some kind of "watch dog system" for booting the computer time to time. Nowadays the cameras have been developed so that they are able to communicate directly with other computers in the local area network (LAN) or by means of modems if needed. With the high speed communication protocols (ISDN, ADSL) it is also possible use a so-called revolving head with the cameras, which allows several viewing angles to the cameras, e.g. the both driving directions with the same camera.

According to a long period experience in Scandinavia, the best way to collect and to use camera images is to put one common personal computer (PC) connected to LAN to collect all images into the network within certain period. The greatest advantage of RWCs is the complementary road weather data they provide. In most cases, the RWCs and RWOs are located in different places. Thus the images and data are not directly comparable to each other.

The Road Weather Cameras are very suitable for:

- Observation of rain and definition of rain form - especially snow-fall;
- Estimating the amount of snow in the area of RWC;
- Estimating the cloudiness or clarity of weather during day time;
- Estimating the amount of packed snow on roads.

However, it has to be considered that RWC images do not generally provide a reliable view on slipperiness on the road network.

Figure 2-12 Time series of RWC images over the effects of salt sanding on road.

2.4 Other Road Weather Telematics

With the means of telematics road users can be informed automatically or semi-automatically on hazardous road conditions. Telematics can consist of Variable Text and Picture Signs on the roads, and they can be instructed by the RWIS. The signs mentioned are mostly equipped with LED (Light Emitting Diode) and fibre optic techniques. Prism technology (mechanical functioning) is another type, which is less expensive but less adaptable accordingly. They can be controlled either nearly automatically based on road surface and traffic conditions or manually in Road Weather Dispatch Centres or in other monitoring centres.

The main purposes of the signs mentioned are to give warnings and information to road users in the following circumstances:

- Warnings of slippery and dangerous road conditions;
- Warnings of dangerous weather phenomena on road network:
  - Extremely heavy rain (snow, water);
  - Storm wind, etc;
- Warnings of hazardous situations on the road:
  - Serious traffic accidents (big disturbance to traffic);

  - Broken roads or bridges (road closed), etc;
  - Road works (pavement work, etc.);
- Information of diversions etc. on the road;
- Information of traffic congestion on the road;
- General announcements to road users:
  - Suggestions to reduce vehicle speed, etc;
  - Greetings.

Variable Picture Signs can also be used for changing speed limits signs. Technically that system is similar, but the number of the variable signs has to be rather big and the characteristic of information needs very reliable control and e.g. the data storing of the different states (speed limit changes) of every variable signs.

2.5 Thermal mapping

Thermal Mapping is a process, which will "quantify" the variation of the road surface temperature on road network. Thus, it will describe the typical road surface temperature along the road. The prevailing weather, road structure and the local environment influence the range of temperature variations.

Road pavements absorb solar radiation during daylight hours and emit the radiation at night. The radiation emitted is in the form of heat. This therefore results in pavement cooling during periods of darkness. The amount of heat loss differs at any given point along the pavement due to changing physical properties of the road structure and sub-grade. This thermal characteristic is further influenced as the road travels its route and is subjected to changing external factors. Such examples would be altitude, proximity to urban development, local microclimate and degree of exposure to direct sunlight.

During the winter period when the road pavement cools and approaches the zero point these differing thermal characteristics can often lead to sections of a route being both above and below the zero point simultaneously. By recording the relative residual surface temperature in any pavement length at any given point, the "thermal fingerprint" of a route can be mapped. The thermal fingerprint is a graphic line presenting temperature along a route.

The largest influence on pavement heat loss during the hours of darkness is cloud cover. It is usual therefore for three thermal maps to be produced. These map types are known as the following types:

- <u>Extreme:</u> calm, clear weather conditions;
- <u>Intermediate:</u> partial cloudy, windy weather conditions;
- <u>Damped:</u> low cloud weather conditions.

The production of the thermal map commences with the recording and subsequent analysis of road surface temperature readings. The data is recorded by utilising a vehicle mounted infrared thermometer that is suitably insulated from external influence. Temperature readings are taken every 5 to 20 metres usually from within the middle of the coldest traffic lane.

For extreme and intermediate map types the route data set is recorded twice, to enable arithmetic averaging and the reduction of any erroneous figures. For the damped map it is usual for only one data set to be recorded. This is because of the stabilising affect of total cloud cover on pavement heat loss. In certain circumstances the damped map type can be arithmetically calculated.

Once the data sets are completed the thermal maps can be produced by the interpretation of the data sets. Once completed the maps are verified on site and then digitised and loaded into the RWIS. Within the RWIS the maps are linked to representative Outstations for the different climatic domains the route may pass.

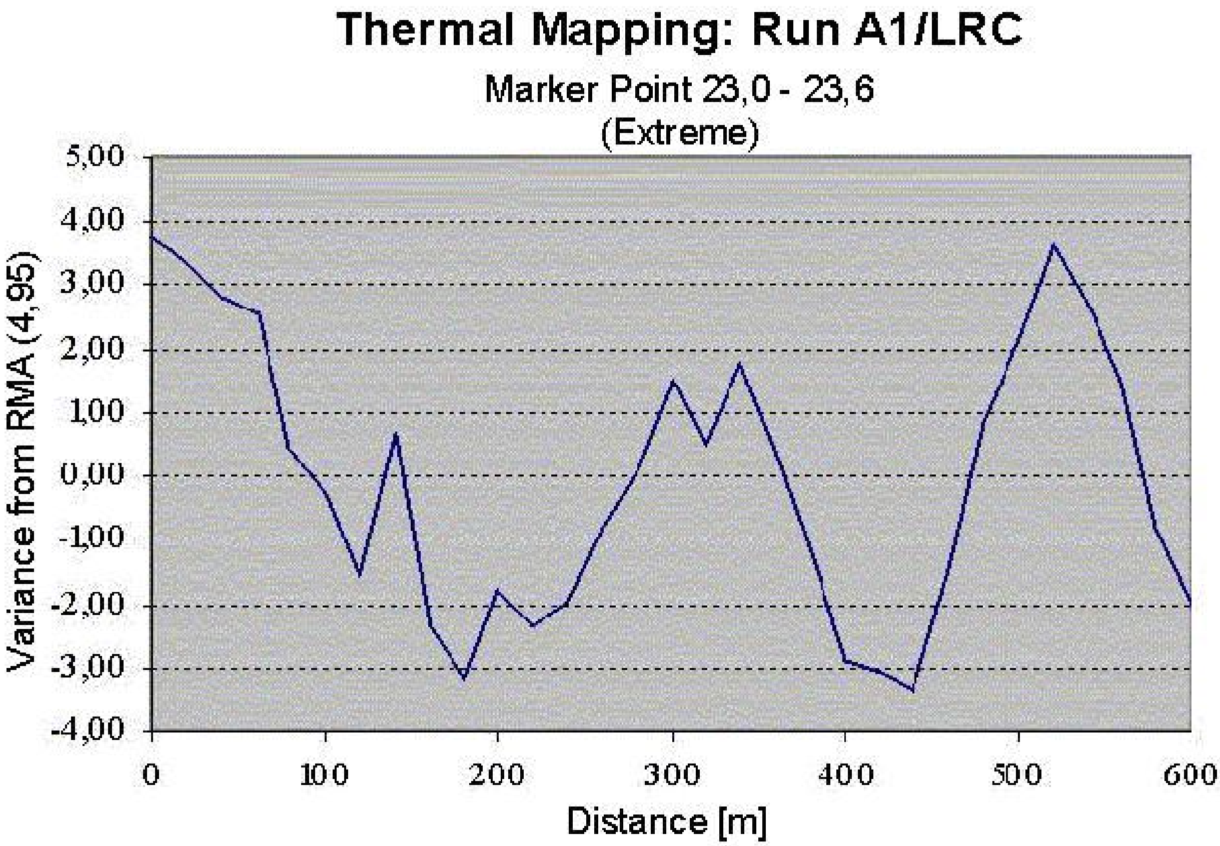


Figure 2-13 Schematic presentation of the Thermal Fingerprints on some road section of Leningrad Region in Russian

By forecasting road surface temperatures for these Outstation(s), based on satellite forecasts and the historic meteorological performance of the outstation(s), the original loaded thermal map is driven to provide a thermal representation of the road surface across the route. The forecast modified map is specific to the minimum road surface temperature predicted and for the time that this minimum will occur during the forecast period. The specific forecast map enables early warning for the deployment of maintenance units and de-icing material or equally enables proactive targeted deployment of the available resource. Together with data of the outstations this mean will afford to an experienced dispatcher a relative true description of the prevailing road surface temperature on the road network. Thus, he can easily find out the most probable time and places on the roads, which may freeze first. Thus the maintenance units can be informed to start salting actions selectively on certain sections.

The use of a thermal map is most effective in temperate or marginal weather sectors, typically where road surface temperatures are forecast to hover around freezing (+/- 3 ^{O}C) during the forecast period. In these marginal conditions the map may often lead to only sections of the route being treated. In addition, in extreme weather conditions the forecast modified thermal map enables advance warning of expected severity of road surface temperatures and therefore optimum de-icing material application rates.

2.6 Communication infrastructure

Reliable data transfer is a very critical component for this kind of information systems. It can be divided to several parts as follows:

- Communication with RWOs, RWCs and e.g. with VTSs and VPSs, which are located on the road;
- Communication between Central Computer and Workstations;
- Communication with the participants as follows:
    - Meteorological Service;
    - Other road authorities in different regions and countries;
    - Maintenance regions;
    - Road users, etc.

2.6.1 Communication with Outstations and Workstations

In general there can be alternative means for connection to outstations mentioned; including telephone line, leased line and serial line (RS-232). Also wireless connections, like NMT or GSM mobile telephone network, may be useful in cases, when there are no other suitable communication alternatives in some area.

The main characteristic of the communication with outstations mentioned is a little bit different compared to the others. One connection from the computer, like Central Computer, will be generally one to two minutes, but the connections may be carried out several times per hour. That's why the communication speed of the connection will not be very significant; modems can operate even with speed of 300 baud. On the other hand, the reliability of the connections shall be very high and stable. The demand mentioned causes sometimes that either leased lines or wireless connections should be used instead of telephone lines.

Generally communication between computers mentioned, like Central Computer and Workstation, functions similarly as described before. However, the amount of data during one connection will be much bigger than during connections to Outstations and therefore the demand of the communication speed is higher. Often weather data are transferred between computers via special data lines by using some network protocol e.g. TCP/IP, but also modems with telephone lines are in most cases applicable.

2.6.2 Communication with the other participants

Communication with the other participants mentioned is mostly collaboration between different authorities and administrations, but this collaboration can also include some data delivery. This data can be delivered by different kind of means, e.g. by e-mail or even by some special communication software, but nowadays Internet solutions have become one of the most popular means to exchange information e.g. between local and foreign administrations and even inside administration or contractors.

3 Road Weather Meteorology

The weather influences the safety of road users, especially in wintertime. Higher risk for accidents arises from slippery roads, poor visibility, strong wind, snow and ice. Weather and road conditions also affect the volume of traffic on the roads.

Climatological consultation should be used already in the planning phase of roads to prevent problems arising from adverse meteorological conditions. Advice can be given on:

- The choice between alternative routes purely on ground of weather hazards;
- The identification of particular locations of proposed new routes, where weather hazards may be a problem;
- The quantification of the weather hazard in terms of its severity and its likely frequency;
- How the hazard might be ameliorated.

In the climatic conditions of Northwest Russia, however, this kind of consultation has quite little importance for the winter conditions on the roads. The main difficulties that the road maintenance services face in wintertime are connected to slippery road surfaces, snowfall or drifting snow. Slipperiness is caused by several ways as follows:

- Freezing of wet surfaces;
- Rainfall on a cold surface;
- Freezing rain or sublimation of moisture on the road surface.

New road winter management technologies that are more cost-effective and environmentally friendly are being introduced. Effective use of these technologies demands more accurate information about the prevailing and expected meteorological conditions.

3.1 Meteorological Phenomena affecting Road Conditions in Winter Period

Snow or slippery road surfaces cause the main weather-related difficulties for road transport.

Snowfall

The effect of snowfall depends on the intensity of snowfall, temperature and amount of traffic. When temperatures are low, individual snowflakes are small and have less branching structure. They are quite easily blown away from the road if there is enough traffic. This kind of situation, however, highly deteriorates visibility on the road.

At temperatures close to 0°C snow becomes wet and sticky and the falling snow is easily compacted on the road surface by the traffic. Wet snow is more slippery than cold.

Figure 3-1 RWC image of the very heavy snowfall on the road on daytime

Drifting snow

Drifting snow may block roads with snow even if no snowfall is present. Mainly this phenomenon appears at wind speeds higher than 8 m/s. Snowdrifts can be extremely dangerous, especially in the darkness, as they appear unexpectedly for the driver.

Snowdrifts can effectively be fought, but not totally prevented, by road structure planning.

Figure 3-2 RWC image of drifting snow on the road

Freezing surfaces

Freezing of wet or moist road surfaces is a major problem that causes slipperiness especially during autumn and spring.

Hoarfrost

Hoarfrost appears when the road surface temperature is below 0°C, and below the dew point temperature of the air. In these conditions, the water vapour sublimates on the road surface forming a layer of hoarfrost consisting of crystallised ice. The amount of hoarfrost formed depends on the difference between the road surface temperature and dew point temperature, and on the duration of conditions favouring sublimation.

Hoarfrost itself is not very slippery but under traffic it may become compacted and form a very slippery icy surface. Especially this happens if traffic densities are not high enough to wear out the frost layer. The hoarfrost formation is voluminous at temperatures close to zero, when the moisture content of the air is high.

Figure 3-3 Schematic presentation of the hoarfrost formation

There are two typical situations, when hoarfrost forms. The first are clear nights, when the out-radiation from the road surface is high and the road surface temperature cools several degrees under the air temperature. The second is thawing after a long frost period. The frost period leaves the road structure cooled and it takes several days to warm it again to temperatures close to the air temperature.

Freezing rain

Freezing rain appears as rain droplets in the atmosphere fall through a cold air layer with temperature below 0°C and become under-cooled. Under-cooled droplets have temperature below freezing point but still remain in liquid form. As these droplets encounter a solid surface, like the road pavement, they momentarily freeze.

Freezing rain forms icy surfaces that are very difficult to clean away. The formation of this kind of surface can be very fast, if the intensity of freezing rain is high.

Rain on cold surfaces

After frost periods the road surface temperature remains low. Fast warming up of the weather may cause liquid rain to fall on these cold surfaces and to freeze. This kind of icy surface with water above the ice is especially slippery.

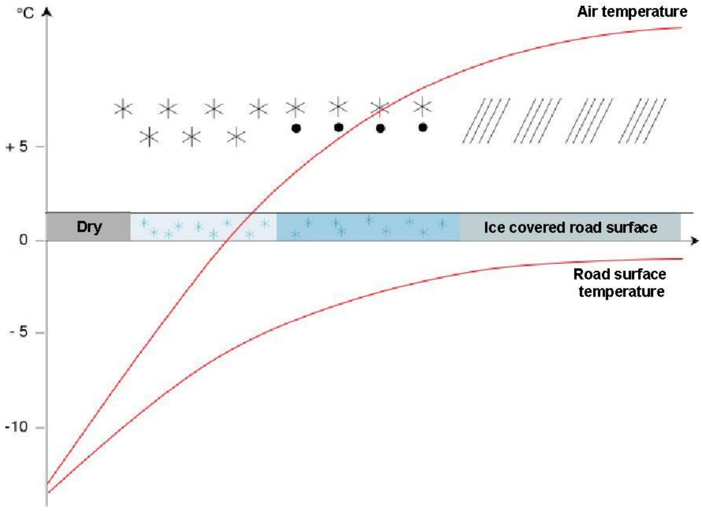


Figure 3-4 Schematic presentation of rain on cold surfaces

3.2 Weather Forecasting for Road Winter Maintenance

The meteorological information for road winter maintenance differs somewhat from the standard weather forecasts. The main parameters are the same but some additional information gives added value to the forecasts. In most cases, road weather forecasts include information about:

- Wind direction and speed;
- Air temperature;
- Dew point temperature;
- Road surface temperature;
- Weather phenomena like rain, snowfall, drifting snow, fog etc.; and
- Cloudiness.

Out of these, road surface temperature and dew point temperature are not included in regular weather forecasts of general purpose but are of crucial importance for road winter maintenance, especially for combating slipperiness. Dew point temperature is included in regular meteorological observations and thus some data is available. However, road surface temperature data is available only from specialised observations of RWOs. To be able to provide good quality road weather forecasts the weather service should have access to the RWIS. Specific advantage of the RWIS is also that it provides observation data with very short intervals. The regular interval of observations at synoptic weather stations is three hours, whereas the RWIS is able to transmit fresh data several times per hour.

Although most of the parameters included in the road weather forecasts are part of the standard general forecasts, the accuracy needed for winter maintenance purposes is different. Tailoring of the forecast means production of special road weather forecasts transmitted only to the road authority. The special features of these forecasts are as follows:

- Inclusion of specific parameters like dew point and road surface temperature;
- Need for high accuracy of temperature forecasts at temperatures near 0 °C;

- Higher specification in space and time than in standard forecasts; and
- Detailed forecast of amount and type of precipitation.

Typical weather forecast products for road winter maintenance are:

- Aerial forecasts for very short, short and medium range
- Point prognoses for beforehand specified points in the region (usually some RWOs)

The actual combination of these always depends on the possibilities of local weather service to provide different products, and on the organisation of winter maintenance operation and on its needs.

Aerial forecasts provide the general view on the expected weather in the region. Very short-term (under 12 hours) forecasts are used for decision-making on the moment. Short-term (24 hours) forecast allow planning of actions and allocation of personnel during the next two work shifts. Medium range (usually up to five days) forecasts give overall picture about the future development of road conditions and can be used for operational planning purposes.

Point prognoses are made in the same points where an automatic road weather outstation (RWO) is situated. These points have been chosen as sites representing different climatic zones in the area of the Road Weather Dispatch Centre (RWDC).

The following parameters are included in each point prognosis:

- Wind direction and wind speed,
- Cloudiness (in 1/8 parts regionally)
- Precipitation probability,
- Precipitation intensity (in scale of 0-5),
- Type of precipitation (rain, sleet or snow),
- Air temperature,
- Dew point temperature,
- Road surface temperature, and
- Freezing probability for the road surface.

Weather forecasts and other meteorological information from local or regional weather service complement the information obtained from the RWIS. Using both sources the dispatchers in a Road Weather Dispatch Centre (RWDC) can form an idea about the expected road conditions, and alert the maintenance operation groups to take actions such as salting and snow ploughing when necessary.

4 Planning Factors for the RWIS Development

4.1 Roads, Traffic and Accidents

The road network of Arkhangelsk Region comprises total of 8,338 km roads, out of which there are 533.7 km federal and 7804.2 km regional roads. About 30% of the public roads are paved. In addition to the built roads, there are so called winter roads, which are passable only during the winter period. Some of the winter roads have an important meaning for the transportation, enabling to reduce the distances even hundreds of kilometres.

The only federal road in the region is the highway no M8 from Moscow to Arkhangelsk. Length of this route in the Region is roughly 600 km.

The most important federal and regional road links with approximate length, traffic density and pavement type are presented in the following table.

Table 4-1 The most important federal and regional road links. The numbers of links refer to the map Figure 4-1.

№	Road name	Administrative importance	Length, km	Traffic density, veh/day	Operational category	Pavement type
Links to the Center (South – North)						
1	Moscow - Arkhangelsk	Federal	533.7	1510	II-III	Asphalt
2	Arkhangelsk (settlement Brin-Navolok) – Kargopol – Vytegra (settlement Prokshino)	Territorial	436.9	552	III	Asphalt/ gravel
3	Arkhangelsk – Malye Karely – Belogorsky – Pinega – Shirokoye – Leshukonskoye - Mezen	Territorial	527.6	482	III – IV – V	Gravel/ not paved
4	Access Arkhangelsk - Severodvinsk	Territorial	35	5156	III	Asphalt
5	Arkhangelsk – airport Talagi	Territorial	8.9	5008	II	Asphalt
Links with the neighbouring regions (West - East)						
6	Arkhangelsk – Onega (from Rikasiha)	Territorial	96.6	987	IV	
7	Dolmatovo – Nyandoma – Kargopol - Pudozh	Territorial	286.1	764	IV	Asphalt/ gravel
8	Ust – Vaga - Yadriha	Territorial	300.4	908	III - IV	Asphalt/ gravel
9	Kotlas – Koryazhma – Viled – Ilyinsko-Podomskoye- Komi Republic border	Territorial	186	2496	II – III	Asphalt
10	Konosha – Velsk - Shangaly	Territorial	209.5	956	III	Asphalt/ gravel
11	Konosha - Nyandoma	Territorial	100.4	534	IV	Asphalt/ gravel
12	Uren–Sharya – Nikolsk - Kotlas	Territorial	22.9		III	Asphalt
13	Kotlas – Solvychegodsk - Yarensk	Territorial	215.8	378	IV	Asphalt/ gravel

14	Vogvazdino - Yarensk	Territorial	11.6	913	IV	Asphalt
15	Kulogory – Sovpolye - Kizhma	Territorial	135	-	IV	Gravel/ not paved
16	Savinsky – Yarnema - Onega	Territorial	206.7	210	IV	Asphalt/ gravel
17	Karpogory - Veegora	Territorial	53.1	115/1951 (near Karpogory)	IV	Asphalt/ Gravel/ not paved

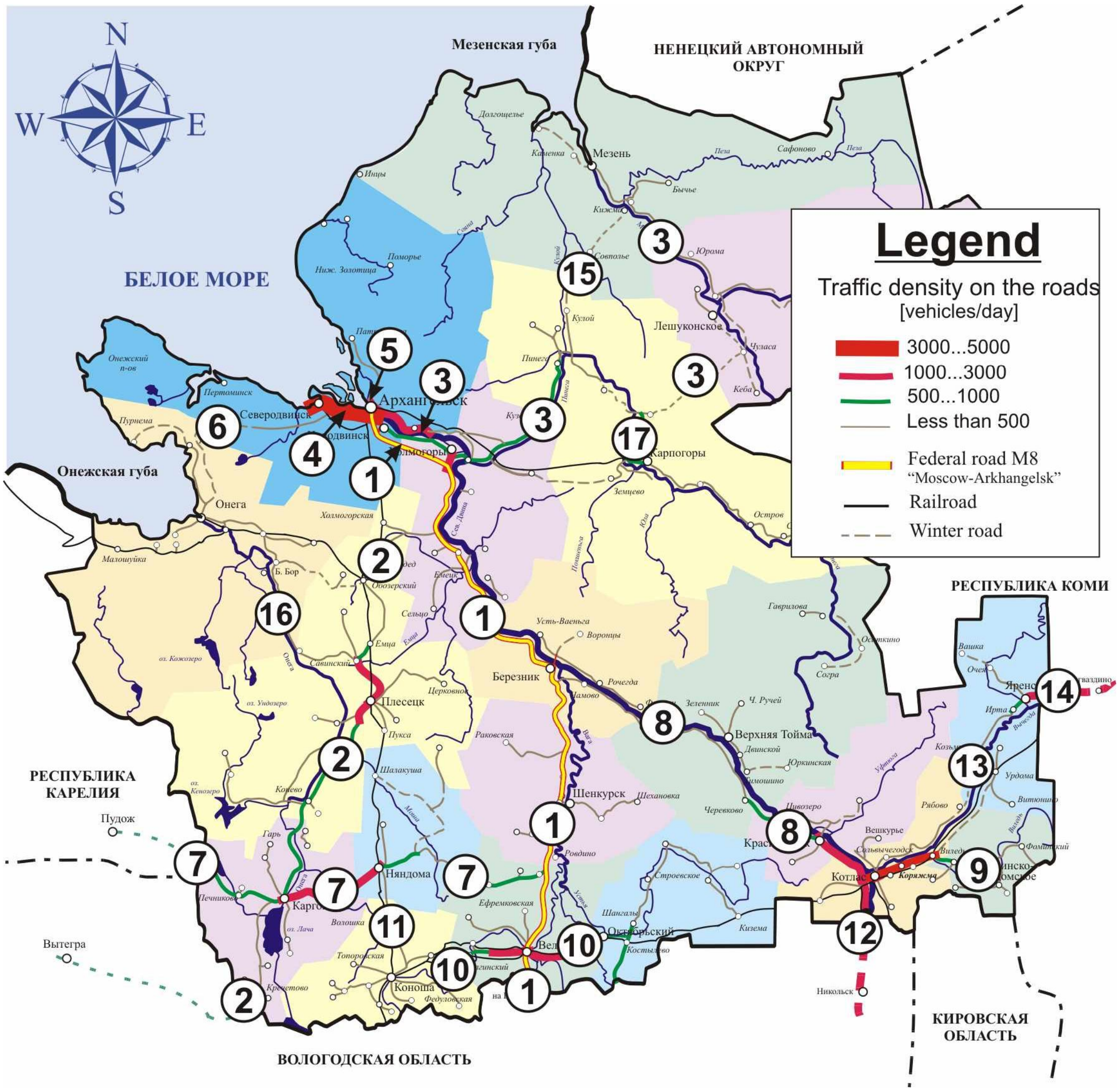


Figure 4-1 The most important federal and regional road links in figures with traffic density intensification.

One of the most important winter roads is the road between Kotlas and Syktyvkar, the capital of Komi Republic. This shortens the distance between the capitals of the neighbouring regions, Arkhangelsk and Komi, by hundreds of kilometres.

The highest traffic density of the Region is on the road between Arkhangelsk and Severodvinsk (No 4). The other busy roads are federal road M8 (No1), Pinega road (No 3) and Talagi airport road (No 5). Naturally, the traffic densities in general are highest near Arkhangelsk City being the biggest population centre in the Region. The federal road M8 carries on the whole of its length fairly high traffic density. Kotlas is a rather big city in the Oblast and there are also some road sections with high traffic density. Traffic density on the other roads is relatively low, which is quite natural, as the population of the Region is only 1,5 million and the area is very large.

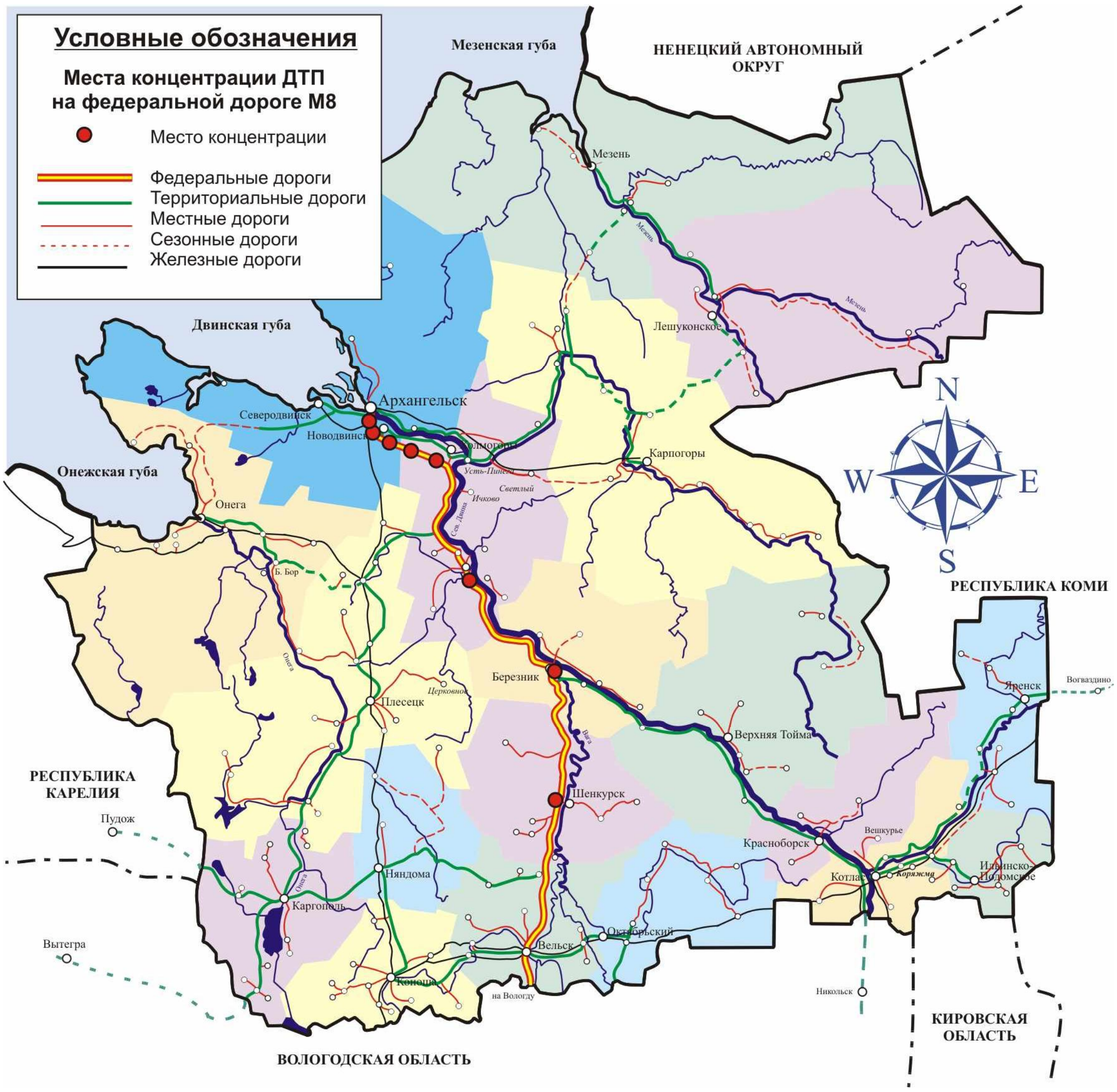


Figure 4-2 A map of the traffic accident black spots identified along M8-road.

Most of the accidents in the Region take place on the roads with highest traffic density, near the urban areas, which is quite self-evident. Often there are many reasons for the accidents, and it is difficult to identify accidents caused by such poor road conditions, which could be avoided by the means of RWIS. Another reason for the difficulty to separate out this kind of accidents is the reporting methodology. The road police, who report on the accidents, do not necessarily pay sufficiently attention to the correct reason of an accident. It may also be that more training would be needed in the accident reason analysis, but in general, an accident is usually a consequence of several factors taking place simultaneously. A map of the accident black spots identified along M8-road is presented below in

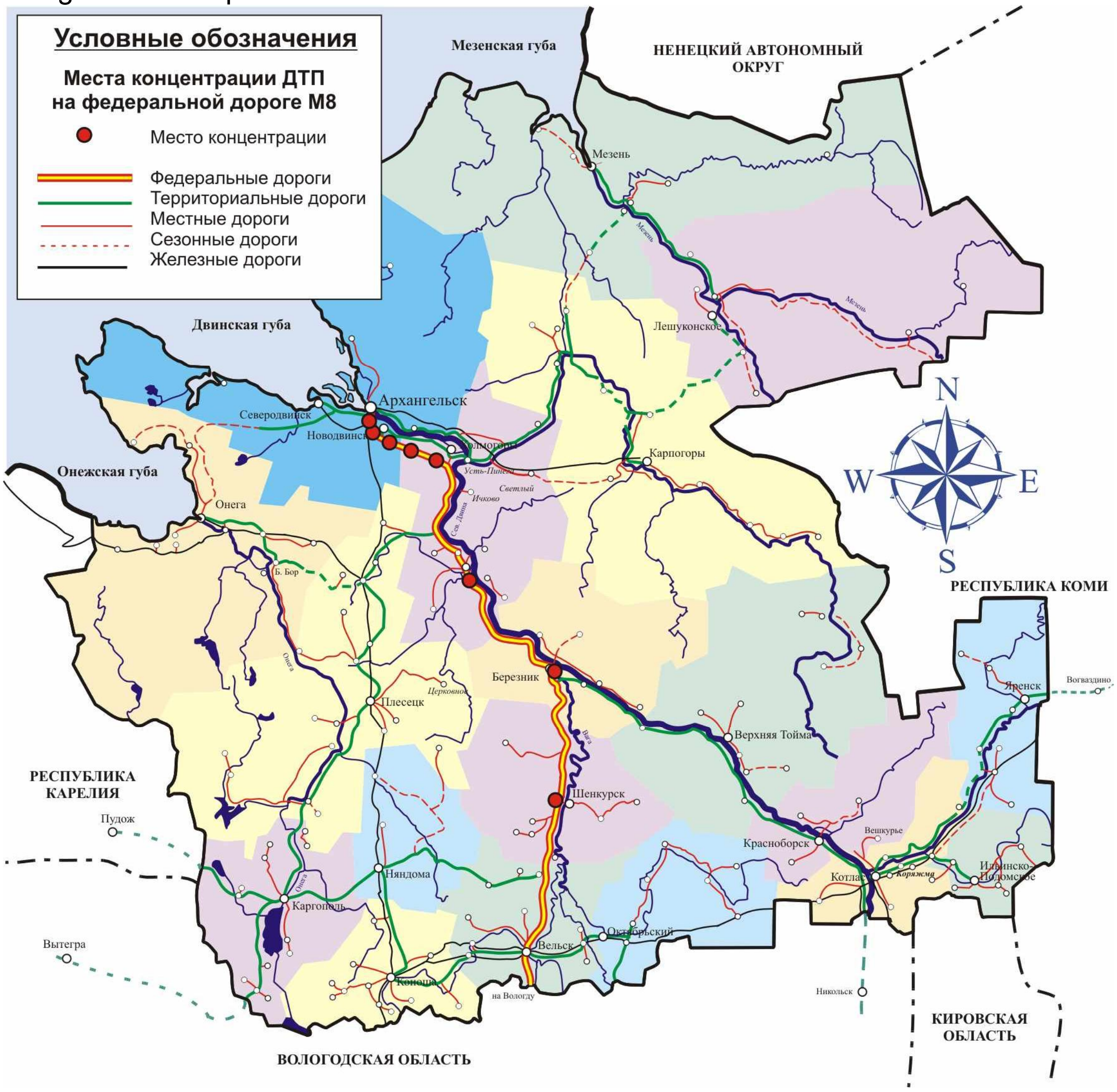


Figure 4-2

Most of the black spots situate near Arkhangelsk, where the traffic density is highest. The pilot RWIS scheme to be installed within this project will cover this area and contribute to the improvement maintenance on that section.

4.2 Climatic and Weather Conditions

4.2.1 General Climatic Conditions

While planning a network of road weather outstations it is necessary to take account of climatic and weather conditions as well as their influence on road winter maintenance activity. Road winter maintenance is affected by natural and climatic conditions, which are as the following: weather factors (duration of winter road maintenance period, snowstorm conditions, wind and temperature conditions, amount and types of precipitation, depth of a snow layer), relief and vegetation.

The Arkhangelsk Region territory occupies 590 thousand square kilometres and belongs to the north-western part of the Russian plain. It includes Timansko-Bolshezemelnaya region of tundra and the northern forest region of the Russian plain. The climate of the Arkhangelsk Region is conditioned by its geographical location: it lies between 60° northern latitude in the south and the Polar Circle in the north. Due to vicinity of the Arctic Ocean as well as the Barents and the Kara Seas the territory is often affected by advection of arctic air causing in air temperature to fall till -30°C and lower during winter period. The absolute minimum of -52°C was recorded at the Koynas weather station in 1973. The same reason causes recurrence of cold weather during spring and summer seasons. Therefore, average duration of frost-free period in the territory varies from 80 to 110 days.

All year round the territory is located in the zone of high cyclonic activity that establishes relatively stable climatic conditions for the region as whole.

The range of average air temperature on the territory lies within about 2 degrees. The average annual air temperature in the southern part of the territory does not exceed + 1,5°C, in the northern districts (Mezen and Leshchukonsk districts) it is below -1°C, Figure 4-4.

The amount of annual precipitation has little variation within the territory, but there is a slight tendency of increase southwards. Liquid and mixed precipitation dominate during the warm seasons, solid form constitutes 30% of the annual sum.

According to multiyear average data a stable snow layer appears in the second decade of October and lasts till the first decade of May in the northern part of the Region and till the end of April in the southern part.

4.2.2 Climatic and Weather Conditions Affecting Winter Road Maintenance

General amount of winter road maintenance works as well as amount of appropriate material and financial resources depend on duration of winter road maintenance period. In the northern districts of the Arkhangelsk Region the winter period lasts seven months from October 31 till May 31. In the southern districts of the Region the period lasts for five and a half months. Winter road maintenance period may be even longer, because de-icing actions may be needed outside that period.

Probability of road drifting snow as well as amount and types of snowdrifts are mainly determined with snowstorm regime (general amount of snowstorm hours observed during winter period, type and duration of each snowstorm, wind speed during a snowstorm). Amount of snow transfer (general amount of snow transferred by snowstorms during a winter period) depends on general duration of snowstorms during a winter period and wind speed during a snowstorm. Different barriers (vegetation, relief etc.) halt part of moving snow, the other part called "snow influx" appears on roads. The velocity of the snow accumulation on roads depends on the intensity of a snowstorm. According to climatic data the largest number of days with snowstorms varies from 35 to 111. The maximal number of days (111) was registered in the Indiga district.

Road snow-drifting mostly depends on wind conditions. In case of the wind blowing along a road or at an acute angle drifts appear more seldom. High wind speed increases probability of drift formation. The highest average wind speed, up to 6,5 m/s, is observed in the northern districts of the Arkhangelsk Region. The dominant wind directions are south-eastern, south-western and southern.

Road surface conditions are mostly defined by temperature regime. Physical properties of a precipitation layer on the road depend on temperature conditions. In districts, where temperatures below 0°C period last for long periods, snow is usually loose and easily removed. Frequent cases of temperature crossing the freezing point increase cases of road slipperiness. The largest average number of days when roads are slippery (65 days) was observed in Mezen district.

Road conditions also depend on the amount and intensity of precipitation falling during winter period. High precipitation intensity deteriorates visibility parameters. Precipitation type is also considered to be an important factor. Freezing rain is one of the main reasons causing road slipperiness. Amount of mixed precipitation can serve as an index defining conditions for road slipperiness formation. This index is high for the eastern districts of the Arkhangelsk Region (Koynas, Sura).

Depth of the snow layer can be used as an indicator for the possibility of snowdrifts. In the whole Region the snow layer is deep enough. The maximum depth (up to 111cm) is observed in the Koynas district.

Dependence of winter road maintenance on natural and climatic conditions allows to perform a zoning of the territory according winter maintenance conditions. This zoning was done for the territory of the former USSR. The amount of "snow influx" was used as the main zoning criterion, because it includes all the conditions (snowstorm, wind and temperature) affecting snow removal conditions. Thus, seven zones were defined and they are as follows:

1. Territories, with only periodical need for snow removal;
2. Territories, with easy snow removal conditions;
3. Territories, with medium-difficult snow removal conditions;
4. Territories, with difficult snow removal conditions;
5. Territories, with very difficult snow removal conditions;
6. Territories, with extremely difficult snow removal conditions;
7. Mountain territories (pass sections of mountain roads).

According to the zoning the northern part of the Arkhangelsk Region belongs to the zone 5 and the other part belongs to the zone 4.

4.2.3 Characteristics of Unfavourable Weather and Climatic Conditions

Climatic conditions of the Arkhangelsk Region can have unfavourable impact on road conditions during different seasons. First of all should be mentioned frequent unstable weather periods between seasons, thawing periods during winter, frequent snowstorms, slipperiness cases and long-lasting rainy and foggy periods.

Characteristics of unfavourable climatic conditions were defined during a special analysis of multiyear data collected from 11 weather stations. The characteristics were published in "Scientific and Applied Reference Book on the USSR Climate", series 3, issue 1, 1989. The reference book was published to provide different industries, including transport planning and designing, with climatic data.

Weather parameters and phenomena are often characterised using such climatic indices as frequency of phenomena (relative frequency of the given phenomenon during an observation period and expressed in percents) or frequency of the given gradation (range) of a weather parameter (relative frequency of the given weather parameter interval during an observation period and expressed in percents or decimals).

Figure 4-3 Location of the meteorological stations in Arkhangelsk Region

Temperature conditions of the territory are presented in the tables 4.2 - 4.6. The most unfavourable weather conditions for road transport of the Arkhangelsk Region are thaws followed with sharp frosts. From December to February frequency of thaws is 10%. According to the data collected from the weather stations average duration of thawing periods in December is 67 hours, in January - 20 hours, in February - 15 hours.

Frequent cases when the freezing point is crossed during spring and autumn are also unfavourable weather conditions. According to the table 4.6 frequency of cases when air temperature is above zero in March, April and October is rather high (20-40%) and it is when average monthly temperature is below zero. Besides, a large amount of days when air temperature is lower than -30°C (wind speed can be ≥ 8 m/s as well, the table 4.6) should also be considered as an unfavourable weather condition.

Table 4-2 Average Monthly and Annual Air Temperature

Weather station	1	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen	-14.3	-13.7	-9.5	-2.6	3.4	9.9	13.6	11.9	6.6	-0.2	-6.2	-11.4	-1.1

Koynas	16.5	-15.0	-9.6	-1.3	4.6	11.8	15.2	12.7	6.6	-0.3	-6.8	-12.9	-1.0
Arkhangelsk	-12.9	-12.5	-8.0	-0.9	6.0	12.4	15.6	13.6	7.9	-1.5	-4.1	-9.5	0.8
Kholmogory	-13.4	-12.8	-8.0	-0.2	6.2	12.8	15.8	13.5	7.8	1.0	-4.9	-10.4	0.6
Onega	-12.0	-11.6	-7.2	0.1	6.4	12.7	15.9	13.9	8.4	1.9	-3.6	-9.0	1.3
Sura	-15.1	-14.0	-8.7	-0.2	6.2	12.8	16.0	13.5	7.4	0.6	-5.7	-12.0	0.1
Emetsk	-14.1	-12.8	-7.3	0.1	6.6	13.4	16.1	13.9	8.0	1.2	-4.5	-10.2	0.9
Verh. Tojma	-14.6	-13.3	-7.3	0.6	7.4	14.0	16.6	14.3	8.0	1.0	-4.9	-10.9	0.9
Nyandoma	-13.0	-12.1	-6.7	0.6	7.3	13.3	16.0	13.9	7.7	1.0	-4.7	-9.9	1.1
Kargopol	-12.7	-11.9	-7.0	1.0	8.1	13.7	16.4	14.0	8.3	1.6	-4.1	-9.6	1.5
Shangaly	-13.7	-12.4	-6.3	1.4	8.3	14.3	16.7	14.5	8.3	1.3	-4.6	-10.2	1.5

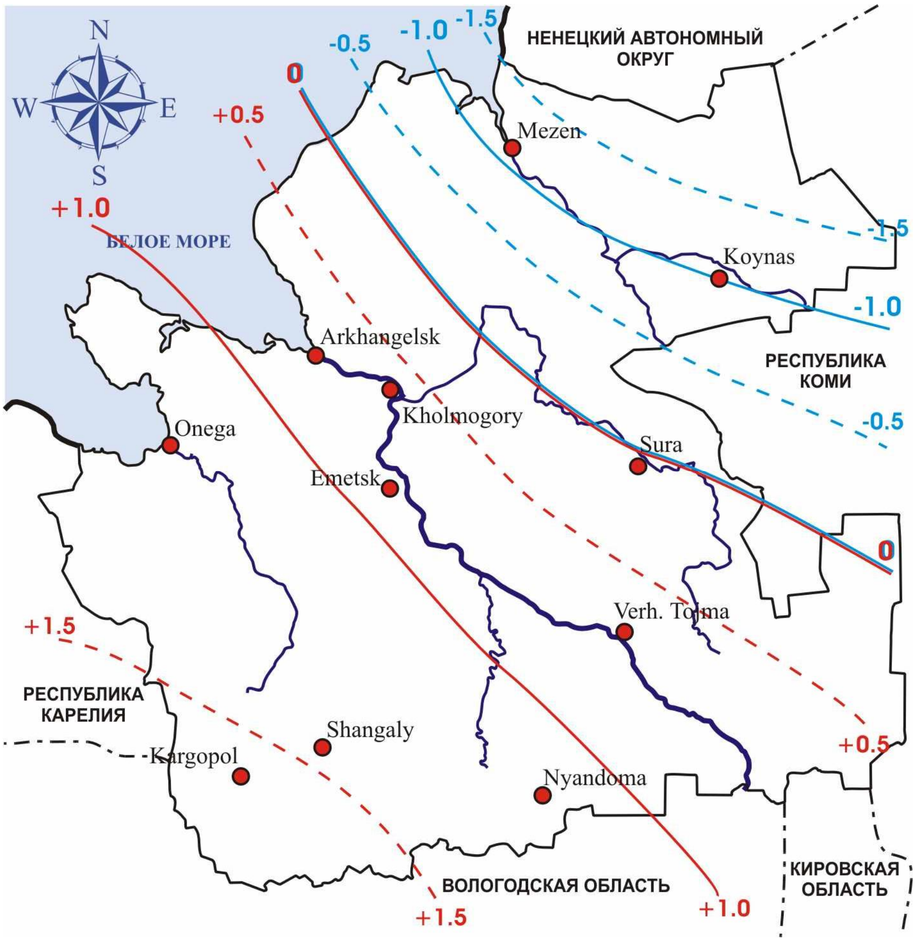


Figure 4-4 Average Annual Temperatures [ºC]

The regime of annual average air temperature is characterised by constant decline from south-west to north-east. The highest average annual temperatures in the region, about +1.5 °C, are observed around Kargopol. As its coldest the average annual temperature is about –1,1 °C near Mezen. This range is a consequence of the influence of the Arctic Ocean in the north and relatively often-occurring cyclonal activity bringing warm air from southwest.

Table 4-3 Absolute Minimum of Air Temperature during Observation Period

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen	-49	-44	-44	-31	-16	-5	-2	-4	-12	-26	-43	-43	-49
Koynas	-52	-52	-45	-32	-19	-6	-1	-6	-11	-28	-43	-52	-52
Arkhangelsk	-44	-45	-42	-30	-16	-4	-1	-4	-8	-22	-37	-43	-45
Kholmogory	-44	-45	-41	-28	-13	-4	1	-2	-7	-24	-36	-46	-46
Onega	-43	-43	-38	-28	-15	-4	0	-3	-5	-21	-33	-41	-43
Sura	-53	-52	-47	-36	-16	-4	0	-5	-9	-24	-44	-51	-53
Emetsk	-46	-46	-38	-24	-12	-2	0	-2	-5	-20	-36	-48	-48
Verh. Tojma	-45	-45	-39	-27	-12	-4	0	-2	-6	-23	-37	-48	-48
Nyandoma	-41	-39	-32	-25	-12	-3	+2	-2	-7	-20	-30	-43	-43
Kargopol	-44	-44	-37	-27	-13	-3	+2	-2	-7	-20	-40	-48	-48
Shangaly	-45	-43	-35	-27	-12	-3	+1	-2	-7	-20	-40	-48	-48

Table 4-4 Number of Days with Air Temperature below -30°C (Average for the Observation Period)

Weather station	1	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen	3,8	2,8	1,3	0,02							0,2	2,6	10,7
Koynas	6,8	5,0	3,3	0,1							0,9	4,7	20,8
Arkhangelsk	3,2	2,3	1,2	0,02							0,05	1,6	8,4
Kholmogory	3,5	2,0	1,1								0,1	1,7	8,4
Onega	2,2	1,5	0,6								0,01	1,1	5,4
Sura	6,4	4,8	3,1	0,1							0,5	4,4	19,3
Emetsk	4,5	2,2	0,9								0,1	2,1	9,8
Verh. Tojma	4,8	3,3	0,7								0,1	2,6	11,5
Nyandoma	2,1	0,8	0,04									1,0	3,9
Kargopol	3,4	2,0	0,5								0,02	1,6	7,5
Shangaly	3,8	1,8	0,4								0,1	1,6	7,7

Table 4-5 Dates of the First and Last Frosts, Duration of Frost-free Period

Weather station	Last	Early	First	Duration	
				Average	Maximal
Mezen	16.VI	14.V	6.X	83	133
Koynas	8.VI	23.V	28.VIII	80	124
Arkhangelsk	8.VI	18.V	3.IX	86	131
Kholmogory	28.VI	30.IV	14.IX	108	151
Onega	31.V	1.V	16.IX	107	154
Sura	3.VI	5.V	3.IX	91	130
Emetsk	28.V	8.V	13.IX	107	145
Verh. Tojma	1.VI	10.V	8.IX	98	140
Nyandoma	30.V	8.V	11.IX	103	141
Kargopol	28.V	30.IV	14.IX	108	145
Shangaly	29.V	8.V	11.IX	104	148

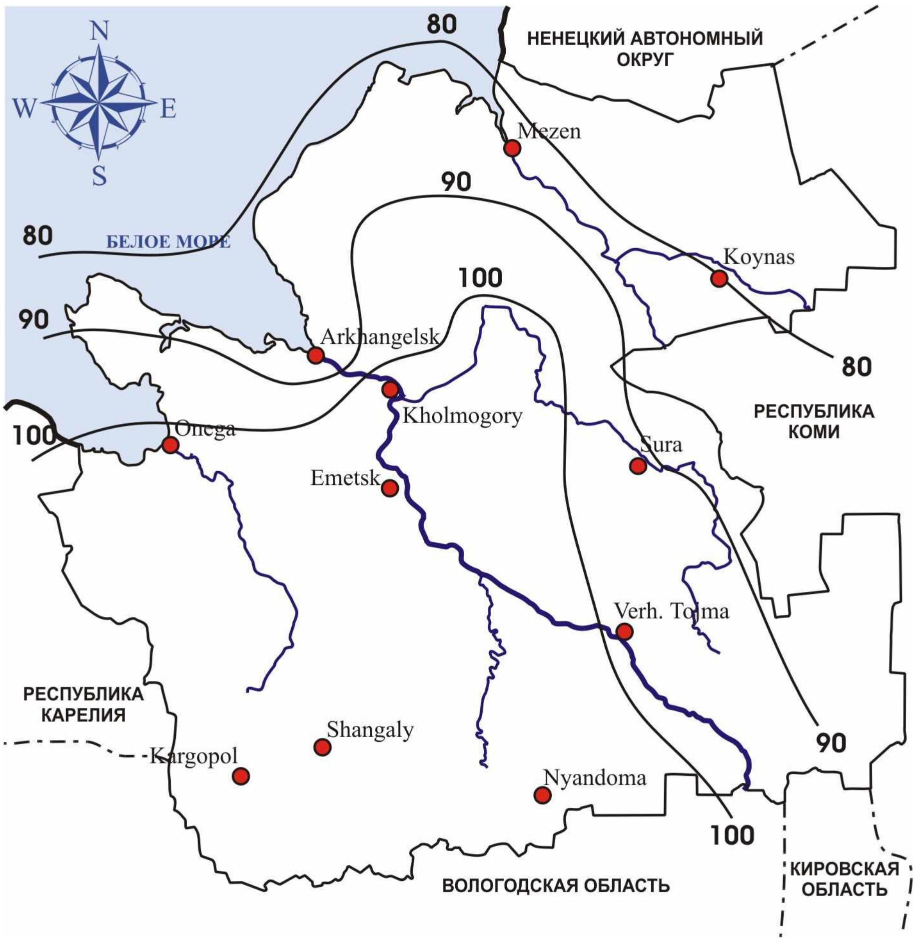


Figure 4-5 Average Annual Duration of Frost-free Period [days]

A specific feature for the duration of frost-free period (Figure 4-5) in Arkhangelsk Region is that it is relatively short by the White Sea compared to inland. By the warm sea winter establishes quite late but frosts start occurring earlier as nights become cold. Even more significant the influence of sea for the frost-free period is in spring as the sea remains ice-covered and cold until late spring thus keeping the coastal zone prone to night-frosts.

From the point of view of road traffic the spring frosts are not as dangerous as the ones occurring in autumn as the air humidity in spring is low and does not usually give conditions for hoarfrost formation.

Table 4-6 Frequency (%) of Cases with Air Temperature above Zero

Weather station	I	II	III	IV	X	XI	XII
Koynas	2,1	1,1	6,0	45,6	42,6	18,0	4,3
Arkhangelsk	2,8	2,3	27,5			18,8	8,8
Onega	3,6	3,1	23,1			30,9	11,0

Table 4-7 Number of Days with Wind Speed ≥8 m/s

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen ≥8 ≥15 ≥20	12 1 0.07	11 1	12 2	11 2	14 2	13 1 0.07	10 1	9 0.6	10 1	12 1	12 1 0.1	12 0.6	139 15 0.2
Koynas >8 >15	3 0.1	2 0.3	4 0.4	3 0.4	3 0.4	4 0.1	3 0.1	2 0.2	2 0.2	3 0.2	3 0.2	2 0.2	34 3
Arkhangelsk	7	5	5	5	6	4	2	3	4	5	6	6	58
Kholmogory	8	7	8	7	8	6	4	4	6	8	8	7	81
Onega	5	5	6	6	7	6	4	6	7	6	6	6	68
Sura	5	4	6	6	7	6	3	3	4	5	5	4	59
Emetsk	6	5	6	6	6	5	4	3	5	5	6	7	63
Verh. Tojma	6	5	7	6	7	6	4	3	5	6	6	6	66
Nyandoma	6	4	7	4	4	4	2	2	3	5	4	5	51
Kargopol	9	8	9	7	8	6	4	4	6	8	9	10	89
Shangaly	5	5	8	6	8	6	3	3	4	6	5	6	64

The tables 4.8 - 4.10 present the **precipitation data**. According to the Table 4-8, Arkhangelsk Region is characterised with large number of days with precipitation all year around, especially during the cold season (14 - 22 days). The average duration of precipitation exceeds 220 hours and maximal annual duration of precipitation is observed at the Kholmogory station (more than 300 hours).

Number of days when precipitation amount is essential (≥1,0 mm) does not vary during a year a lot, being in the entire region and during all months 5-13 days. Liquid and mixed precipitation falling during winter period (November - March) is also an unfavourable phenomenon for road traffic Table 4-10.

Table 4-8 Number of Days with Precipitation ≥0.1 mm

Weather station	1	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen	20	17	16	14	15	15	14	18	19	21	20	20	206
Koynas	21	19	19	15	15	15	13	16	19	21	21	21	215
Arkhangelsk	20	18	17	13	12	13	12	14	17	19	20	21	198
Kholmogory	21	18	16	12	13	14	13	15	17	19	20	21	199
Onega	20	18	17	13	12	13	12	14	18	21	21	22	201
Sura	20	17	16	14	14	13	15	18	20	20	20	20	202
Kargopol	20	17	16	13	13	14	13	15	17	19	20	22	199
Average Precipitation Duration, hours													
Koynas	256	230	209	143	115	79	70	81	131	206	246	251	2016
Arkhangelsk	262	249	185	115	88	75	63	79	117	171	224	256	1885
Kholmogory	302	279	213	129	102	81	71	86	125	191	256	303	2138

Table 4-9 Number of Days with Precipitation ≥1,0 mm

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen	6,6	5,1	5,5	5,9	7,6	9,0	8,5	10,2	12,5	11,2	9,0	7,0	98
Koynas	10,4	8,4	9,4	8,5	9,2	10,3	9,2	11,0	12,5	13,1	11,2	11,3	124
Arkhangelsk	9,3	8,0	8,1	6,8	8,5	9,2	8,7	10,3	12,1	12,6	11,7	11,0	146
Kholmogory	8,1	7,2	6,8	6,7	8,1	9,4	9,1	10,4	11,1	11,3	9,9	9,6	108
Onega	8,8	7,3	7,1	6,8	7,6	9,3	9,0	9,8	12,2	13,4	12,0	11,0	114
Sura	8,4	6,9	7,2	7,5	8,7	10,2	8,6	10,2	12,6	12,3	10,0	10,0	112
Kargopol	8,2	6,6	7,4	7,3	8,4	10,5	10,0	10,6	11,7	11,2	10,0	9,0	112

Table 4-10 Monthly Amount (mm) of Liquid, Solid and Mixed Precipitation

Weather station	1	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mezen liquid	-	-	-	6	17	45			52	17	4	-	273
solid	22	17	18	10	7	1			1	14	23	22	120
mixed	4	2	2	10	11	5			14	23	13	6	86
	-	-	1	8	24	60	71	70	56	18	4	-	313
Koynas	34	30	29	13	7	-	-	-	1	20	29	36	196
	4	1	3	17	18	6	-	-	12	22	14	5	104
	-	-	-	6	26	59	64	67	59	26	6	-	313
Arkhangelsk	31	28	26	13	7	1	-	-	1	17	32	34	189
	4	2	4	12	13	2	-	-	9	20	13	8	89
	-	-	-	6	25	58	64	71	53	22	5	-	291
Kholmogory	28	24	23	13	7	1	4	-	1	15	27	29	175
	3	2	3	11	12	2	-	-	8	17	11	7	82
	-	-	-	8	28	54	62	70	63	26	7	-	322
Onega	34	28	21	10	4	1	-	-	2	15	33	34	183
	5	4	6	13	12	8	-	-	11	26	10	11	103
	-	-	1	7	23	3	69	69	56	25	4	-	293
Sura	30	25	25	11	8	-	-	-	1	16	25	33	184
	3	1	2	14	17	62	-	-	12	17	12	4	98
	-	-	-	6	24	54	57	66	53	21	4	-	274
Emetsk	26	22	20	12	7	1	-	-	1	14	25	27	165
	3	2	3	11	12	2	-	-	8	17	11	7	77
	-	-	1	13	43	76	73	75	76	36	9	-	429
Nyandoma	40	30	31	15	3	-	-	-	1	15	35	42	214
	3	3	6	16	11	2	-	-	4	26	19	10	71

The tables 4.11 - 4.15 present data about the most dangerous phenomena affecting road traffic and maintenance (fog, snowstorm and slipperiness).

It should be noticed that the number of days and duration of phenomena during the given year could be considerably different from average multiyear data (for example, maximal number of days with slipperiness can be 4 times larger than the average one, Table 4-14). Therefore, it is important to use not only average values, but also actual weather data.

On the contrary, it is important to add observation data with appropriate weather parameters as well.

Table 4-11 Average Number of Foggy Days

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	X-III	IV-IX	Annual
Mezen	4	3	4	4	3	2	3	4	4	6	5	5	27	20	47
Koynas	1	1	0,8	2	1	0,8	2	4	4	2	1	1	7	14	21
Arkhangelsk	3	3	3	3	1	1	1	3	3	4	3	3	19	12	31
Kholmogory	4	3	3	2	1	1	1	3	4	4	4	3	21	12	33
Onega	3	3	3	2	2	1	0,8	2	3	3	2	2	16	11	27
Sura	3	1	2	1	0,9	0,8	2	5	4	2	2	2	12	14	26
Emetsk	3	2	2	2	1	0,5	0,9	2	3	4	3	3	17	9	26
Verh. Tojma	3	2	2	2	1	0,6	1	3	5	3	2	2	14	13	27
Nyandoma	4	4	3	4	3	1	3	5	7	9	8	6	34	23	57
Kargopol	3	4	4	3	2	0,9	1	4	5	5	5	4	25	16	41
Shangaly	2	2	2	2	1	1	2	5	6	3	2	2	13	17	30

Table 4-12 Frequency (%) of Cases with Fog duration of 0-4 Hours and 8 Hours

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Arkhangelsk	66 12	65 14	60 17	62 6	67 9	81 4	76 3	70 5	70 7	72 11	72 13	72 9
Onega	76 6	70 7	76 6	74 12	75 5	85 2	84 3	76 5	79 6	77 7	79 4	75 5
Sura	76 2	70 6	78 1	73 4	78 -	75 -	79 1	74 6	69 11	82 6	82 5	82 3
Kargopol	72 11	65 13	69 10	64 9	65 9	79 2	84 3	76 5	66 11	67 11	62 14	68 12

Annual average duration of foggy periods is 180 hours in Mezen, 134 hours in Arkhangelsk, 95 hours in Sura, 183 hours in Kargopol.

Table 4-13 Average Number of Days with Snowstorms

Weather station	IX	X	XI	XII	I	II	III	IV	V	VI	Annual	Max.
Mezen	-	1	5	8	10	8	9	4	0,8	0,02	46	73
Koynas	-	0,9	3	4	5	5	6	2	0,3	0,02	26	53
Arkhangelsk	0,03	0,8	3	5	6	5	5	1	0,3	-	26	49
Kholmogory	-	0,5	3	5	6	6	6	1	0,2	-	28	46
Onega	-	0,9	4	5	7	6	5	2	0,3	0,02	30	53
Sura	-	1	4	5	6	6	6	2	0,1	-	30	49
Emetsk	-	0,3	2	3	4	4	4	0,7	0,1	-	18	43
Verh. Toyma	-	0,3	2	3	4	4	4	1	0,02	-	18	35
Nyandoma	-	1	4	8	10	8	9	2	0,2	-	42	60
Kargopol	-	0,6	4	8	10	9	8	2	0,1	0,02	42	62

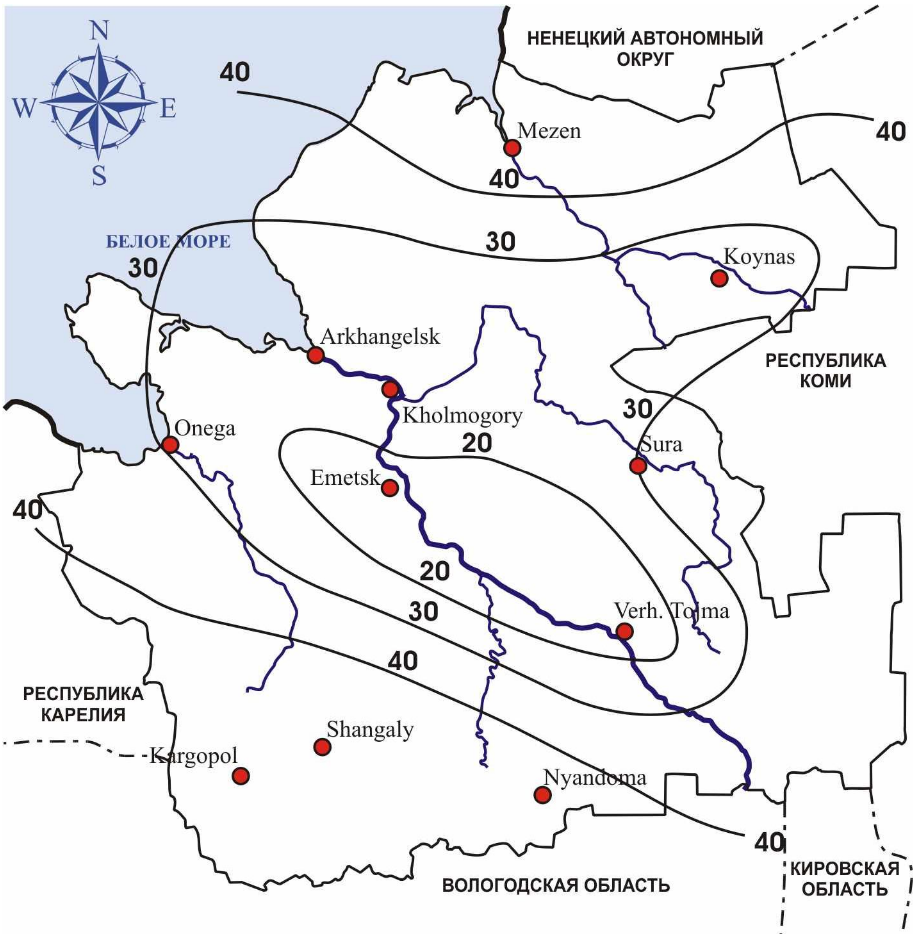


Figure 4-6 Average Numbers of Days with Snowstorms

The occurrence of snowstorms (Figure 4-6) in Arkhangelsk Region is lowest in the lowlands surrounding the River Dvina. More snowstorms occur in the higher laying areas in the southern and northern parts of the region.

Table 4-14 Average Duration of Snowstorms (Hours)

Weather station	X	XI	XII	I	II	III	IV	V	VI	Annual	Daily
Mezen	6	33	52	72	66	68	26	6	0,1	329	7,2
Koynas	6	21	20	33	31	39	12	2	0,1	164	6,3
Arkhangelsk	1	12	28	33	29	22	6	1	-	132	5,3
Kholmogory	2	18	34	44	45	42	10	2	-	197	7,0
Onega	4	21	31	41	37	35	10	2	0,1	181	6,0
Sura	9	24	31	42	42	39	13	1	-	201	6,7
Kargopol	4	23	66	83	80	65	14	1	0,2	336	8,0

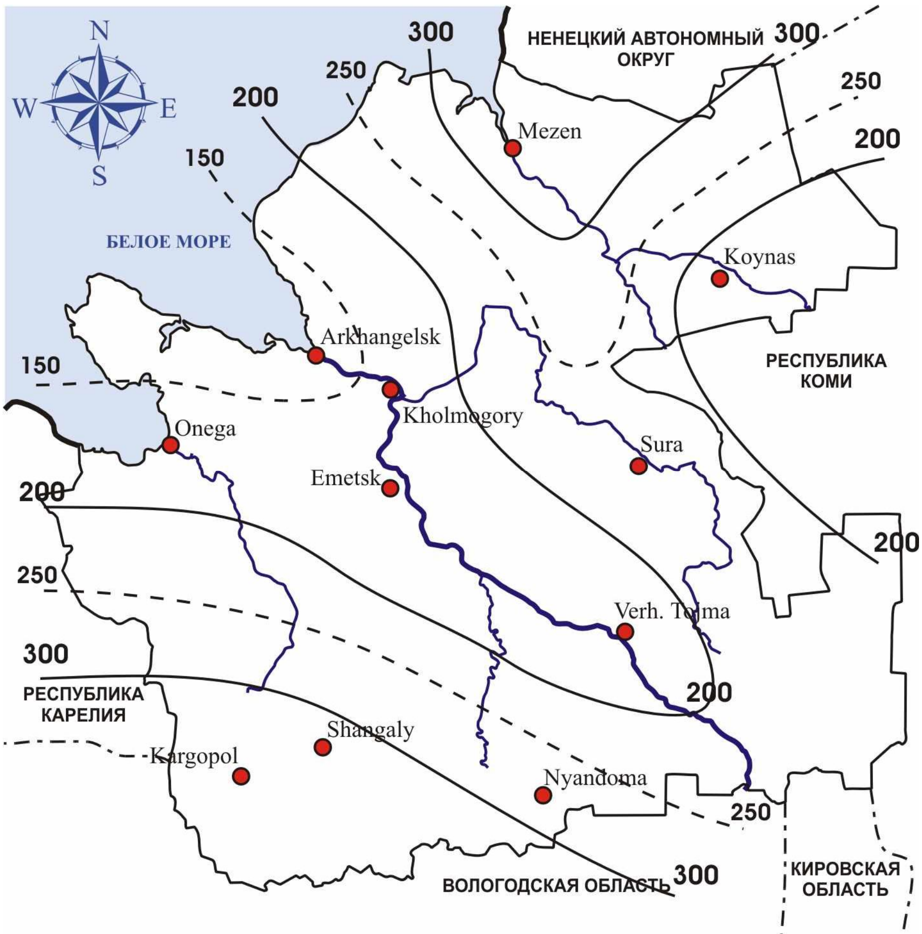


Figure 4-7 Average Duration of Snowstorms [hours]

The pattern for the average duration of snowstorms (Figure 4-7) is quite similar to the number of days with snowstorms. The lowlands round River Dvina are better sheltered from snowstorms than the higher areas around the river valley.

Table 4-15 Number of Days with Slipperiness

Weather station	IX	X	XI	XII	I	II	III	IV	V	VI	Annual	Max.
Mezen		1	3	3	3	2	0,6	0,4	0,4	0,02	13	27
Koynas		0,9	2	2	1	0,9	0,3	0,4	0,1		8	26
Arkhangelsk		0,8	2	3	3	2	0,5	0,2	0,03		12	20
Kholmogory		0,9	3	4	3	2	0,6	0,2	0,0		14	39
Onega		0,5	1	3	2	1	0,5	0,1		0,02	8	36
Sura	0,03	1	3	4	4	1	0,3	0,2			14	31
Emetsk		0,3	3	4	3	1	0,3	0,1			12	28
Verh. Tojma	0,02	1	4	6	4	2	0,5	0,5	0,1		18	36
Nyandoma		2	6	9	6	3	1	0,3	0,1		27	49
Kargopol		0,7	3	4	3	2	0,7	0,4	0,1		14	32
Shangaly		1	3	3	3	0,8	0,5	0,3			12	25

Table 4-16 Maximal Daily Growth of Snow Layer (cm)

Weather station	IX	X	XI	XII	I	II	III	IV	V	VI
Mezen	12	15	15	10	11	10	16	14	10	3
Koynas	2	15	11	15	12	12	13	19	11	2
Arkhangelsk	7	12	13	18	13	12	12	13	14	16
Kholmogory	2	11	14	16	18	12	16	15	13	-
Onega	10	12	14	13	11	16	12	14	8	-
Sura	10	13	12	19	16	12	18	12	9	5
Kargopol	3	10	13	12	9	13	17	19	7	2

Table 4-17 Average Snow Layer Depth at the End of Month (cm)

Weather station	IX	X	XI	XII	I	II	III	IV	V	Average	Max.	Min.
Mezen		5	12	22	29	37	40	19	-	43	88	20
Koynas		6	20	37	52	63	67	34	6	71	106	42
Arkhangelsk		4	11	21	28	35	38	8	-	42	70	12
Kholmogory		3	11	20	29	35	36	6	-	41	83	10
Onega		3	14	26	37	47	46	6	-	54	79	24
Sura		4	11	25	35	45	47	14	-	52	83	20
Kargopol		3	8	21	30	39	41	7	-	47	83	14

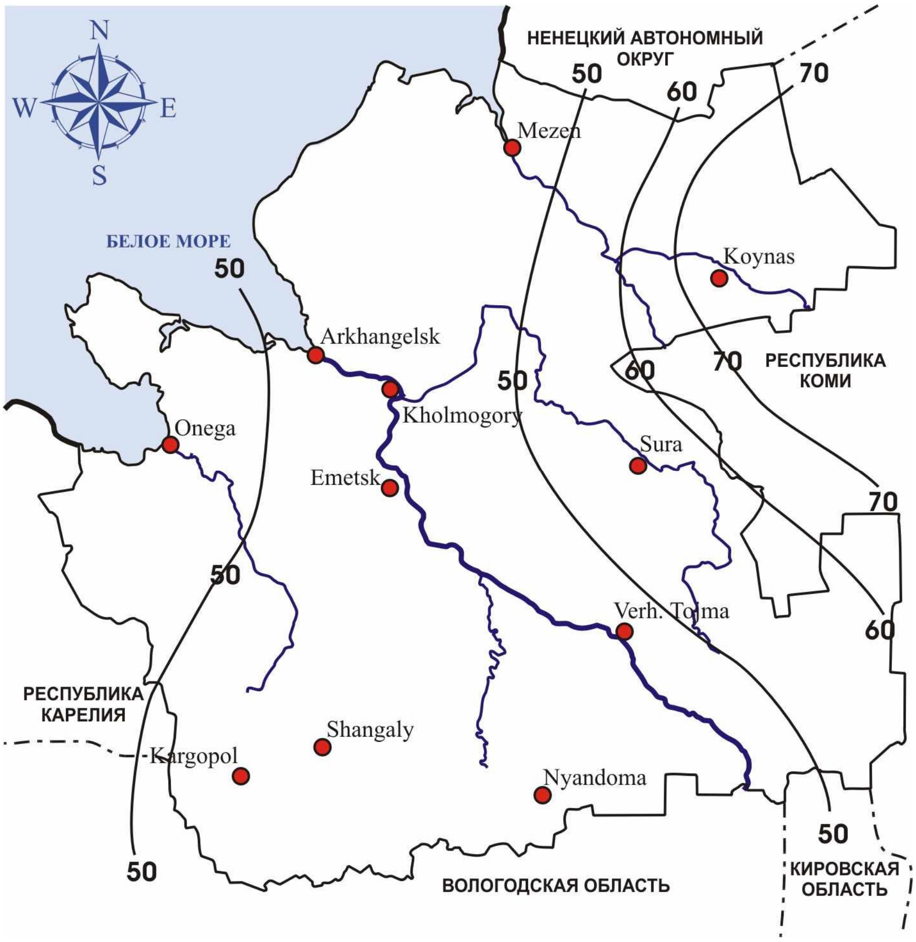


Figure 4-8 Average max. Snow Layer Depth [cm]

In average, the highest snow layer depths in Arkhangelsk Region appear in inland, in the part close to Komi Republic (Figure 4-8). As in the case of snowstorms, the lowest values appear in the River Dvina valley.

4.3 Telecommunication

4.3.1 Data transmitting possibilities

Wire phone communication

That is the most preferable option, as it is the cheapest. Quality of current telephone cables is weak. The locations where outstations are intended to be constructed do not have phone connection. Installation of cables will raise costs and needs a lot of time.

Cellular phone communication

There is no need to install cables, thus the outstation could be constructed anywhere within area with signal reception. Cost of connection is not high in comparison to wire communication. Additional equipment has to be provided (radio-modems or fixed data terminal equipment). Traffic cost is not expensive at the moment with present contracts. Quality of communication is acceptable.

Taking into account everything mentioned above, cellular connection is more preferable.

4.3.2 Existing cellular communication possibilities

There are 4 cellular communication providers in Arkhangelsk at the moment, representing 3 standards (NMT-450, GSM, AMPS).

NMT-450 (JSC "Artelecom-Sotovaja")

This is the federal analog standard of cellular communications. Traffic speed is limited to 9,6 kb/s. Old-fashioned standard. Equipment is manufactured in limited quantities which results in high cost. It seems that the network of this standard will not be expanded in future. Avtodor has an agreement with "Artelecom-Sotovaja" for 5-year utilization (started in 2000) free-of-charge of 5 phone lines. But additional 5 terminals will require new negotiations with "Artelecom-Sotovaja" and most probably they will be payable.

Needed equipment for NMT-450i standard: Nokia 10i or equivalent.

When connected to a regular phone with tone dialing, it works as a cellular phone. This apparatus is the most convenient equipment for areas where installation of regular phone is impeded. Power supply can be – 220/12 V. So it could be connected to a car accumulator.

Functions are as follows:

- Wall and table installation;
- Regular telephone 2-cable socket;
- Possibility of parallel connection of 3 different additional devices: regular telephone, fax, coin-box telephone;
- Socket for connection of external antenna.

GSM (JSC "Telecom XXI"; JSC " NorthWest-GSM ")

This is the federal digital standard of cellular communications. It is most progressive of existing standards. Equipment is not very expensive. Traffic speed is limited to 19,6 kb/s. There are two providers of GSM services in Arkhangelsk, which means absence of monopoly. By the end of the 2002, third provider (JSC "AMS") will appear on the market. That should decrease prices in the near future. Both providers are regularly modernizing their equipment.

Needed equipment for GSM-900/1800 standard: Nokia 22 or equivalent.

Connection: regular telephone apparatus, mini-ATS, office ATS – as a trunk line and private branch exchange (PBX), computer (RS-232). Data and fax transmitting by means of computer. Standard built-in antenna, external antenna. Possibility to access Internet and to use terminal as a gateway between cellular and wire telephone networks.

AMPS (JSC «AMS»)

This is a non-federal analog standard of cellular communications. Traffic speed is limited to 9.6 kb/s. Old-fashioned standard. Equipment is manufactured in limited quantities that results in high cost. It seems that the network of this standard will not be expanded in future. As was mentioned earlier, JSC "AMS" is planning to operate as a GSM service provider in close future. Thus, AMPS standard network will be demolished soon and there is no need to rely on it.

4.3.3 Conclusion

Taking into account analysis and characteristics of equipment, the appropriate standards could be GSM or NMT. To choose exact provider, there is a need to negotiate with all of them, because initial costs are approximately the same.

4.4 Winter maintenance organisation

Arkhavtodor is responsible for the maintenance of federal and regional roads as well as an increasing amount of local roads. It agrees on annual contracts with DRSUs, road maintenance organisations, to carry out the road works. In Arkhangelsk Region, there are altogether 20 DRSUs, out of which 6 are federal and 14 regional.

Winter maintenance readiness in DRSUs is kept up during the period of 16 October to 16 April. For the continuous alerting system, there is a central Dispatch Centre in Arkhavtodor and local Dispatch Centres in each DRSU. All the Dispatch Centres operate 24 hours a day. The central Dispatch Centre collects information and informs road users via local media and radio channels on adverse weather conditions. The local Dispatch Centres transfer road information for the road maintenance purposes. The central Dispatch Centre receives once a day a road weather forecast from the Hydrometeorological Service, and this information is forwarded to DRSU Dispatch Centres for the planning of operations.

At DRSUs the staff has been organised to work in shifts and the nightshift workers are in preparedness in the maintenance bases regardless of weather conditions. With these arrangements, the DRSUs are able to start operations quickly. However, in the long run it causes high costs to have the workers at the workplaces at night if it were not required by the weather conditions. Effective utilisation of RWIS and weather forecasts through Dispatch Centre operation could provide significant savings.

The roads are divided into different winter maintenance classes according to the traffic density. The winter maintenance classes have different requirements for the level of maintenance service, such as

- Maximum response time for the maintenance action;
- Maximum allowed loose snow on the road;
- Maximum allowed packed snow on the road.

The requirements are naturally highest for the roads with highest traffic density. Accordingly, by the means of RWIS these requirements could be supported.

Capacity of the winter maintenance equipment in Russia is generally rather low compared to the EU. This means that maintenance lorries are smaller and for example the snow ploughing effectiveness is less. Only few lorries are so powerful that they can be used simultaneously for snow ploughing or packed snow grading with under-body-blade and for salt spreading. However, the recent tendency is to procure bigger lorries facilitating multi-functional operations. For tackling slipperiness, sand-salt mixture is used. This is a fairly ineffective and expensive method, when a lot of sand has to be hauled together with salt. However, the intention of Arkhavtodor is to introduce new technology of spreading plain salt on the main highways after RWIS has been taken into use. On the basis of experience from the EU and some other countries, it is obvious that the annual application of salt can be reduced with the new technology and accordingly, the harmful environmental impacts will decrease.

5 Technical Configuration of Arkhangelsk RWIS

5.1 Pilot system

Within the scope of this Tacis-project, one of the objectives is to introduce a pilot Road Weather Information System (RWIS). During the Inception phase, the general plan was produced, and the scope of the system was introduced including the procurement plan. Budget for the procurement of RWIS equipment is 94,000 EUR. Depending on the tendered price level, it is planned that the Pilot System will include the following items:

- 3 - 5 Road Weather Outstations;
- Central computer;
- 1 - 3 Workstation computers;
- Communication devices (modems, possibly cellular phones);
- Calibration equipment;
- Software for collection, storing and displaying of data.

Technical specification of the Pilot System follows the requirements of a state-of-the-art system described in the Chapter 2 of this report. In the EU countries or in CIS countries, there are not many manufacturers of this type of equipment, and it may make the competition in the tendering difficult.

5.1.1 Communication

Reliable communication links between the road weather outstations and the centralised computer system is crucial for the operation of the Road Weather Information System. The central computer collects information from the road weather outstations along the roads with a certain interval varying from a few minutes to a few hours. There are data transfer modems at both ends of the link, at the central computer and at the outstation.

The communication connections taking place in the Pilot System can be divided into the following categories:

- The Central computer collects data from road weather outstations;
- The Workstations collect data from the Central Computer.

Usually, the amount of data, which is transferred at one time, is not that big. Therefore, the data transfer speed does not have to be fast. However, it is necessary that the connection can be established quickly and reliably as often as needed.

In general, the communication infrastructure in Arkhangelsk Region is not very developed. The situation is usually similar also elsewhere in Russia.

In the pilot project, the means of communications used will be as follows:

- Ordinary telephone network;
- NMT or GSM.

GSM and NMT can be regarded to be a more reliable solution, but they are not available in all places, especially in remote areas, and the price level of the communication may be high. There are modems suitable for use in all systems.

5.1.2 Installation

It is planned that the Road Weather Information System (RWIS) will first be established in the area of Primorsk DRSU surrounding Arkhangelsk City. This pilot system will then demonstrate the usability and benefits of RWIS and the system can later be expanded to cover a wider area of Arkhangelsk Region.

Arkhavtodor is committed to take care of the local costs occurring from the installation of the system as well as from running the system. These include such issues as minor civil construction works, provision of electricity and communication facilities.

The outstations will be installed on selected locations along the roads of Primorsk DRSU mainly. It has been planned that the Pilot System will include 3 - 5 road weather outstations. Tentatively the locations will be as shown on the following Figure 5-2. These locations represent different important road sections, and they cover the area widely. In addition, there are road police (GIBDD) posts on-site, which guarantee security to the outstations.

The numbering in the Figure 5-2 describes the priority order of the outstations to be procured.

Figure 5-1 A Road Weather Outstation, procured with Tacis-funding, in Ust-Labinsk, in Krasnodar Krai, Southern Russia, protected with light fence.

Figure 5-2 Planned locations of Road Weather Outstations in the Pilot System.

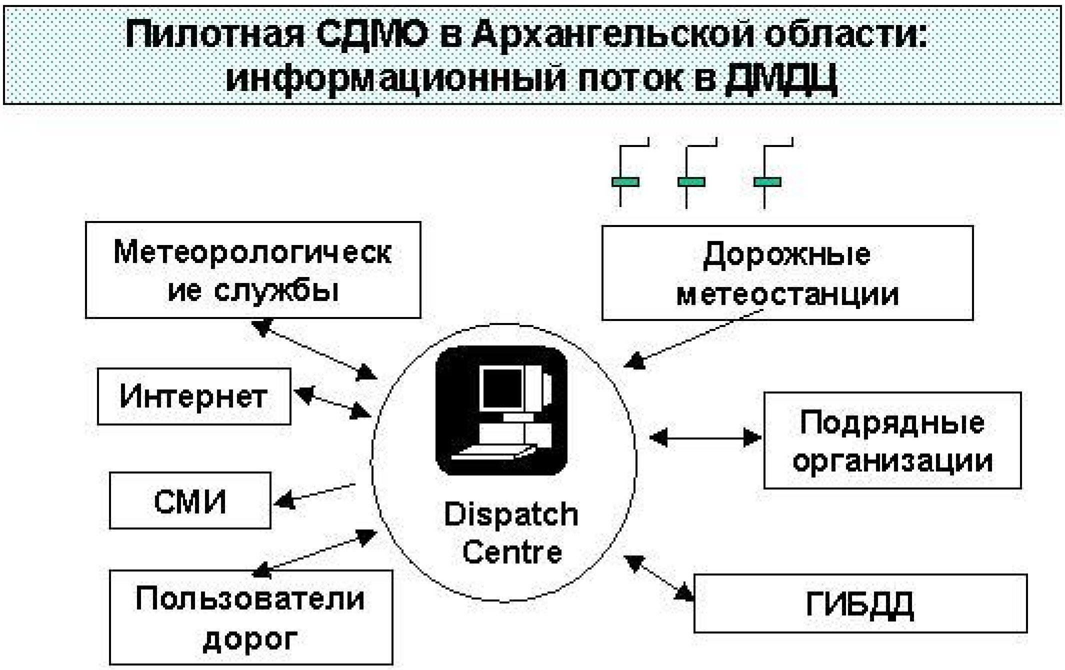


Figure 5-3 Schematic picture on information flows.

It would be most feasible to place the central computer at the main office of Arkhavtodor, where the central Dispatch Centre is situated. The operators at the central Dispatch Centre will then be the main users of the new system. In addition, it is recommended that Workstations will be installed at Primorsk DRSU Dispatch Centre and at Hydrometeorological Office. Thus, the weather and road conditions could be followed in those places as well, and particularly the meteorologists could prepare more detailed and reliable forecast for the coming road conditions.

5.2 Further development

As described earlier in this report, a developed Road Weather Information System may consist of:

- Road weather outstations with related software;
- Road weather cameras with related software;
- Weather radar and satellite images;
- Meteorological forecasts;
- Various information systems to road users.

It is feasible to arrange separate computer systems for the operation of the images from the satellite, radar, forecast map and weather camera. Theoretically, they all could be run in one computer, but experience has shown, that running several demanding applications in one computer at the same time will create problems.

5.2.1 Expansion principles of RWIS

Experience has proved that such highly developed, large IT systems should be implemented step by step to their completeness to allow the users time to learn to take advantage of all the features of such advanced systems. In this particular case the approach to the system mentioned would be compatible with the Pilot System to be implemented as the first step.

The pilot RWIS scheme has been specified so that the RWIS can be expanded in Arkhangelsk Region by adding components to the pilot system. This means that it is possible to install additional road weather outstations and connect these to the pilot RWIS software. There is a requirement in the Pilot System specification that it must be possible to increase the number of outstations to 30. This is sufficient for Arkhangelsk Region in the near future, say next ten years. In addition, it is required that 4 to 5 workstations can be connected to the system.

Construction of this kind of a system is always a task of several years. First there is the pilot phase when experience is gathered. Based on this experience, the system can then be gradually expanded. It is a big investment, which needs economic and technical justification as well as confidence that it is worth investment. New road weather outstations in the system can be increased piece by piece according to the available budget. Additional outstations improve the coverage and accuracy of the system. Priority of the additional outstations can be determined according to the importance of the roads and geographical coverage.

As the computer technology develops so fast, it is naturally quite evident that there will be a need to update the computers after some years, even though the specified computers of the Pilot System are very powerful and more than sufficient for the present use.

Another option for the additional workstation connection could be utilisation of the Internet, which would enable an unlimited number of subscribers to join to the system, in a way determined by the system operator.

One limitation for a large number of weather outstations is the modem connection capacity. One modem connection to a weather station lasts 1-2 minutes, and thus, one modem at the collecting computer can not handle too many outstations. One round of RWO Data gathering should not last too long, e.g. more than 10-15 minutes. Otherwise it may make the comparison of different observations quite difficult. As a result, additional modems and their controlling software need to be installed in the expansion of the outstation network.

When the general communication infrastructure in the region develops, it will be feasible to change to more powerful communication links than modems. These may be for example ISDN, ADSL or TCP/IP connections. Usually, it is most cost effective to connect with the general networks and not to build any special connections. In some places, it may be best to use direct radio transmitters, if other communication infrastructure does not exist.

5.2.2 Proposed development of Outstation and Camera network

Factors based on roads and traffic

The indisputable fact is that the most significant sections of road network in Arkhangelsk Region are situated south from the latitude of Arkhangelsk City. These circumstances indicate that when planning the further steps in RWIS development, the additions to the Road Weather Outstation (RWO) and Road Weather Camera (RWC) networks after the Pilot System should be implemented on the road sections located in the southern parts of Arkhangelsk Region.

The most significant road according to the traffic density and accidents is, of course, the road M8, Moscow - Arkhangelsk. Thus, it is quite natural after the RWIS pilot implementation to start improving the RWO network along the road mentioned in the direction to Moscow.

In the near future, the planned East-West Corridor from the Komi Republic trough the Arkhangelsk Region to the Karelian Republic and to Finland will also become quite important especially among the transportation of heavy goods like timber. Some road sections belonging to the Corridor might be the most logical continuation after the first steps when further improving the RWI System.

Climatic factors

As described earlier in Chapter 4, the climatic variations in Arkhangelsk Region are quite small, but some elements important for RWIS development can be noticed.

When observing the M8 road, there can be distinguished at least three climatically different zones as follows:

- **The coastal zone** from Arkhangelsk down to Kholmogory.

  On this road section, there can be noticed weather phenomena resulting from the closeness of the White Sea like high humidity, strong winds and relatively long, mild autumns.

- **The river valley zone** along the river Dvina from Kholmogory down to Bereznik

  In wintertime, when the river is ice covered, this road section may be the most harmless. On the other hand, during autumn, humidity from the River Dvina can cause troubles when freezing on the roads. This phenomenon is called black ice formation.

- **The inland zone** from Bereznik down to the southern border of the Arkhangelsk Region.

  On this relatively long road section the amount of snow may be the most difficult factor for road winter maintenance. This section is also close to the tributary of the River Dvina so that the black ice formation may cause troubles during autumn.

When observing roads belonging to the East-West Corridor, it can be said that weather conditions are quite similar along the roads mentioned and also quite similar in comparison with the inland zone on the M8 road. So, generally taken snow will cause the biggest problems for the winter road maintenance also in this area.

The road sections geographically north of the Arkhangelsk City can almost totally be ignored when planning the further steps with the RWIS. Information from this area carries almost purely meteorological value. However, in certain weather conditions it may prove extremely useful to get up-to-date information about weather phenomena approaching from that direction. With a larger scale RWI System one or two RWOs may be located in this area.

The Outstation network development in steps

Experience has also proved that decentralisation of the outstations to the whole area to be covered is the most effective principle in placing the outstations. Thus, the first additional RWOs should be placed quite evenly across the southern Region.

It may be considered that every step of additional Outstations could consist of 5 RWOs. According to the above-described procedure at least three separate steps (total 15 RWOs) would be needed to cover the whole Arkhangelsk Region well enough. Consequently, the total amount of RWOs together with the Pilot System would rise up to 18 - 20 units during next 10 years. After that the RWO network may be improved further with only one or two pieces per time according to the experiences and e.g. needs of increasing traffic volume on some road sections.

On the map in Figure 5-4, the planned, preliminary locations for the outstations are described. The outstations are divided into three phases in this plan.

The Camera network development

It is recommended that road weather cameras will be installed along the roads in addition to road weather outstations. In practise, it is simplest, in the first phase, to install a road weather camera system, which is separate from the actual RWI System. This means that the computers, software and communication devices are separated.

As earlier described in Chapter 2.3 the road weather cameras give additional to the RWO data information for the dispatchers. Generally the camera network does not need to be as large and dense as outstation network. It will be enough that cameras give additional information from the most difficult spots on the road network like e.g. spots where drifting snow or generally hard snowing conditions are common. Sometimes also the big bridges over rivers may be favourable places for the cameras because of their special climatic features like high humidity causing slipperiness and hard wind causing drifting snow. In that case, it should be noticed that the road conditions could be quite different from the conditions shown by the camera, even rather close to the bridge.

Further, it has to be taken into account that effective utilisation of cameras will also be adopted step by step only. Thus, also the camera network shall be implemented and improved gradually according to the outstation network improvement.

In addition, it would also be useful for the dispatchers' learning process to provide one camera in connection with the pilot phase or at least not later than in connection with the first outstation network improvement phase.

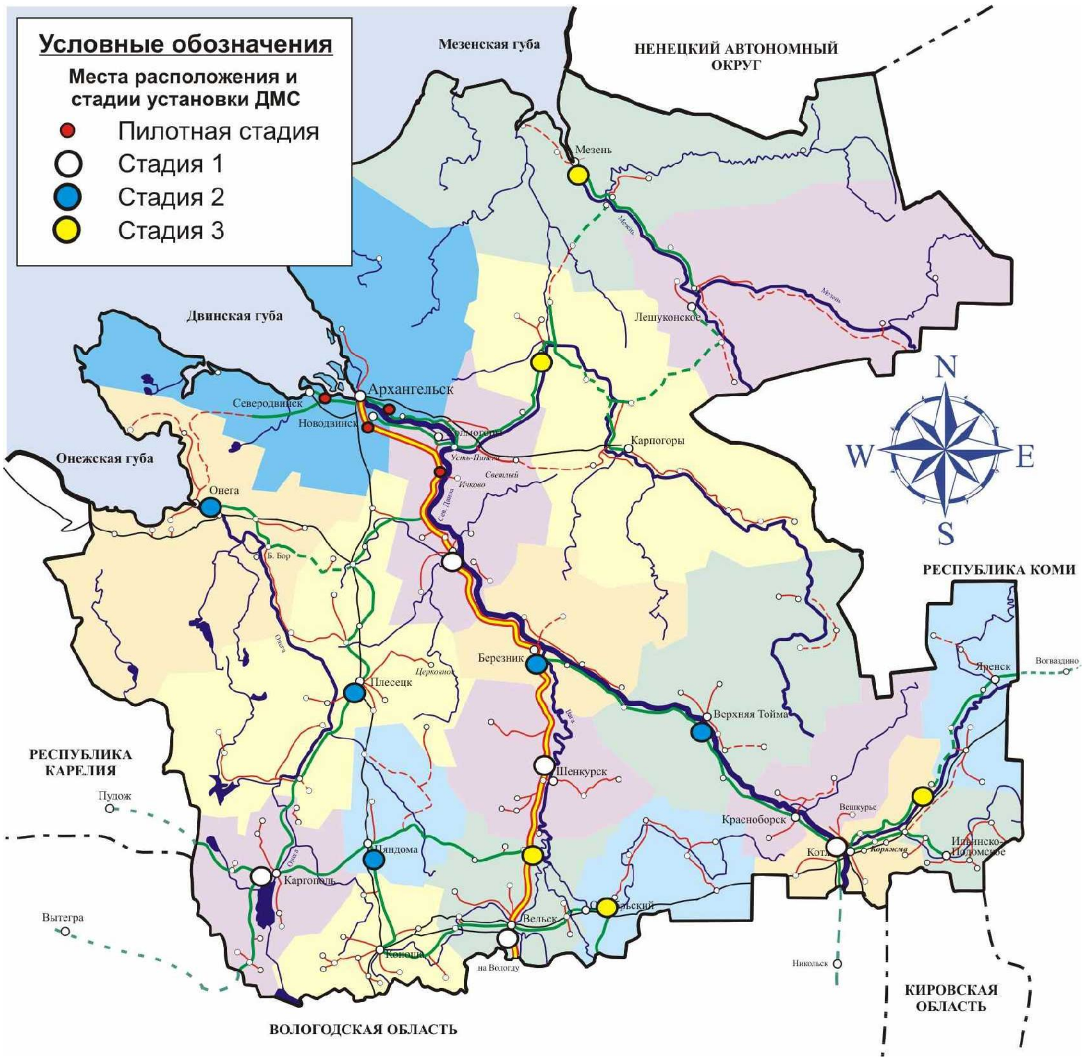


Figure 5-4 Schematic presentation of the preliminary RWO network divided into three phases.

5.2.3 Satellite and Radar Images

Satellite and radar images provide valuable information for the Dispatch Centre. They complement substantially the information received from the road weather outstations. In Arkhangelsk, the local Meteorological Service has satellite images available.

At present, the meteorological radar in Arkhangelsk is not operational. There are plans to replace it with modern automated radar, which could become operational during the year 2003. Availability of radar images for the Dispatch Centre should be discussed with the Meteorological Service.

Technically the satellite and radar images could probably be transferred rather easily to the computers of the Dispatch Centre, and they would improve the reliability of the dispatcher's work. When co-operation between Arkhavtodor and the Hydrometeorological Service is developed, this is one important aspect to be taken into account.

It is quite evident that it is not feasible for a road authority to purchase radar for itself. However as an example, in Finland the road authority has paid a part of the cost of one weather radar investment as the information from radar was regarded so important for the RWIS operation and traffic service.

5.2.4 Various information systems for road users

In the near future, the most feasible channel to provide information to the road users are radio and TV broadcasting as well as the Internet. It is a fairly easy and low-cost solution to build up a link from the RWIS and camera system to the Internet-server and give the public free access to this information.

Internet

The Internet as a mean of communication offers the greatest possibilities to reach people everywhere. At the same time it will also be the most demanding and expensive instrument of the Road User Information. However, the system may be utilised not only for road user information but simultaneously also inside a road administration or contractor for the distribution of necessary information e.g. from Dispatch Centres.

The Road User Information on Internet will also be bound to the same starting points as the rest of information. It means that the old or irrelevant information should never be available in the Internet. Otherwise people will quite fast lose their interest in those sites and the original, good and important aim of the sites in question will be wasted.

Other telematics

At a later stage, it may become feasible to introduce variable traffic sign technology on road sections with heavy traffic. These are relatively costly investments. Therefore, the benefits should also be substantial. With relation to the RWIS, the first systems could be warning signs for slippery roads attached possibly with text signs (e.g. “warning”, “road and air temperature”)

Table 5-1 Drafted expanded RWI System in Arkhangelsk Region including Outstations and Cameras with related items.

Device	No of devices
Road Weather Outstations	**18 - 20**
Road Weather Cameras	**4**
RWIS Central computer + software	**1**
Workstations in DRSUs	**5**
Camera computer + software	**1**
Communication devices etc.	**Needed equipment**

6 Operation of RWIS

The main function of a RWIS is to support road winter maintenance decision-making. Road Weather Dispatch Centre (RWDC) should be the focal point for all issues related with winter maintenance. Without well-organised RWDC operation the benefits from the RWIS will not be fully utilised.

Weather monitoring and interpretation of the measurements and phenomena are the operative tasks of a RWDC. There should also be staff for ensuring the functioning and service of the equipment and computer system. With modern tools and means, the RWDC can monitor the development of weather conditions very efficiently. Centralising of this activity also ensures equal information to all area. In the long run, concentrating these activities in one point can help to reduce personnel costs on winter maintenance activities by avoiding overlapping duty schemes.

Timing is the key factor as far as winter maintenance operations are concerned. The RWDC monitors the road conditions 24 hours a day facilitating quick responses to the changing weather. With the assistance of the Meteorological Service and by following the road and weather conditions through RWIS, the RWDC can stay up-to-date on the development of conditions on the roads.

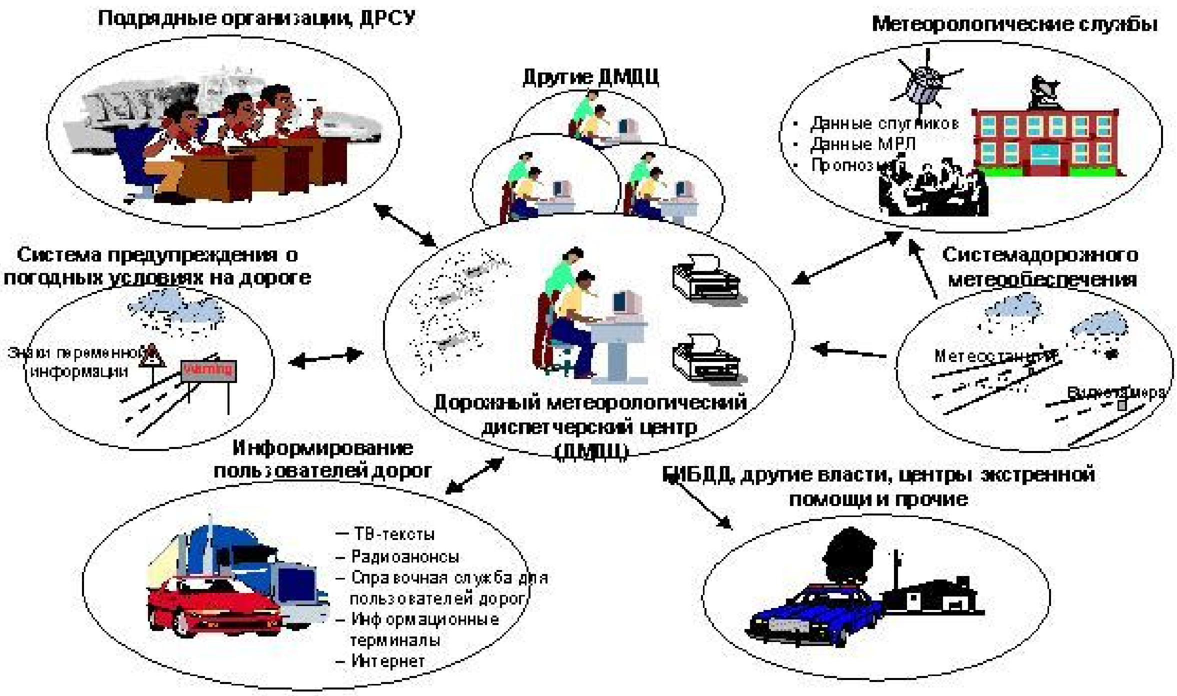


Figure 6-1 Schematic presentation of the main functionality in RWDC Co-operation.

6.1 Present organisation of the Dispatch Centre in Arkhavtodor

At the moment each DRSU carries out the monitoring of road conditions independently. There is some co-ordinating monitoring activity in Arkhavtodor Dispatch Centre, but it does not have tools to operate efficiently. The system is quite heavy with overlapping duty schemes.

The Dispatch Centre in Arkhavtodor works 24 hours a day. The personnel consist of the head of the centre and five dispatchers. A dispatcher's work shift is from 6 a.m. till 6 a.m. next morning. Additionally, each DRSU has its own dispatcher system.

The operational work in each DRSU centre is organised in two shifts: day shift (from 6 a.m. till 7 p.m.) and night shift (from 7 p.m. till 6 a.m.). Operators on duty have drivers' qualifications. During a shift they sustain readiness to start appropriate maintenance works, and if necessary, a shift might be prolonged. The dispatchers in DRSUs work from 6.00 a.m. till 10.00 p.m. Their duties are to provide operators with trip tickets, execute medical control and perform operative communication among working parties. At night-time a road master acts also as a dispatcher.

Distinctive for the present situation is overlapping duty schemes in Arkhavtodor and the DRSUs. The work shifts, especially in the case of the dispatchers of Arkhavtodor, are very long.

To develop an effectively functioning RWDC system following actions will be required:

- Identifying the goals, status and authority of the centres
- Determining the forms of co-operation with the weather service
- Developing co-operation models for the dispatch centres of DRSUs and the main dispatch centre of Arkhavtodor
- Developing the practices for road user information.

Each step calls for a need for intensive training.

6.2 Recommended Development of the Arkhavtodor Dispatch Centre towards a Road Weather Dispatch Centre

The main task of a Road Weather Dispatch Centre (RWDC) is to analyse available information about weather and road conditions, and to prepare recommendations for contractors concerning execution of maintenance works.

The two important factors for effective functioning of a RWDC are:

- **Information available;**
- **Organisation of work.**

Effectively functioning RWDC is the focal point for all information concerning the road conditions. RWDC should receive information about the following issues:

- Start of winter maintenance activities: when, on which roads, which kind of works (ploughing, salting, etc.), expected duration if known;
- End of winter maintenance activities;
- Detected hazardous situations on the road network;
- Large traffic accidents (disturbance to traffic), broken roads or bridges, unexpected slipperiness, etc.;
- Observed exceptional weather conditions in the area;
- Information about small construction projects on road network during winter before they start.

The dispatcher in RWDC, on the other hand, will have to contact only one, regularly changing person on duty, in each DRSU. This will decrease dispatcher's workload by decreasing the number of contacts to maintenance departments.

It is the responsibility of the dispatcher in RWDC to inform the maintenance personnel about the following:

- Coming rain fronts: when and where the rain will start first, form of rain (snow, slush), expected duration;
- Coming and detected black ice areas on road network;
- Start of the winter maintenance works in the Maintenance Departments (DRSU) in the neighbourhood: when, on which roads, which kind of works, expected duration if known;
- Start of the winter maintenance works in the neighbouring Regions (if this information is available): when, on which roads, which kind of works, expected duration if known;
- Detected hazardous situations on the road network or in the neighbourhood:
- Large traffic accidents (disturbance to traffic), broken roads or bridges, etc.;
- Other facts, which could have influence upon the winter maintenance works in the district in question.

6.2.1 Information required in a RWDC

For effective operation, the RWDC needs information about the present and forecasted meteorological conditions, and about the winter maintenance works being performed on the roads.

Information about the meteorological conditions comes in to the RWDC from two sources: the regional centre of the Northern Hydrometeorology and Environmental Monitoring Service (NHEMS-R or Weather Service) and Arkhavtodor's own RWIS.

The Weather Service can provide weather forecasts, satellite images, and possibly soon also weather radar data. Tailoring of standard products of Weather Service to respond to the specific needs of road winter maintenance will be needed to get the best benefit of them. This issue is further dealt with in the Chapter 6.3.

At the first stage, the number of Road Weather Outstations in Arkhangelsk Region will be limited to only four or five. Even this limited number of RWOs will provide valuable information about the road conditions not available from other sources. This information will come in to the Dispatch Centre through the RWIS.

Dispatch Centre should also be informed about all the maintenance works carried out on the roads. The drivers of maintenance vehicles, as well as the local road masters, should inform the Dispatch Centre about the works, and about all the deviations of the conditions on the roads from the forecasted ones.

The availability of information could be considered near to ideal if following information were available in the RWDC:

- Data from RWOs updated each 10 - 60 minutes;
- Weather radar images presenting precipitation fronts and updated each 10 - 60 minutes;
- Weather satellite images giving the overall picture about weather phenomena on large territories and updated preferably each 30 or 60 minutes;

- Detailed short term weather forecasts for 9 - 12 hours updated each 3 or 6 hours giving the forecast of air, road surface and dew point temperature, intensity and form of precipitation for each DRSU (DEU) (4 - 8 forecasts a day);
- 24-hour weather forecasts for each DRSU (DEU) twice a day (beginning of day and night shifts);
- Medium term weather forecast for 3 - 5 days for Arkhangelsk region (once a day);
- Storm and other warnings about dangerous weather conditions;
- Data concerning road weather conditions on the road sections being out of reach of installed outstations. This data is provided by road patrols.

6.2.2 Organisation of work in the RWDC

Timing is the key factor as far as winter maintenance operations are concerned. The RWDC monitors the road conditions 24 hours a day facilitating quick responses to the changing weather.

The RWDC is situated in Arkhavtodor and functions 24 hours a day. The RWDC staff consists of a head of the centre and necessary number of dispatchers to fill all the shifts. It would also be recommended to have one or two additional persons trained to this work to cover for the permanent staff in case of necessity. The work shifts of dispatchers should not exceed 12 hours to ensure full working capacity on this demanding post.

The dispatcher on duty in the RWDC analyses all the incoming information about weather and road conditions and on-going and planned maintenance activities. Based on this information he/she prepares recommendations about the maintenance activities required within 24 hours.

The dispatcher on duty will have the responsibility to follow up the development of road conditions. He/she alerts the DRSUs on unexpected changes and dangerous situations. Responsibility of making decisions about maintenance works lies on the DRSUs.

The information on weather and road conditions in Arkhangelsk region, including RWO observations, satellite and radar data as well as weather prognoses should also be accessible to the road masters in the DRSU bases wherever technically possible. If it is not possible to organise permanent data connection, the DRSU dispatcher will be responsible for organising the delivery of information to the road master on duty.

6.2.3 Personnel required in the RWDC

Capable staff is a crucial issue for the functioning of RWDC. It is very important that the personnel working at the dispatch centres are professionally skilled. The persons involved should have experience in the area of road weather monitoring. In the long run, it is recommended that dispatchers have a considerable authority to give strong recommendations or in some instances even orders to the field. The reason for this is that the most up-to-date knowledge is in the centres.

Personnel of the RWDC should be comprised of following persons:

Head of the RWDC	Responsible for the organisation of work in RWDC, development of the functions, also participating in the shifts, when needed.
RWDC dispatcher	Working on duty in the RWDC. He/she should have profound understanding about road winter maintenance, and be trained on road meteorology issues. He/she uses the RWIS, monitors the weather and road conditions, and interprets the available information. He/she is in contact with the weather service, when necessary. When the situation requires, he/she contacts and alerts the road maintenance units (DRSUs). RWDC operates 24 hours per day, and the dispatchers can work either 8 or 12 hours' shifts. 6 - 8 persons are needed for this position. In the beginning it is recommendable to have two persons working together to pass the knowledge more effectively.
System specialist	Maintaining the hardware and software at the RWDC. Except in the installation phase, this position does not require full-time employment of an expert, but can after some additional training be performed by a specialist from the Data Processing Centre of Arkhavtodor. To ensure operation of the RWIS at night times, during weekends and holidays, there should be some on-call duty scheme for this post.
Equipment engineer	Maintaining the operation of the RWOs, including communication issues. This is a work of an electrical expert, who can install, service and repair the outdoor equipment. This position does not require full-time employment of an expert but can after some additional training be performed by a specialist of Arkhavtodor responsible for operation of traffic weighing and counting systems.

The task of the Dispatcher includes new activities and responsibilities, which have not existed in the organisation before. According to international experience, staff from other groups such as technical personnel, office workers or maintenance machine operators can be trained for this job. Naturally, they have to have rather good basic education, willingness to learn new and feel “computer minded”. Experience from winter road maintenance would be a good asset to understand the circumstances on the road.

Road masters (maintenance supervisors) in the DRSUs will also need training to be able to adjust their working habits to the opportunities provided by modern RWIS technology.

6.3 Co-operation with Meteorological Service

Weather forecasting is a very demanding task, which requires many kinds of tools and means in addition to RWIS system. The most cost-effective way to solve this problem is to have close co-operation between the road authority and the local (regional) weather service. The weather service has the expertise in meteorology as well as all its own observation networks and has access to world-wide observation data as well as numerical weather forecasts, satellite images, and hopefully in the near future weather radar data. This data is often difficult to understand for non-professionals and has to be processed to a more applicable form of concrete weather forecasts.

In the case of Akhangelsk, the regional weather service is the regional centre of the Northern Hydrometeorological and Environmental Monitoring Service (NHEMS-R), representing Rosgidromet, the central meteorological authority of Russia.

Successful production of specialised weather forecasts to the needs of road winter maintenance requires specific observation data only available from the RWIS. Therefore, RWIS should include a workstation located in the weather service and providing access to the road weather data meteorologists.

The task of weather service is to provide detailed weather forecasts to the RWDC as described in Chapter 6.2.1. The dispatcher in RWDC processes these weather forecasts into clear recommendations to the road maintenance units.

Except weather forecasts, the weather service should provide the RWIS with additional information like satellite and weather radar images, whenever technically possible. All this information should be available, not only to the RWDC dispatcher, but to all DRSUs.

The contact with the weather service should not be only one way. In cases when there is something unclear in the forecasts, or there is some important information to communicate, the dispatcher should have the possibility to contact directly the meteorologist on duty at the weather service.

In this scheme, the road authority is a specific client for the weather service. It means that the road authority should pay for the tailored services it needs. On the other hand, the weather service shall dedicate special attention to a paying customer. It is recommendable to nominate a specific liaison officer, who takes responsibility on developing this service. Getting to know the problems and needs of the customer, will be the first step towards successful co-operation.

7 Training Needs

Implementation of RWIS technology and establishment of RWDC in Arkhangelsk region will require training of specialists responsible for the operation and maintenance of the system as well as the users of the information provided by the RWIS. Two separate groups can be distinguished:

- Technical experts (specialists on information technology, equipment engineers) to be trained in the RWIS maintenance;
- RWDC dispatchers, system users / road maintenance experts (road masters and dispatchers from DRSUs), meteorologists from the regional weather service, etc.

The first three-day training seminar for both groups will be organised within this Tacis project. This seminar will give basic understanding of the mission, functioning possibilities and use of the RWIS. The company supplying the equipment will provide specified technical training.

7.1 Technical Staff

7.1.1 Equipment Experts

The group includes the following experts:

- Equipment engineer responsible for the functioning of the network of RWOs road weather outstations, including communication issues, 1 person;
- Engineers/electricians involved in the installation and maintenance of outstations, 2-3 persons.

7.1.2 System (software) experts

The group includes the following experts:

- System specialist (system manager) responsible for running hardware and software in Arkhavtodor and DRSUs, probably a specialist from the Arkhavtodor data processing department, 1-2 persons.
- System specialist (system manager) responsible for running hardware and software in the weather service, 1 person.

The exact contents of the technical staff training will depend on the type of RWIS to be installed. This training should give the equipment and system experts the required knowledge to run the RWIS satisfactorily. This training will be organised by the supplier of RWIS equipment.

The main contents of the training will be as follows:

- Structure of road outstation equipment;
- Road outstation operation;
- System configuration operation and maintenance;
- Technical specifications and installation of outstations;
- Installation of central computer and workstations;
- Starting and setting-up;
- Data presentation.

Special attention is to be paid on the understanding of the task of the RWI System and resulting from it requirements to the quality of data produced.

7.2 System Users

This group consists of all the users of the information provided by the RWIS. The aim of this training is to provide the basic knowledge about road meteorology, the information provided by RWIS, and the utilisation of RWIS for more effective winter maintenance.

The following specialists need to be trained:

- All dispatchers from the Arkhavtodor RWDC;
- Road masters and dispatchers from DRSUs;
- Forecasters from the regional weather service;
- Decision-makers and other related persons from Arkhavtodor to get understanding about the possibilities of the RWIS.

The training for system users will contain:

- Basics of meteorology;
- Special problems of road meteorology;
- RWIS technology;
- Utilisation of RWIS data;
- RWIS data in winter maintenance decision-making;
- RWDC operation;
- Co-operation between RWDC, maintenance units and weather service.

8 Economic Analysis

8.1 Introduction

An economic evaluation exercise has been carried out for a full RWI System for the road network in Arkhangelsk Region.

The full operational system specification is assumed to include the following:

- Up to 18 - 20 RWOs at varying locations within the Arkhangelsk Region;
- Up to 4 RWCs linked to the File Server, separate from the RWI System;
- 5 workstations connected to the RWI System Server (Central Computer) within the Road Weather Dispatch Centre (RWDC).

Unless otherwise stated, all costs are specified in Euros as per 2002 price level. As is usual in this type of analysis, changes in costs due to inflation have been excluded, as have all taxes and other transfer payments.

8.2 RWIS Implementation and Operating Costs

8.2.1 Capital Costs

Table 8-1 below defines the costs of capital equipment and commissioning for the RWIS based on unit rates established for earlier procurements in Russia.

It is estimated that implementation of the full region scheme based on the specification outlined above will incur a total cost of around 320,000 EUR. Around 287,000 EUR of this is on capital equipment with the remainder being allocated to transport, installation and commissioning. A procurement allowance of 5% of total costs has been assumed.

Table 8-1 Capital and Implementation Costs for RWIS in Arkhangelsk Region

Component	Unit	Unit Cost EUR	No. of Units		Total Costs	
			Pilot	Further Phases	Pilot	Further Phases
Road Weather Outstation	Pcs	16 000	3	15	48 000	240 000
Central Computer and Software	Set	17 000	1		17 000	0
Workstations	Pcs	2 500	2	3	5 000	7 500
Camera	Pcs	6 000		4	0	24 000
Calibration Equipment	Set	1 400	1		1 400	0
Communication Equipment for Central Computer	Set	1 000	5	15	5 000	15 000
Installation and System Commissioning	Lot	4 000	1	3	4 000	12 000
Delivery	Lot	2 100	1	3	2 100	6 300
Procurement (5%)		-	1	3	3 820	14 325
TOTAL					**86 320**	**319 125**

Implementation of an RWIS scheme for the Region based on the specification outlined above will incur a total capital and installation cost of 320,000 EUR divided to four lots, to the Pilot System lot and to three additional procurement lots.

8.2.2 RWIS Operating Costs

Following implementation, the RWIS will incur ongoing operating costs on an annual basis. These may be defined as follows:

- Additional staffing costs;
- Training costs;
- System maintenance costs;
- Power and communications costs.

These are dealt with in turn below.

Additional Staffing Costs

It is anticipated that the RWIS will employ up to 10 people during the winter period and over the course of the year. These staff will be responsible for operating and maintaining the RWO/RWC equipment and managing the work of the RWDC, including broader research and data management.

The costs are defined in Table 8-2 as follows:

- Monthly salary costs based on the information of this Tacis Projects;
- Overall annual cost calculations assume that staff are employed on RWIS duties for winter months of the year and monthly salary is uplifted by 40% to allow for sickness, holidays etc.;
- Duty Officials assumed to have required meteorological knowledge to receive and analyse RWO, radar and satellite data into RWDC.

Table 8-2 RWIS Additional Staffing Costs

Staff Category	Number	Monthly Salary (RUR)	Monthly Cost (RUR)	Man-Months Per Annum	Annual Cost (EUR)
System Specialist	2	2 400	3 360	12	1 493
Maintenance Technician	2	2 400	3 360	10	1 244
Duty Officials	6	1 900	2 660	30	2 956
TOTAL	**-**	**-**	**-**	**52**	**5 693**

Training Costs

There will be a requirement to provide training to the employees involved in the management and maintenance of the RWIS. It is envisaged that training will be provided principally in Russia according to the rates and costs indicated in Table 8-3 below.

The first training seminar will be held within this Tacis Project and next training seminars to be held annually.

Use of international consultants or overseas study visits (e.g. to Finland or to Sweden) will increase overall training costs considerably.

Table 8-3 Annual RWIS Training Costs

Staff Category	Duration (Days)	Unit Costs ($/Day)	Costs ($USD)
System Specialist	5	500	2 500
Maintenance Technician	3	500	1 500
Duty Officials	5	500	2 500
TOTAL			**6 500**

System Maintenance Costs

The requirements for essential maintenance and spare parts of the RWOs, RWCs and associated communications and data processing systems are unknown at this stage and could vary substantially. For the purposes of this evaluation, however, these costs are assumed not to exceed 5 % of the total costs of capital investments each year. This equates to around 19 000 EUR per annum, when the whole RWI System has been implemented in Arkhangelsk Region.

However, in western countries like in Sweden and Finland experience has proven that the system maintenance costs includes lot of work and are therefore much more substantial, even more than 10% of the capital costs per annum.

Communications Costs

It is assumed that data would be gathered from the RWOs for the six winter months, equivalent to 180 days per year. For 80 days per winter when the temperature hovers between +5 °C and -5 °C, data would be gathered twice an hour and for 100 days per winter where the temperature is above or below these, once per hour, with an average connection and data transmission time of 1 minute.

Weather Camera Images would be transmitted twice per hour for 180 days (winter period) and once per hour for 185 days of the year.

It is assumed that the average cost per minute for each transmission would be 1.00 RUR, allowing for the fact that some calls would be local and therefore incur no cost.

These costs are detailed in Table 8-4 and equate to around 12,500 EUR per annum, when the whole RWI System has been implemented. However, this will depend considerably on the contracts Avtodor can make with the telecommunication operators.

Table 8-4 RWIS Communications Costs

Device	Connections Per Day	Operating Days Per Annum	Connections Per Annum	No. of Items	Duration of 1 Connection [min]	Average Unit Price (RUR/min)	Total Communications Costs (EUR)
Road Weather Outstation							
+5 - -5°C	48	80	3840	20	1	1	2 965
> +5, < -5°C	24	100	2400	20	1	1	1 853
Workstation							
+5 - -5°C	48	80	3840	5	3	1	2 224
> +5, < -5°C	24	100	2400	5	3	1	1 390
Camera							
Winter	48	180	8640	4	2	1	2 669
Summer	24	185	4440	4	2	1	1 371
TOTAL							**12 472**

Total Operating Costs

On the basis of the above analysis, total annual operating costs of the complete RWI System, excluding staff training, can be estimated as around 37,000 EUR as shown in Table 8-5.

Table 8-5 Total RWIS Operating Costs

Cost Item	Annual Cost (EUR)
Additional Staff Costs	**5 700**
Equipment Maintenance Costs	**18 100**
Communications Costs	**12 500**
TOTAL	**36 300**

8.3 Specification of RWIS Benefits

The principal purpose of the proposed RWIS for Arkhangelsk Region is to improve the management of road and weather conditions so that winter maintenance can be carried out systematically and at the appropriate time. This results in a number of specific quantifiable benefits as follows:

- Accident savings as a result of improved winter maintenance and better driver information;
- Reduced journeys times and vehicle operating costs;
- Potential direct financial savings to the DRSUs in road maintenance costs due to more targeted of work effort.

8.3.1 Savings in Accident Costs

Basis of accident costs

The chief consequence for road users of more effective winter road maintenance will be a reduction in the risk of accidents related to slippery or icy carriageway conditions.

Recent research from the European Transport Safety Council (ETSC) estimates that road weather telematics may have the potential to reduce injuries by up to 10-15% for those vehicles and traffic flows “within scope” for the most safety beneficial systems.

Data of previous Tacis Projects has estimated the cost of a Russian fatality at around 280,000 EUR, based on an evaluation of values elsewhere in Europe and North America. The cost of an average casualty, taking account of the empirical ratios between fatal, serious and slight categories, is estimated at around 10,400 EUR.

Estimations for calculations

Estimating the accident savings for the Region resulting from RWIS is highly uncertain due to the lack of empirical data in the Russian context. However, it is assumed that these will derive from more focused road maintenance and more careful driving behaviour during winter road conditions as a result of improved information from the road weather information system. Comprehensive enough traffic data is not available at Region level for making reliable traffic growth forecasts for future. However, as the vehicle ownership (vehicles per 1000 inhabitants) has been growing at a rate of around 6% per annum generally in Russia, it can be said that vehicle use increases accordingly. This is therefore taken as a proxy for ADT growth within the Arkhangelsk Region.

For the purposes of this exercise, it is assumed that implementation of the RWIS will save, firstly one year after the implementation of the Pilot System, one serious accident a year (€ 38,500). Further, two serious accident more one year after the Phase 1 (€ 77,000) and finally one serious accident more one year after the implementation of the Phase 2 (€ 38,500). Thus, using the value for Russian traffic accident costs, this reduction is costed at around 154,000 EUR per annum one year after the implementation of the whole RWI System, 10 years after the implementation of the Pilot System. This includes savings of 4 serious accidents per annum, which can be assumed very realistic and even modest savings.

The estimations above seem to be quite complicated, but experience has proven that the real benefits of RWIS have to be waited relatively long time.

Table 8-6 Estimated Russian Accident Costs

,Accident Category	Value Per Casualty (USD/1999)	Value Per Casualty (EUR/2002)
Fatality	220 000	280 000
Serious	30 000	38 500
Slight	1 000	1 300
Damage-Only	250	320
All Personal Injury Accidents	8 100	10 400
All Accidents (Inc. Damage Only)	770	1 000

8.3.2 Savings in Journey Times and Vehicle Costs

More effective salting and/or snow ploughing with the assistance of RWIS can be expected to improve the overall traffic flow and improve driving time. However, it is believed this effect is likely to be marginal and in any case is not consistent with overall objectives of encouraging a reduction in accidents through slower and more responsible driving behaviour.

More effective snow ploughing with the assistance of RWIS can be expected to reduce the overall thickness of snow on the carriageway and overall vehicle operating costs in terms of fuel consumption and wear and tear.

These items are relatively marginal, only few percents of total driving costs and not estimated as a quantified benefit.

8.3.3 Savings in Road Maintenance

Annual routine road maintenance costs incurred by Arkhavtodor are in the region of about 15,0 million EUR, for coverage of the whole Region. Of this, around 60-70% is due to winter maintenance. These numbers are based on the earlier Report of this Tacis Project (DEU Development Plan for Primorsky DRSU in Arkhangelsk Region).

Estimating that around 10,0 million EUR per annum is spent on winter road maintenance it is difficult to argue that RWIS in itself will result in substantial savings on this, at least without parallel investment in institutional restructuring and new road treatment equipment.

It is assumed that RWIS will allow more timely road treatment in response to the sudden onset of winter road conditions, saving on the need for some staff patrolling. A broad estimate of this potential saving is one man-year for the whole Region, assumed to be equivalent to around 2,000 EUR per annum, about 2 % of total winter maintenance costs, rising by 2 % per annum according to the better RWI System and work methods utilisation.

The issue of winter maintenance savings is considered further below in relation to the sensitivity testing.

8.3.4 Other Benefits

In addition to the specific benefits identified above, RWIS could potentially have additional uses, which are not explicitly considered within the quantitative analysis. These include the following:

- Extension of weather monitoring to wet and cloudy conditions year round linked to driver information;
- Use of the road weather telematics for driver warning, route guidance and other forms of driver information, including advance warnings of accidents and road works up ahead;
- Enhanced meteorological information for improved weather forecasting and public broadcasts, and pooling of data between the meteorological service and Arkhavtodor;
- The establishment, by Arkhavtodor, of a road and weather condition and traffic control department, which can serve as the basis of future traffic control and telematics applications, firstly, for road M8, Moscow - Arkhangelsk, and accordingly for other important road sections in the Region.

Some of these functions require additional equipment and/or software and are therefore likely to incur extra procurement and operating costs.

8.4 Economic Analysis – Base Case

A “Base Case” economic evaluation for RWIS has been undertaken based on the costs and range of benefits as set out above. An assessment period of 10 years and a 12% discount rate has been used, in line with other calculations in this Tacis Project.

Table 8-7 presents the results of the economic evaluation for the Base Case as set out above in terms of Net Present Value (NPV) and Internal Rate of Return (IRR). This shows that given modest savings in accidents, the proposed RWIS project is economically viable for the Region since:

- The NPV is fairly positive at + 109,800 EUR over the ten year assessment period;
- The Internal Rate of Return at + 25,2 % is also fairly in excess of the selected discount rate of 12 %;
- For the RWIS implementation period, as specified above, to break-even economically, an accident saving of approximately 73,800 EUR a year with no index increment is required, less than preventing only two serious accidents per annum.

Table 8-7 RWIS Economic Evaluation: Base Case

Year	RWIS Costs (€ '000)				RWIS Benefits (€ '000)			Cost–Benefit (€ '000)	
	Capital & Implementation Costs		Annual Operating Costs	Total Costs	Accident Savings	Winter Maintenance Savings	Total Benefits	Undiscounted Benefits-Costs	Discounted Benefits-Costs
0	**Pilot**	92,8	11,6	104,4	0,0	0,0	0,0	-104,4	-104,4
1		6,5	11,6	18,1	38,5	2,0	40,5	22,4	20,0
2		6,5	11,6	18,1	38,5	2,0	40,5	22,4	17,9
3	**Phase1**	112,9	20,2	133,0	38,5	2,1	40,6	-92,4	-65,8
4		6,5	20,2	26,7	115,5	2,1	117,6	91,0	57,8
5		6,5	20,2	26,7	115,5	2,2	117,7	91,0	51,6
6	**Phase2**	112,9	27,7	140,6	115,5	2,2	117,7	-22,9	-11,6
7		6,5	27,7	34,2	154,0	2,3	156,3	122,0	55,2
8		6,5	27,7	34,2	154,0	2,3	156,3	122,0	49,3
9	**Phase3**	112,9	35,3	148,2	154,0	2,3	156,3	8,1	2,9
10		6,5	35,3	41,8	154,0	2,4	156,4	114,5	36,9
TOTAL		**477,0**	**249,1**	**726**	**1078**	**21,9**	**1099,9**	**373,7**	**109,8**

Notes:
All figures in 2002 € '000s at a discount rate of 12%.
Capital and Implementation Costs include annual training costs.
Annual Operating Costs include system maintenance, additional staff and communication costs.

Cost-Benefit Analysis Results	
Net Present Value (NPV)	**+109,800 EUR**
Internal Rate of Return (IRR)	**+25,2%**

8.5 Sensitivity Testing

Given the uncertainties in estimating costs and benefits accurately, we have undertaken sensitivity testing of the evaluation results based on variations to some of the key input parameters. Taking the Base Case as the starting point, the following variations have been applied:

- RWIS capital and operating costs increased by 10%;
- The value of traffic accident cost savings in Russia increased by 20%;
- Potential accident savings reduced to an assumption that only two serious accidents are saved per annum during the whole RWIS implementation phase;
- Potential accident savings increased to three serious accidents per annum from the first beginning of the RWIS implementation phase;
- A lower discount rate of 10% over the life of the project.

The results are shown in Table 8-8. This shows that the economic viability of RWIS for the Region is highly sensitive to assumptions made about the extent of forecasted accident savings, the value of accident costs and the discount rate used. Nevertheless, it appears likely that the proposals remain viable under a wide range of circumstances.

Analysis conducted in Arkhangelsk Region shows that the economic case for RWIS is also substantially enhanced, if the system can be used to reduce DRSU costs in providing winter road maintenance. Unlike accident savings, these benefits will also be directly realised in financial and accounting terms. It is therefore important that Arkavtodor considers the potential linkages between the provision of timely road weather information and operational procedures employed by the DRSUs.

Table 8-8 RWIS Economic Evaluation: Sensitivity Tests

Item	**Base Case**	Costs Increased by 10%	Value of Traffic Accident Cost Savings Increased by 20%	Accident Savings Reduced to 2 Serious Accidents per Annum	Accident Savings Increased to 3 Serious Accidents per Annum	Discount Rate Reduced to 10%
NPV (€'000)	**+109,8**	+66,9	+215,2	+18,0	+235,5	+137,9
IRR (%)	**+25,2**	+19,4	+35,55	+19,5	+74,26	+25,2

The analysis conducted for this Tacis Project demonstrates that the economic case of a full RWIS scheme for the Region is fairly justified on the basis of even relatively modest accident savings. It is also possible to justify the investment on the basis of additional non-accident benefits as mentioned in this Report.