
# IRWIN

## Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios

# Final Work Plan and State of Art

Inception Report Nr 1

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Foreca Consulting Ltd

Klimator AB

Department of Earth Sciences, University of Gothenburg

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**Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios**

# Report Nr 1 – Final Work Plan and State of Art

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# Executive summary

Improved tools for road owners are urgently needed to help them cope with rapidly progressing climate change. A very important tool for planning their activities is to have access to good scenarios regarding spatial and temporal resolution of what to be expected of climate variations in the future, especially regarding severe weather events. Traditionally climate change scenarios are calculated based on ordinary meteorological data, which have large limitations in respect to resolution. The idea of IRWIN is to combine the best traditionally made scenarios with the much more accurate spatial data from field stations in the Road Weather Information systems (RWIS) installed in most northern hemisphere countries. The goal is to develop an improved winter road index capable of assessing the implications of climate changes in various weather parameters and also assessing related costs and benefits.

IRWIN started on 1st November 2008, and this first Report summarises the work done in the first month. It presents the IRWIN Work Plan in more detail, as refined and agreed in the project kick-off meeting in Göteborg on 11th November 2008. In addition, state-of-art of Global Climate Models (GCM), winter indexes and recent studies on climate impact on road networks are presented.

The project will have two phases. Objective of the first is to develop a database of possible future road condition scenarios through combination of historic RWIS-data with widely accepted climate change scenarios. As the RWIS-data traditionally are used for decision making regarding winter maintenance needs, the combination will lead to a straightforward connection with mapping of the present day situation as well as future needs in relation to scenario calculations. RWIS-data time series from Sweden and Finland are collected and processed for the database.

The second part will develop and test a winter index technique to evaluate such things as the spatial variations of winter maintenance needs as well as the cost/benefit of various winter maintenance strategies. With the help of the database and index calculations, other types of weather related events, such as strong winds, heavy precipitation, flooding, freezing and thawing, can be mapped and assessed. With well-defined interfaces, the new system can be easily adapted to other countries outside the project test areas in Sweden and Finland. Possibilities of using Austrian road weather data will be investigated.

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# 1 Introduction

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research project was initiated. The funding National Road Administrations (NRA) in this joint research project are Federal Ministry of Transport, Innovation and Technology (BMVIT), Austria, Federal Ministry of Transport, Building and Urban Affairs (BMVBS), Germany, Ministry of Transport, Danish Road Directorate (DRD), Denmark, Centre for Studies and Research in Public Works (CEDEX), Spain, Finnish Road Administration (Finnra), Finland, National Roads Authority (NRA), Ireland, Directorate of Public Works and Water Management (RWS), the Netherlands, Norwegian Public Roads Administration (NPRA), Norway, General Directorate of National Roads and Motorways (GDDKiA), Poland, Swedish Road Administration (SRA), Sweden, and Department for Transport, Highways Agency (HA), the United Kingdom.

Improved tools for road owners are urgently needed to help them cope with rapidly progressing climate change. A very important tool for planning their activities is to have access to good scenarios regarding spatial and temporal resolution of what to be expected of climate variations in the future, especially regarding severe weather events. Traditionally climate change scenarios are calculated based on ordinary meteorological data, which have large limitations in respect to resolution. The idea of IRWIN is to combine the best traditionally made scenarios with the much more accurate spatial data from field stations in the Road Weather Information systems installed in most northern hemisphere countries. The goal is to develop an improved winter road index capable of assessing the implications of climate changes in various weather parameters and also assessing related costs and benefits.

IRWIN started on 1st November 2008, and this first Report summarises the work done during the first active project month. It presents the IRWIN Work Plan in more detail, as refined and agreed in the project kick-off meeting in Göteborg on 11th November 2008. In addition, state-of-the-art of Global Climate Models (GCM), winter indexes and recent studies on climate impact on road networks are presented.

Winter indexes are useful tools when comparing winters with each other and average conditions in varying climatic regions of a country or a continent. A fully developed winter index can be used for different applications like compensation for winter maintenance costs in particular contract areas. They can also be utilised as planning devices, since historical and scenario data can be used to provide general needs in an area of varying size. The large benefit with winter indexes are that those are closely linked to the costs and needs associated with maintenance activities and thus make it possible to map the present situation as well as calculate the changes expected due to climate changes. Another great advantage with winter index techniques is that the results can be used for other type of activities/situations that are related to climate. An example of such use is the frequency of situations with heavy precipitation that can be used for evaluating road construction risks, or strong wind situations that can be used for construction dimensioning.

However, presently winter indexes are not very detailed nor take into account local climatic variations. Instead using synoptic national meteorological observing networks as is presently the case, observations from road weather information systems (RWIS) should be used as input to winter index calculations due to a number of reasons. First of all the measurements are taken close to the road, which the calculations should also represent as well as possible.

Secondly, the RWIS-stations record data with a short sampling interval revealing even short and local weather events. Finally, the RWIS-station network is much more dense compared to ordinary meteorological networks. These facts give the RWIS data large advantages for road related studies and assessments.

The key idea of IRWIN is to develop an improved local road winter index, which is sufficiently detailed and comprehensive that road authorities and owners can use it to assess the implications of future scenarios and climate change implications, and perform reliable cost/benefit analyses. The index will be developed using Swedish and Finnish RWIS data, but will have well-defined interfaces so the system can later be implemented in any other country with a RWIS network as well.

Development has several phases. First it is necessary to develop a database for possible future road condition scenarios through combination of historic RWIS-data with widely accepted climate change scenarios. As the RWIS-data traditionally are used for decision making in winter maintenance, this combination will lead to a straightforward connection with mapping of the present day situation as well as the future needs in relation to scenario calculations. Through the winter index technique it will be possible to evaluate such things as the spatial variations of winter maintenance needs, as well as the costs/benefits of various strategies. With the help of the database, other types of weather related events, such as strong winds and heavy precipitation, impacts of freezing and thawing, and depth of ground frost, can be easily mapped and assessed. The IRWIN winter index will have a large application potential among road owners and road administrators, in particular in their strategic planning work, but also in more pragmatic day-to-day and annual planning of management of maintenance operations.

# 2 Background

There is now general agreement within the scientific community that further increases in atmospheric greenhouse gas concentrations are inevitable and will cause significant global warming in the coming decades, with inherent risks for local weather and climate. FinnRA initiated recently a study on the implications of climate change on road maintenance (Saarelainen and Makkonen, 2007). Conclusions were that, in Northern latitudes, the warmer climate of the future will also bring much more rainfall, heavy showers, floods and changes in regional coverage of freezing and thawing. This will cause many challenges to e.g. friction control, snow removal, erosion control and flood protection. To be able to assess these challenges, first we must have the best possible scenarios and know the risk levels of the changing weather parameters.

Global circulation models (GCM) are the best existing tools for studying climate change. Unfortunately the spatial resolution of these models is too rough to be used for climate changes on regional and local scales. Different downscaling methods have therefore been developed to interpret the results from the global models so as to generate a more detailed view of how climate change will affect a specific region. Since extreme weather may have devastating consequences, extreme weather statistics are of much greater interest than changes in the average climate factors for community planning, decision making and risk managing.

A fundamental problem within the climate modeling is that the spatial spread of severe weather events usually is too small to be represented in the global climate models, where the calculation grid is as rough as 200-300 km. Even the regional climate models, with the much higher resolution of 30-50 km, may be unable to simulate small-scale weather systems. This makes the statistical downscaling method interesting, since it can generate climate scenarios for very small areas and even point-locations.

Statistical downscaling establishes empirical relations between large-scale and small-scale climates. In Scandinavia the large-scale climate is governed by the air pressure distribution over Europe and the North Atlantic, which determines how and when weather systems will pass our region (Chen and Hellström, 1999; Chen, 2000). Topography, distance to the sea, land-use and vegetation govern the large-scale climate and result in a mosaic of regional and local climate conditions (Johansson and Chen, 2003). For statistical downscaling, the understanding of small-scale climate variations in relation to large-scale climate is of great importance.

Research results indicate that, to a large extent, the enhanced greenhouse effect will cause the frequency of severe weather events to increase. The question is whether the climate changes will affect the frequency and proportion of unusual weather situations such as extreme precipitation, long-lasting dry periods or very strong winds. Today's community, with its high level of infrastructure development, is without doubt very vulnerable to unusual weather situations. Disasters caused by excessive precipitation, such as landslides, slumps or flooding, will harm humans as well as the environment and the community and it is of great interest to have knowledge about how roads and transportation will be affected in the future.

Calculations performed by SWECLIM (Swedish Regional Climate Modeling Program) show that the enhanced greenhouse effect will increase the yearly mean temperature of Northern Europe by about 2 – 4°C over the next 100 years. The temperature increase is therefore larger for Scandinavia than for the mean temperature for the rest of the world. The temperature will increase more in wintertime than in summer, which may have large consequences for the distribution of severe weather events. As an example, the model shows that precipitation in spring, autumn and winter will be wetter by 20-40 % compared to today, while the summers will be drier (Hellström *et al*, 2001). What is similar for all seasons is that precipitation will be more intense, which increases the risks for environmental damage to the infrastructure (SMHI, 2002).

# 3 State-of-Art

## 3.1 Global Climate Models

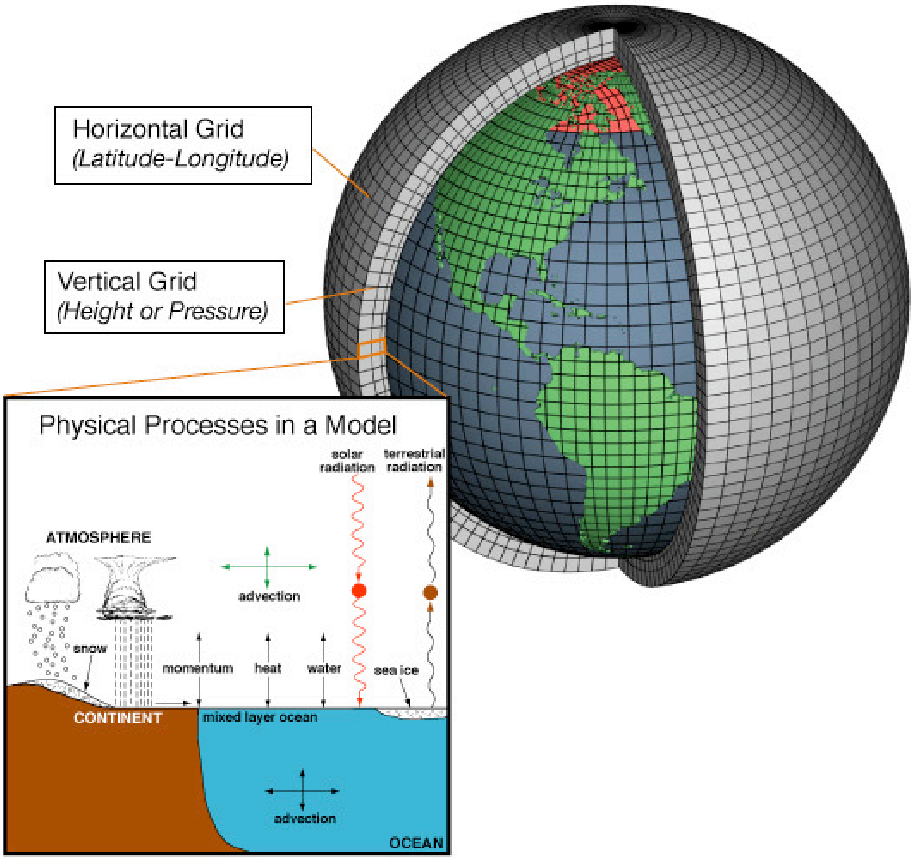


**Figure 1: Global Climate model schematic.** [1]

Global climate models (GCMs) are computer programs, which encode well-established basic laws of physics, fluid motion, and chemistry. The models represent the atmosphere-land-ocean system as a 3-dimensional grid, and they calculate how the conditions in a grid cell will affect neighboring grid cells at some short time into the future. Atmospheric processes, which are too small-scale to be represented by the interactions between cells (eg. clouds, thunderstorms) are represented statistically and calculated for each cell individually, a process referred to as *parameterization*. By repeating the calculations many times, the evolution of global change can be investigated.

It is important to understand that GCMs cannot produce *forecasts* (in the sense that we understand the term "weather forecasts") because of the chaotic nature of the climate system. GCMs cannot be used to determine what weather phenomena will occur at a given time and place in the future. However, they can be used to estimate the effect of changed

[1] *source: http://celebrating200years.noaa.gov/breakthroughs/climate_model/modeling_schematic.html*

boundary and atmospheric conditions, and in particular, changes in greenhouse gasses. We know from own experience that next winter will be colder than next summer because of changed boundary conditions (less solar radiation) *even though we cannot forecast what the weather will be on any particular day.* Similarly, GCMs tell us that increasing greenhouse gasses will cause warmer global climates, even though they do not give specific forecasts. So, GCM outputs can be used to answer questions such as – what is the average change, at a particular place, over a period of time?

Approximately 20 GCMs have been developed by research groups around the world. These are able to reproduce many observed features of recent and past climate changes, and there is considerable confidence that they provide credible estimates of future global temperature change at continental and larger scales.

All GCMs show global temperatures will increase as greenhouse-gas concentrations increase. Model inter-comparisons have shown, however, that the level of temperature increase is different among different models. Further, the projected changes in other climate parameters – in particular, average precipitation – vary significantly between the models.

The spread in the GCM's predictions is thought to arise mainly because of the different parametrisations used in different models, especially with regard to cloud physics. These differences in turn reflect the limits of our knowledge about atmospheric processes. Thus, when using climate change scenarios from GCM models, it is important to investigate at least two model outputs to sample the uncertainty in the projections.

### 3.1.1 Greenhouse gas emissions scenarios

It is impossible to know how much greenhouse gas our civilization will produce in the future. Most GCM climate change simulations use hypothetical *emissions scenarios* from the Special Report on Emissions Scenarios (SRES) report prepared by the Intergovernmental Panel on Climate Change (IPCC).

The SRES report contains a number of different scenarios, and each make different assumptions about future technological and economic developments. Future scenarios for greenhouse gas emissions, land-use change, and other driving forces are derived based on these assumptions. Most scenarios include an increase in the consumption of fossil fuels.

The emission scenarios are organized into *storyline and scenario families*, and these families are commonly referred to as “SRES scenarios”. The scenarios most commonly used in climate modeling are summarized below, and the global warming associated with each scenario is illustrated in Figure 2.

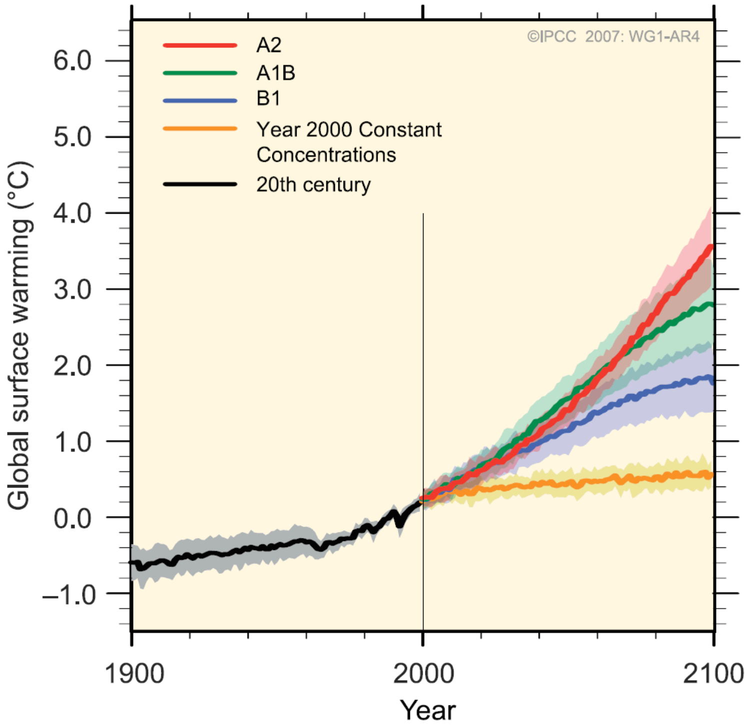


**Figure 2: Multi-GCM global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. [From IPCC 2007:WG1-AR4 Figure SPM.5]**

**SRES A2**. The A2 scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Population increases continuously, economic development is primarily regionally-oriented and per capita economic growth and technological change are more fragmented and slower than for other scenarios.

Greenhouse gas emissions and global temperatures for the A2 scenarios in 2100 are the highest of the three scenarios discussed here.

**SRES A1B**. The A1 scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. The major underlying themes are convergence among regions, capacity building and increased cultural and social interactions. The A1 scenario family is classed into sub-groups which describe alternative directions of technological change in the energy system, with the A1B scenarios representing a balance across all energy sources.

Greenhouse gas emissions and global temperatures for the A1B scenario are initially high, but as emissions decline they are overtaken by the A2 scenario projections.

**SRES B1**. The B1 scenario family describes a convergent world with a global population that peaks in mid-century and declines thereafter. There are rapid changes in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies.

Greenhouse gas emissions and global temperatures for the B1 scenario are consistently the lowest of the three scenarios discussed here.

### 3.1.2 Global climate change scenarios

GCM experiment outputs are publicly-available from PCMDI, and will be used as inputs for regional downscaling in this project – we will not run new GCM simulations. Our analysis will use the same GCM outputs which were used to support the IPCC 4th Assessment Report (AR4), so the project results will be compatible with the scientific conclusions from that report.

Figure 3 shows the average projected temperature increase, calculated using all GCMs considered in AR4, under the SRES A1B scenario. The models generally project higher warming over land than over the oceans, with the exception of the Arctic where very large temperature increases are projected.

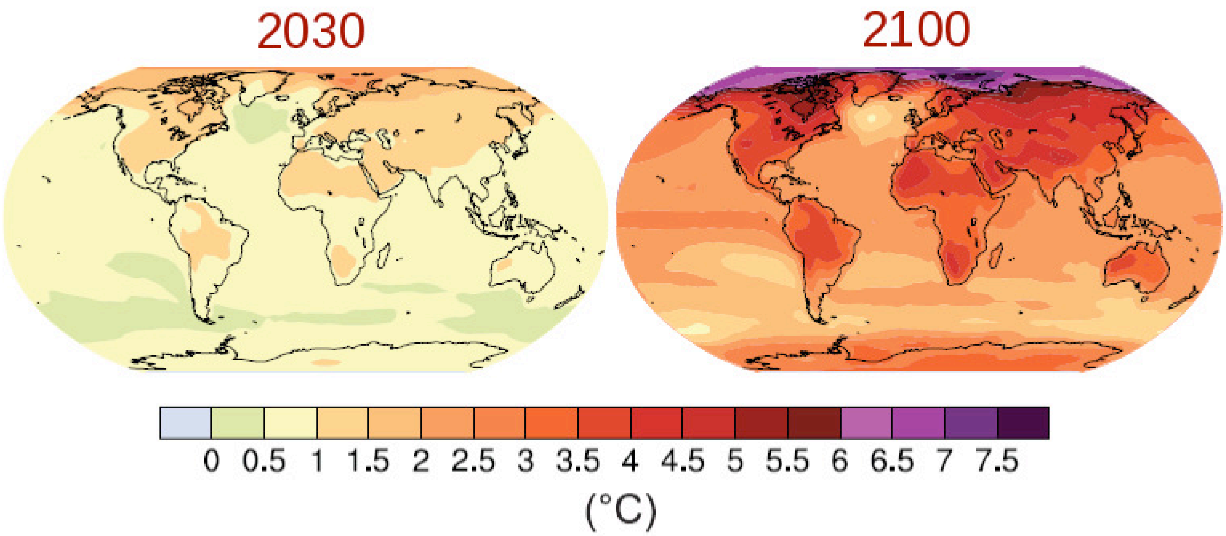


**Figure 3: Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999, showing multi-model average projections for the A1B SRES scenario averaged over the decades 2020– 2029 (left) and 2090–2099 (right). [From IPCC 2007:WG1 -AR4 Figure SPM.6]**

## *3.2 Effects of climate change on the road network*

The effects of climate change on road networks are a matter of great concern to road owners, as many decisions especially on investments in the infrastructure may have implications over decades. A change in the impacts may cause a need to change road structures. Improvements of drainage, erosion control and raising the road surface levels may be needed. Other adaptation and proactive measures are control of design criteria and improvement of current roads to assure the service level. Services for road users may need changes as well, in order to deliver appropriate warnings and other valid information through the most efficient channels.

Studies based on the most recent climate scenarios are in progress and several have already been concluded around the world, e.g. Galbraith, Price and Shackman (2005) in Scotland, Thordarson (2008) in Iceland, Youman (2007) in Australia, Natural Resources in Canada (2007) and most recently a comprehensive study in the USA by the National Science and Technology Council (2008). A feature common to all climate scenarios is that the changes will be most dramatic near the poles and during the winter, due to the positive feed back effects of the shrinking snow and ice coverage. For instance, according to Saarelainen and Makkonen (2007), some of the most probable and prominent changes in the

Finnish climate affecting the road maintenance will be:

- Mean annual temperature will rise by 3-5 °C.
- Maximum temperatures will rise by 5 °C in summer and 10 °C in winter.
- Annual rainfall amount will increase by 15 %.
- Risks for heavy rainfall showers and flash flooding will increase. The probability of very heavy showers will increase by 25%, and by 50% in certain areas.
- Though snowfall amounts will decrease in southern parts of the country, the number of traffic disturbances due to heavy snowfall will increase.
- The total amount of freezing and melting cycles will decrease in southern parts of the country but will increase further north.
- Even though there are no indications that destructive storms will increase, trees will fall more easily during wintertime storms. The reason is because the layer of thawing will be thinner in the future.
- It will be more and more difficult to maintain the present ice roads.

Details of the effects of climate change on road networks will naturally change depending on the particular features of climatology, topography, land use and other prominent local factors. However, the implications from recent climate scenarios all indicate that the changes will be remarkable and sometimes drastic, and will happen rather sooner than later.

## *3.3 Winter indexes*

Winter indexes can be used for summarizing climate characteristics that are, for example, relevant to road conditions. They are often used to describe the main characteristics of the climate in an area and give a view of the severity of the winter (e.g. Boselly III *et al.,* 1993). Such an index can be displayed on a temporal scale to show changes over time, or it can be displayed spatially. In this way, the weather can be compared between different areas, different years or different seasons (Boselly III *et al.,* 1993; Gustavsson, 1996). Earlier indices were usually used in cost/benefit calculations, to decide about the cost effectiveness of an already existing warning system (e.g. Knudsen, 1994), or to calculate maintenance costs for a specific area.

The factors that need to be taken into account for a Road related Winter Index are discussed below.

### 3.3.1 Ice

Low temperature is a condition needed for ice formation. It is common to use temperature falls from positive to negative degrees to indicate the risk of ice formation and the need for salting operations.

### 3.3.2 Precipitation

<u>Snow</u>

Different types of snow affect traffic differently (Perry and Symons, 1991). Types include: direct snowfall, with air temperatures below 0°C, melting snow, or drifting snow when the snowfall occurs with strong winds. Cold snow is more suspendable by wind and can hence cause snow drift as well as poor visibility from snow smoke, while melting snow is an important slipperiness factor. The latter occurs with heavy snowfall when air temperature is above 0°C. Studies in Canada reveal that accident risks increase by over 100% during snowfall, but the snow accidents are usually less severe (Audrey and Mills, 2003). The relative costs caused by accidents increase by 70% during precipitation. This increase is accounted higher for snowfall cases than for rain, which is attributed to the fact that drivers are more cautious in snowy weather. The snow hazard lingers for a period of time even after the snowfall has ceased.

Rain

Rain, especially intense rain, may influence road safety by decreasing visibility and by causing aquaplaning. A study of rain-related accidents in Canada revealed that during intense rainfall the accident rates were increased by 70 %, but decreased again as soon as the rainfall subsided (Andrey and Yagar, 1993). Super cooled rainwater or rains preceded by cold weather are hazardous as well since they may cause ice on the roads.

### 3.3.3 Wind

Wind can create unsafe conditions in traffic in different ways. Strong winds may force vehicles off the roads or in unwanted directions. Fallen trees or flying materials such as tree branches or litter may be troublesome to drivers. Winds may also create road blocks from drifting snow. In particularly exposed areas the wind may be troublesome; especially for high-sided vehicles and two-wheelers since the wind pressure is proportional to the squared wind speed and to the area of the vehicle (Moran and Morgan, 1991; Perry and Symons, 1991). The strongest and most gusty winds usually appear in the afternoon and increase with altitude (Moran and Morgan, 1991), which makes topography an important factor in considering wind conditions.

### 3.3.4 Calculation of winter indexes

Winter indexes are used in Road Climatology to describe the main characteristics of the climate in an area and relate to the amount of maintenance activity needed. Index calculations can show the severity of winter in a specific area by comparing different climate parameters, or compare the climate between different years or seasons (Boselly III *et al.,* 1993; Gustavsson, 1996). Most winter indices that are applied in Road Climatology are used to calculate the cost effectiveness of winter maintenance (e.g. Knudsen 1994, Mahle & Rogstad 2002). In order to get information about such factors, the correlation between the index and the cost of salt or snow control could be used.

Different weights can be applied in indices if there are some parameters that are more severe than others. In Road Climatology weights are usually used in relation to the cost of maintenance that a particular parameter may cause. An index for winter maintenance may need different weights for snow than for ice and hoar frost since they do not demand the same type of maintenance activity.

The index that is going to be developed with in this study will have a somewhat different use than the applications described above. By use of the new index it should be possible to calculate the present need for maintenance activities but also the need for activities that can be predicted to occur based on climate scenarios. However, it is important that the index calculations could be linked to maintenance costs so that cost/benefit analyses can be made based on the calculations.

# 4 Methods

## *4.1 Downscaling the GCM scenarios to road climatology.*

### 4.1.1 The Analogue model

Neither GCMs nor regional climate models (RCMs) are sufficiently accurate or detailed to allow road weather conditions to be simulated directly. Instead, road-weather time-series must be derived from GCM or RCM outputs using statistical relationships between large-scale atmospheric patterns (which GCMs simulate well) and the observed road weather, a process known as *empirical statistical downscaling*. The relationships between the large-scale atmosphere and the road weather must be determined by analyzing historical atmospheric patterns and road weather time-series.

A great variety of statistical downscaling techniques have been developed, from simple linear regression to complicated variational analyses. Most of the techniques, however, have been developed for downscaling monthly – or occasionally daily – temperature and rainfall time-series from standard meteorological stations. Despite the increasing sophistication of many statistical techniques, it is not clear that they can downscale sub-hourly time-series of non-WMO meteorological data.

A simple statistical downscaling technique, which can confidently be applied for this project is the *analogue model*. This method involves iterating over each day in the GCM future scenario, and for each day finding the day in the historical record for which the large-scale atmospheric patterns match most closely. The future road-weather for each future day is taken to be the historical road-weather on the most closely matched historical day.

For many applications the basic analogue model has a significant shortcoming, in that it cannot generate scenarios, which contain values outside the historically-observed range. This is especially a problem when downscaling temperature time-series under climate change conditions, because in many locations it is very likely that future summer temperatures will be higher than any observation in the historical record.

Because this project is concerned with winter conditions, however, the above shortcoming can be overcome by allowing the method to select days from outside the current winter period. Thus, we will generate future time-series where (under global warming) *the winter road-climate of the future becomes more similar to the fall/spring climates of today*.

### 4.1.2 Atmospheric classification indices for the analogue model

The classification of atmospheric weather states in the Scandinavian region has been studied in detail, and strong relationships have been demonstrated to exist between the derived weather classes and local weather, especially in winter. We will use a circulation classification scheme based on Chen (2000) for this project. The Chen classification scheme is illustrated in Figure 4. Three circulation indices representing the east-west and north-south flow, and a vorticity component, are derived from the sea-level pressure at 16 points. Historical sea-level pressure data derived from peer-reviewed investigations are freely available on the internet. A similar domain will be created for Finland.

Using the circulation indices will allow climate change scenarios to be developed that reflect any changes in atmospheric circulation over Scandinavia. We will also include regional daily temperature as an atmospheric classification index, so as to mimic the drift in the seasons away from the present climate as a result of altered global temperatures.

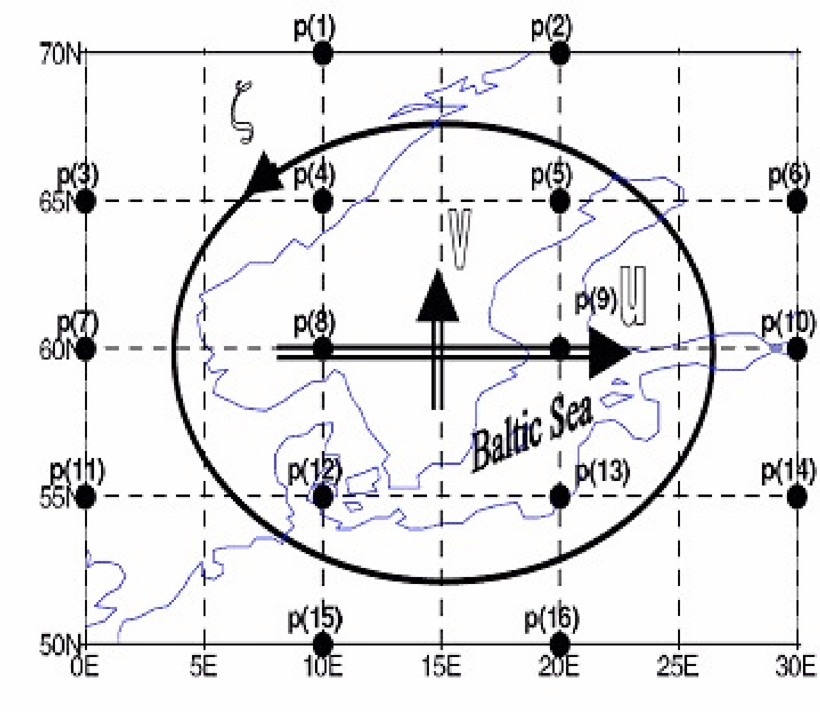


**Figure 4: Map showing the domain for generating the three circulation indices for Sweden (from Chen et al. 2005)**

### 4.1.3 Selecting analogues using the phase-space method.

The atmospheric classification indices can be used to relate the atmospheric state in GCM simulations to historical observations using a *phase-space method*. A simplified, hypothetical example using only two classification indices (in this case, east-west and north-south winds) is illustrated in Figure 5. For each of the 10 GCM days (red squares), the historical day (blue circle) with the most closely-matching winds is selected. For this project, of course, the phase-space will be 4-dimensional (three circulation indices and temperature); this is impossible to visualize, but mathematically is a simple extension of the 2-dimensional case.

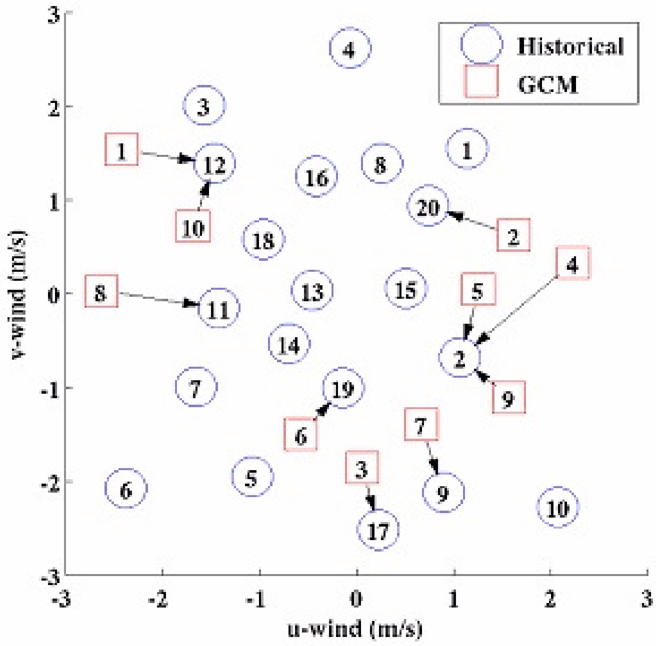


**Figure 5: The phase-space method of selecting historical analogues in two dimensions.**

### 4.1.4 Implementation.

The proposed approach, downscaling RWIS data using relationships with the larger-scale climate patterns, represents a completely new innovation in strategic road climatology. Implementation will be carried out in a series of steps:

- A dataset consisting of homogeneous, high-quality RWIS data for the period 1998 to 2008 will be assembled. The dataset will contain the most important climate variables from the point of view of road weather, namely temperature, precipitation, humidity, and wind speed. Because our downscaling method will approximate warmer future winters to current fall and spring conditions, stations that observe for the whole year (rather than being turned-off over summer) will be prioritized.
- Weather classification indices for the historical period will be developed using the NCEP reanalysis data (Kalnay *et al.*, 1996), based on sea-level pressure and regional temperature.
- A phase-space model will be developed to link the GCM future climate scenarios with the historical climate. Development/calibration will make use of the *Climate of the 20th Century* GCM experiments available from PCMDI.
- The phase-space model will be applied to GCM climate scenarios for the future (again from PCMDI) to create future road-weather climatologies. The exact GCM models and scenarios to use will depend partially on the availability of daily GCM model output data – daily sea-level pressure and temperature are not provided for all GCM models. If the available time-periods are unsuitable (i.e. further into the future than the 2030-2040 target period of this project), the regional temperature in the GCM scenarios will be normalized to an earlier time-period using the global mean temperature change.
- Road surface temperature for the future climate scenarios will be generated using a previously-developed energy transfer model.

## *4.2 Development of IRWIN, the improved winter road index*

The localised climate scenarios will be calculated for pre-selected test areas in Sweden and Finland. The first task is to get RWIS data from three test areas in both countries to include areas with differing local climate features. For instance, in Finland the areas of interest are the southwestern (warm and moist, lots of salting), northeastern (drier, continental climate "Snow-Finland") and Lapland with the largest expected temperature rise due to climate change. There are 735 stations at the moment in Sweden, and about 400 stations in Finland. The best un-interrupted time-series will be selected from the test areas. The archived observations data-base covers the eleven years 1998-2008.

Using the derived weather parameters from these near-historical and climate scenario data-bases, the first improved test version of the IRWIN winter index will be developed. Output from the system will be developed together with the users (i.e. key experts in involved road administrations) to generate a comprehensive tool to evaluate such topics as the spatial variations of winter maintenance needs, as well as the cost/benefit of various winter strategies. With the help of the database and index calculations, other types of weather related events, such as strong winds, heavy precipitation, flooding, freezing and thawing, and depth of ground frost can be mapped and assessed. With well-defined interfaces, the test system can later be easily adapted to other countries outside the project test areas in Sweden and Finland.

The methods developed in this project are also going to be tested versus data or theoretical models in order to verify that the technique can be used in other parts of Europe. It will be investigated whether long datasets corresponding to those from Sweden and Finland are available from other countries (e.g. Austria or Czech Republic). Those may then be used as alternative test areas.

# 5 Expected Results

Project IRWIN will produce several results during its development phases. First, project will develop a new database for possible future road condition scenarios through combination of historic RWIS-data with widely accepted climate change scenarios. These scenarios will extend to 20-30 years into the future.

In the second step the database will be used as input for calculations using improved winter index techniques. With the output from the new IRWIN index, it will be possible to evaluate such factors as the spatial variations of winter maintenance needs as well as the cost/benefit from various strategies. With the help of the database, other types of weather related events, such as strong wind and heavy precipitation, can be easily be mapped and assessed, which has a great application potential. One important outcome of the project is that the results will be disseminated to road authorities for planning purposes of future maintenance strategies. Using these calculations it will be feasible to perform cost/ benefit analyses.

# 6 IRWIN Work Plan

Project work will be divided into five partially overlapping technical work packages:

WP1: State of the art and national overviews regarding maintenance rules and strategies

WP2: Data collection

WP3: Database construction

WP4: Index formulation and calculations based on data from WP3

WP5: Evaluation and cost/benefit analysis

In addition, project management and dissemination actions will be performed throughout the project. Work Packages will be described in more detail in Chapter 6.3.

## *6.1 Role of partners*

Role of the three IRWIN partners will be according to their very sound previous expertise.

**Foreca Consulting** (FORC) will be the coordinator, manage the project and report project progress and use of resources to ERA-NET. FORC will also coordinate all dissemination actions. In development work, FORC will use the Finnish and Swedish RWIS data and use previous experience in analysis of "ColdSpots" of the road network, those that are most sensitive to slipperiness and accidents. FORC is also very experienced in utilising meteorological synoptic data and developing road weather service systems.

**Klimator AB** is well-known expert in road climate, linking climate events and maintenance, accessibility and road accidents, and in performing cost/benefit analyses. Klimator also have long time experience in the field of index calculations in respect of road climate and maintenance. This knowledge will be very useful in this project as it forms the base for linking present day conditions and needs to scenario data.

**Regional Climate Group** has long-term experience in downscaling of climate scenarios, analysing local climate, and characterising extreme events. RCG also possess deep knowledge regarding interpreting climate scenarios for different applications.

Thus the team is optimum in performing project's tasks.

Project takes 14 months, during which period local climate scenarios have been refined to few pre-selected test areas in Sweden and Finland. Using these results, first calculations with IRWIN are made. Project starts 1st November 2008, thus finishing in the end of 2009.

## 6.2 Project timetable

IRWIN timetable (table 1 on the next page) has been structured in a logical manner to be as effective as possible. The first Work Package WP1 analyses the state-of-the art. The three technical work packages WP2, WP3, and WP4 follow each other in a succession and each provides input to the following work package. Enough resources are allocated to the final evaluation and dissemination of results. Three milestones are closely connected to project reporting periods.

## 6.3 Work Packages

In the following, the objectives, tasks and output of each work package are described in more detail.

### 6.3.1 WP1: State-of-the-art analysis (M1-M2)

IRWIN project starts in November 2008 with WP1, lasting for two months. Objective of this first Work package is to summarise the present state-of-the-art of topics relevant for IRWIN project: global climate models, those emission and climate scenarios that have most credibility among the experts, effects of climate change on the road network, winter indexes developed, and the key factors and calculation methods in constructing those. The summary will be presented in the first project inception report (this report). All partners take part in this WP.

### 6.3.2 WP2: Data collection (M2-M3)

Objective of WP2 is to provide spatially and temporarily dense road weather observations to perform the climate downscaling of WP3.

Observations from the Swedish and Finnish RWIS stations will be collected from national Road Administrations from as long time span as has been archived with homogeneous contents and quality. Target is to get 10 years of observations of air and surface road temperature, moisture, wind speed, rainfall amount and precipitation type.

In the next step, the raw archived observational data will be processed to regular interval (30 min) time series and code all missing values. The Finnish and Swedish data will be reformatted to similar data format to allow effective data handling in WP3.

Austrian Road Administration will be contacted to investigate if suitable data is available for climate calculations from Austrian road network. In a positive case, this auxiliary raw data will be processed to similar format as in the Swedish and Finnish case and utilised in the coming Work packages.

The final output will be uniformly formatted road weather observations data archive of Finnish and Swedish (maybe also Austrian) RWIS data, which is suitable for climate downscaling and other climate analysis tasks.

All partners take part in WP2.

### 6.3.3 WP3: Database construction (M3-M7)

The work package starts on M3 (January) and lasts for five months. Objective is to perform climate downscaling and establish a climate database to be used in WP4. Timetable for various tasks is as follow

Table 1. IRWIN timetable.

| | 2008 | | 2009 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |
| **WP1 State-of-Art** | 1.11. | 31.12. | | | | | | | | | | | | |
| **WP2 Data Collection** | | 1.12. | 31.1. | | | | | | | | | | | |
| **WP3 Data base** | | | 1.1. | | | | 31.5. | | | | | | | |
| **WP4 Index development** | | | | | | | 1.5. | | | | | 31.10. | | |
| **WP5 Evaluation** | | | | | | | | | | | | 1.10. | | 31.12. |
| **WP6 Management** | 1.11. | | | | | | | | | | | | | 31.12. |
| Milestones & Deliverables | | | 31.1. MS1, D1 | | | | | 1.6. MS2, D2 | | | | | | 31.12. MS3, D3 |
| PSG/Coordinator meetings | 11.11. kick-off | | | 25.2. | 25.3. | 29.4. | 27.5. | 24.6. | 29.7. | 26.8. | 30.9. | 28.10. | 25.11. | 30.12. |

M3: NCEP/NCAR reanalysis pressure data and temperature data will be downloaded. Circulation classification of historical days based on method of Chen (2000) will be done for Southern Sweden region.

M4: Tasks include: Daily IPCC GCM pressure and temperature data from PCMDI (CCMA and ECHM5 models) downloaded, using a1b emission scenario. Correct biases in GCM pressure data using the historical monthly climatology. Circulation classification for GCM data. Compare classification indices for historical and GCM datasets.

Depending on how realistic the circulation simulations are for the region, there are a couple of options to continue:

- If the GCMs represent the circulation well, we use those circulation types to find the analogues directly.
- If the GCMs representation of the circulation is biased but reasonable, it should be possible apply some corrections so we can still use the GCM circulations for the downscaling. *This is the most likely situation.*
- If the GCM circulation represents the current circulation poorly, we will revert to a simpler model using only surface pressure and temperature instead of circulation.
- If all-else fails, we use historical re-sampling to get the circulation for future days

M5: Daily GCM projections data for 2010-2030 is not available, there is only daily data for 2046-2065 (the SRES time-slices). We will use the 2046-2065 dataset, but the temperature rises in these scenarios will need to be rescaled to be representative of the earlier time-period. Histogram-based rescaling using global temperatures will be used.

The phase-space method to select the historical analogue days matching the future days will be developed.

Matlab code to read “outside season” RWIS xls files into matlab using xls2csv will be written.

The RWIS data for the historical days will be extracted to create the new datasets.

M6: Road weather data from other regions in Sweden, and for Finland will be used and previous procedures repeated. If suitable data from Austria is available, tests on the usability of the method on this data will be made.

Final output of WP3 will be the climate database to be used in WP4. Klimator and Regional Climate Group take part in WP3.

### 6.3.4 WP4: Index formulation and calculations (M7-M12)

Objective of WP4 is to develop the localised winter indexes, based on the climate database created in WP3. The localised climate scenarios will be calculated for pre-selected test areas in Sweden and Finland. Target is to analyse three test areas in both countries with differing local climate features.

Derived weather parameters from the near-historical and climate scenario databases will be used to develop the first test version of the IRWIN winter index to evaluate the spatial variations of winter maintenance needs and the cost/benefit of various winter strategies. Index and the climate databased are used to assess other weather related events, such as strong winds, heavy precipitation, flooding, freezing, thawing cycles, and length of ground frost.

System will contain well-defined interfaces, to allow easy adaptation to other countries outside the project test areas in Sweden and Finland. If RWIS data is obtained, Austria will be used as alternative test area. Klimator and Foreca are responsible for work done in WP4.

### 6.3.5 WP5: Evaluation and cost/benefit analysis (M10-M14)

Object of the last Work Package is to evaluate the developed databases and indexes and the overall system adaptability to areas outside the test countries.

The method for evaluation is Evaserve, an evaluation toolkit developed by VTT in Finland. Both Klimator and Foreca Consulting are familiar with using Evaserve in previous projects.

The analysis includes also cost/benefit assessments. Klimator and Foreca take part in WP5.

## *6.4 Deliverables and Milestones*

Project Deliverables and Milestones are described in the following tables.

**Table 2. IRWIN Deliverables**

| Deliverable | Type | When due | Contents |
|---|---|---|---|
| D1 Final work plan and state of art | Report | M3 | State-of-art of climate models, scenarios and effects, and winter indexes. Detailed IRWIN work plan. |
| D2 Second inception report | Report | M8 | Report on data collection and database construction. |
| D3 Final report | Report | M14 | Summary of project results, index formulations and calculations, and evaluation. |

**Table 3. IRWIN Milestones**

| Milestone | When due | Contents |
|---|---|---|
| MS1 | M3 | Project effectively started, work plan detailed. Kick-off meeting with all participants. State-of-the-analysis performed. First deliverable D1 submitted to PSG. |
| MS2 | M8 | Data collection and database construction performed as planned and finalised. Enough data with high enough quality exists to start index development. Second inception report D2 submitted to PSG. |
| MS3 | M14 | All calculations and evaluations finalised. Cooperation with other ERA-NET ROAD projects and dissemination performed as planned. Final report submitted to PSG. |

## 6.4 WP6 General project management

General project management and dissemination activities are included in the final supporting Work Package 6. Project participants have signed IRWIN Consortium Agreement (CA) before the start of the project. The Desca model for EU/FP7 was utilised as the template. The CA defines e.g.

- The responsibilities and liabilities of the partners,
- Decision procedures
- Quality plan, covering the research and reporting
- Management of exceptional cases such as change of partners
- IPR issues

The main decision making body of the project is the Project Management Board (PMB), having as representatives the assigned administrative contact persons of each partner. Project also has a Project Manager leading the Project Steering Group (PSG), with the following members:

Eira Järviluoma, Project Manager, Finnish Road Administration

Jon Krokeborg, Vegvesen, Norway

Christian Pecharda, AustriaTech

PSG will be informed on project's progress in regular meetings (tele- or webmeetings) with project coordinator, who will also provide them with minutes of meetings. Project will start with a kick-off meeting in November 2008.

The initial travel and meeting plan is as follows:

11th November 2008: Kick-off meeting in Göteborg, Klimator office at the University (PSG, Partners)

31th March – 2nd April 2009: ERA-NET ROAD seminar in Oslo (PSG, partners, other proejcts)

5th May 2009: project working meeting in Göteborg (partners)

3rd November 2009: project working meeting in Helsinki (partners)

The last Wednesday of each month (25.2., 25.3., 29.4., 27.5., 24.6., 29.7., 26.8., 30.9., 28.10., 25.11., 30.12.) will be reserved for PSG/Coordinator meeting or teleconference. Coordinator will organise these meetings as necessary.

All other meetings will be either web or tele-conferences.

## 6.5 Draft Dissemination Plan

FORC as project coordinator is responsible for drafting and maintaining the Dissemination plan and launching the dissemination activities. The initial plan will be revised during the course of the project, taking into account advice from the Project Steering Group. Final Dissemination Plan will be part of the mid-term report (D2).

The first target group for dissemination is the road owners and administrations in ERA-NET countries. The second group covers the road administrations and other interest groups in the EU. To reach these target groups, the project results will be presented in transport forums, publications and conferences active in 2009 and 2010. The following list gives some potential forums where project results can be offered as papers and presentations:

EASYWAY, 16 – 17.3.2009, Lillehammer

World Road Meeting 31 May – 4 June 2009, Lisbon

International Baltic Road Conference, 24 – 26.8.2009, Riga

ITS World Congress 21 – 25.9.2009, Stockholm

Intertraffic 2010, 23 – 26.3.2010, Amsterdam

In addition, project results with scientific interest will be submitted to suitable reviewed journals.

# 7 Exploitation of results

The rapidly changing climate will produce new and not well-known challenges for society. Roads and infrastructure are vital part of our society, and transport is forming a large part of gross national product. Thus, fluent and safe transport is a key resource for thriving economies, not only for today, but also into the future. Road administrators have a lot at stake now and in the future, and thus new tools like IRWIN are necessary.

The impacts of climate change are important to consider when it comes to road maintenance operations and winter maintenance in particular, as wintertime weather poses more risks to road infrastructure and transport users. How to adopt to the new conditions is vital to know many years in advance to be able to optimise different services and organisation measures. The long life span of infrastructure requires the right decisions be made for the decades ahead.

The IRWIN winter index will be developed using the best scientific knowledge available today for assessing impact of climate change on the local road network. Input data will be the best available from the road-network point of view, and the IRWIN outputs will be developed to include those parameters that the experts in road administration find most useful for their strategic long-term as well as short-term planning. Thus the exploitation of results will be most effective.

The results from this study can further be used to address problems and provide solutions on a trans-national basis. The study considers scenarios covering Sweden as well as Finland, but the results are expected to be applicable on other areas as well. **Thus all ERA-NET countries will benefit from the project.**

The basis for the project is the comprehensive data set from the RWIS in Sweden and Finland. In combination with models for downscaling this gives a unique opportunity to combine data for different scales as well as using climate change scenarios in a new approach. The project's approach of downscaling road climatology and then using this information for an applied climatological index is a totally new concept and unique for Northern Europe, but also worldwide.

Using the database with remodelled scenarios for cost/benefit calculations and winter index calculations will provide involved governments and decision makers in all fields of transport with new insights and tools to be used in decision making in various time frames, not only in long-term strategic planning covering decades and centuries, but also in the much shorter-term seasonal and annual action planning. When climate models become more and more detailed and reliable in the future, IRWIN is read to adjust its output to the new models. It will become a very useful tool for road administrators for years to come.

# 8 Conclusions

Project IRWIN has defined its detailed work plan during the project Kick-off meeting on 11th November 2008 in Göteborg. This first inception report describes the overall project objectives and the revised work plan, the selection criteria of observational RWIS databases, the climate models and the downscaling methods tob e used for the localised climate scenarios. Those will go 20-30 years into the future.

IRWIN will concentrate on forming scenarios and improved winter indexes covering Sweden as well as Finland, but the results are expected to be applicable on other areas as well. Austrian data will be tested. Results from IRWIN can further be used to address problems and give solutions on a trans-national basis. Thus all ERA-NET countries will gradually benefit from the project.

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