Final Report of ERA-NET ROAD Programme

"Road Owners Getting to Grips with Climate Change"

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Abbreviations

Abbreviation	Meaning
BASt	German Federal Highway Research Institute
CCSM3	Community Climate System Model Version 3
CEN	European Committee for Standardization
CEDR	Conference of European Directors of Roads
ECHAM5	Fifth Generation Atmospheric General Circulation Model
FEHRL	Forum of European National Highway Research Laboratories
GCM	Global Circulation Models
IPCC	Intergovernmental Panel for Climate Change
IRWIN	Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios
P2R2C2	Pavement Performance & Remediation Requirements following Climate Change
RCM	Regional Climate Model
RIMAROCC	Risk Management for Roads in a Changing Climate
RWIS	Road Weather Information Systems
SWAMP	Storm Water prevention – Methods to predict damage from water stream in and near road pavements in lowland areas
UKCP09	UK Climate Projections

1. Introduction

"ERA-NET ROAD - Coordination and Implementation of Road Research in Europe" is a Coordination Action funded by the 6th Framework Programme of the EC. Within the framework of this action, the call "Road Owners Getting to Grips with Climate Change" was launched as the first cross-border funded joint research programme. 11 National Road Administrations (Austria, Denmark, Finland, Germany, Ireland, The Netherlands, Norway, Poland, Spain, Sweden and the United Kingdom) participated in the programme. The total budget for funding projects was 1,350 MEUR. 19 proposals from 18 different countries were submitted for the call. 8 of those countries are not members of the funding Programme Executive Board (PEB) of ERA-NET Road.

The theme for the programme was selected because the road network is heavily influenced by climate conditions which are expected to change in the future. Climate change may result in more frequent and more intense rainfall, milder winters, warmer summers, and increases in wind speed and storm frequency. Road authorities need to evaluate the effect of climate change on the road network and take remedial action through all components of road management including design, construction and maintenance. At the same time, consideration must be given to safety and accessibility to ensure that user's expectations are not compromised. The adaptation of road networks to these changes is one of the important issues that road authorities need to address. The "Road Owners Getting to Grips with Climate Change" research programme aimed at providing road authorities all across Europe with the knowledge and tools necessary to "get to grips" with climate change and its effects on all elements of road management by adapting design rules, updating and improving data collection, and developing risk management methods.

Four projects were funded in the research programme:

- IRWIN - Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios
- P2R2C2 - Pavement Performance & Remediation Requirements following Climate Change
- RIMAROCC - Risk Management for Roads in a Changing Climate
- SWAMP - Storm Water prevention – Methods to predict damage from water stream in and near road pavements in lowland areas

The project reports can be downloaded from the following websites: http://www.eranetroad.org/, www.cedr.fr and www.fehrl.org

At the conclusion of the programme, a final event was organised near Cologne in Germany. This was held 8 and 9 December 2010. The conference was organized around different workshops, reports, and presentations of the projects results. The outputs of this research programme is a series of reports focusing on different aspects of climate change and its effects on the management of national road networks that can be applied across Europe and that will be important in facilitating the understanding of this research across the countries of Europe. The reports were presented as proposed guidelines. The Forum of European National Highway Research Laboratories, FEHRL organised the event in collaboration with the German Federal Highway Research Institute, BASt. To support the theme of the event, a number of German national projects on climate change adaptation were also presented in the context of the conference. These further informed the debate on the topic.

The purpose of this document is to produce a final report for ERA-NET ROAD Programme entitled “Road Owners Getting to Grips with Climate Change”. This summary document brings together the findings and recommendations from the four projects in the programme (IRWIN, P2R2C2, RIMAROCC and SWAMP) and shows how road authorities can implement the recommendations from each of the projects in an efficient manner.

1.1 Structure and contents of the final report

The final report consists of three parts:

Part I – General information about the projects
A general overview of the four projects is given together with the methodologies used and the results.

Part II – Outcome of workshops at final conference
At the final conference, the participants were split into two groups. Group 1 (workshop 1) focused on the RIMAROCC and SWAMP projects while group 2 (workshop 2) addressed the IRWIN and P2R2C2 projects. Part II of this report presents the outcome of these discussions and the recommendations specific to the projects.

Part III – Implementation strategies
The third part presents the steps needed to ensure a successful implementation of the results across the CEDR members.

PART I – General Information about the projects

2. IRWIN – Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios

2.1 Project Facts

Duration: 01/11/2008 – 31/12/2009
Budget: EUR 258,100

Coordinator: Pirkko Saarikivi, Foreca Consulting Oy, Finland
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Partners: Klimator AB, Sweden
University of Gothenburg, Regional Climate Group, Sweden

2.2 Background and objectives

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 they 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 types 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 of 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. 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 denser compared to ordinary meteorological networks. These facts give the RWIS data large advantages for road related studies.

The main objective of IRWIN is to develop an improved local road winter index, which is sufficiently detailed and comprehensive that road authorities and owners can use to assess the implications of future scenarios and climate change implications, and perform reliable cost/benefit analyses.

To achieve this objective observation from the Swedish and Finnish RWIS stations were collected from national Road Administrations from as long a period as had been archived with homogeneous contents and quality.

2.3 Methodology and outcomes

● State of the art of climate models and winter index formation

Global circulation models (GCM) are the best existing tools for studying climate change. GSMs cannot however be used to determine what weather phenomena will occur at a given time and place in the future, but they can be used to estimate the effect of changed conditions, and in particular, changes in greenhouse gasses in the atmosphere. GCM outputs can be used to answer questions such as – what is the average change, at a particular place, over a period of time.

Neither GCMs nor regional climate models (RCMs) are sufficiently accurate or detailed enough 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 simple statistical downscaling technique, which can and has been confidently applied for the IRWIN 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.

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. 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 feedback effects of the shrinking snow and ice coverage.

Winter indexes describe the main characteristics of the road 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. Winter indexes can be utilized for several applications and needs, e.g. to calculate the cost effectiveness of winter maintenance system in general, to perform more detailed cost/benefit calculations, to access the cost effectiveness of an already existing warning system, or to calculate maintenance costs for a specific area.
With IRWIN index the objective of development and key application has been somewhat different, relating to the rapidly progressing climate change and urgent needs to get new tools for strategic decision-making. Using IRWIN, 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. Linking index calculations to maintenance costs allows making of cost/benefit analyses today but also in the future.
The factors that need to be taken into account when developing a Road related Winter Index are: ice, precipitation in the form of snow or water, wind.

● Data collection and data base

From the total number of about 760 RWIS stations in Sweden, 50 were selected for the IRWIN analysis from three different areas in Sweden: south-western region with 24 stations around Gothenburg, 12 stations in the east around Stockholm and 14 stations in northeast around Sundsvall. These three areas represent three different types of climate in Sweden. The south-western region was the test area for the IRWIN project, and these stations were used to establish methods to be used, and to develop routines for quality assurance etc. The data used for the project include: precipitation type and amount, surface and air temperature, wind speed and direction and dew point (calculated from humidity), for the winter period (November to March), 1998 to 2008.

The national road weather observing network in Finland has been in operation since the 1970s. Archived observations exist from 1997 onwards. Today the network consists of some 500 stations covering also Lapland, the northernmost parts of the country. However, existing road weather stations in Lapland do not have long enough measuring time series, and that is why the climatic regions had to be selected more south compared to what was originally intended. Altogether 49 stations were selected from three climatic regions: the south-western, the south eastern and the north-eastern regions.
General weather observations are quality controlled and corrected before their archival into climate database, whereas archived road weather observations are not ready as such for further analysis. This is because there is no regular quality control and correction routine of observations before saving those into the archived databases. Thus in the IRWIN project, a major effort was the quality control and correction of the raw RWIS data before they could be used for reliable climate analysis.

OUTCOMES
The data collection phase of IRWIN revealed that there was enough archived RWIS data in Sweden and Finland to perform the planned winter index development. The required minimum samples of ten years of observations were collected from 50 road weather stations in Sweden and 49 stations in Finland. Observations in each country were available from three regions with distinctively differing climatic characters, allowing localised climate comparisons. Maintenance actions from the regions of interest were available as well, and were used in the final winter index calculations.
After the tedious but necessary quality control steps, the resulting IRWIN observational database resulted in a set of reliable and unbiased observations. It provides a valuable source for further studies in local road climatology.
The climate database was constructed using well-established and documented downscaling methods, applied on two widely used and acknowledged global climate models CCSM3 and ECHAM5. Thus the IRWIN climate database can be considered as reliable as it is possible in today’s climate research.

Nowadays winter indexes are not very often used operationally in road maintenance activities. For instance in Finland winter index was used earlier in order to compare maintenance costs on a yearly basis. However, this routine is not used any longer. The main reason for this is the earlier convention to have a simple index and use more coarse general weather observations as the basis for index calculations. In this routine the annual variations of weather do not correlate very well with the number of maintenance actions and costs.

Using a more accurate index such as IRWIN, many benefits are expected:
• Better representation of weather and climate of the road network gives better linkage between weather and maintenance needs
• IRWIN index provides better understanding of local weather variations
• IRWIN is a user-friendly tool when assessing the impact of climate change on maintenance needs
• IRWIN index provides better coverage of extreme events; such as heavy snowfall or strong winds
• After assessing the potential change of maintenance needs and actions compared to present, it is straightforward to assess the monetary implications to road owners in the changing future climate.
IRWIN index calculation can be considered also as a service for road owners. A structured self-evaluation of such a service has been performed using ITS service assessment framework developed within the R&D Programme on Real-Time Transport Information AINO, and managed by the Ministry of Transport and Communications Finland. The framework is based on the national guidelines of evaluation of ITS projects from 2002.

Detailed information about the project is available at [1], [2] and [3]. The project reports can be downloaded from the following websites: http://www.eranetroad.org/, www.cedr.fr and www.fehrl.org .

3. P2R2C2 – Pavement Performance & Remediation Requirements following Climate Change

3.1 Project Facts

Duration: 15/09/2008 – 15/03/2010
Budget: EUR 258,100

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Partners: Slovenia National Building and Civil Engineering Institute (ZAG), Slovenia
SINTEF PNP, Norway
Technical Research Centre (VTT), Finland

3.2 Background and objectives

Future climate change and its influence on the performance of the road network is an issue that is concerning more and more countries.
The P2R2C2 project investigated the likely impacts of climate change in Europe, from the Alps and northwards, on the moisture/ice condition in the pavement and the subgrade, and the consequential pavement material behaviour and pavement response to traffic over a 100-year timescale.
The aims of the project were to:

- study the likely differences in moisture (water) condition in the pavements of roads in Europe, from the Alps and northwards, as a consequence of climate change;
- estimate the likely consequences for pavement and subgrade material behaviour and for whole pavement needs;
- perform this study for a range of representative pavement types and representative climatic zones;
- assess uncertainties to permit risk/vulnerability to be evaluated;
- define options for responding to the changes;
- perform cost-benefit analysis to allow road owners to determine best options for their own situations;

The project was performed by a combination of literature review, laboratory evaluation of materials, computational studies of pavement structural and hydrological performance and by the development of recommendations suitable for implementation by national road owners into their specifications.

3.3 Methodology and outcomes

The following methodology was adopted:

● Selection of climate projection models and greenhouse gas emission scenarios
There are an enormous number of climate projection scenarios and models. In the P2R2C2 project, two climate simulation models were used: the Hadley Centre model (which has an atmospheric emphasis) and the Max Planck Institute model (which stresses the importance of the influence of the ocean). The same computer code was used with each model implemented in it, covering only Europe in approximately 50x50km squares (i.e. each variable is deemed to apply equally over this area).
In addition, the climatologist has to make assumptions about anthropogenic inputs to climate change prediction models – of which CO_2 emission is the most politically sensitive. However, CO_2 is only one such factor, there are several others, too. The climatologist has no ability to predict the future magnitude of these. Instead he/she must rely on the political forecaster and the social scientist's predictions. In the 2007 report of the IPCC, 6 families of emissions scenarios were used. In the P2R2C2 project the A2 and B2 scenarios were selected.
With two models and two emission scenarios there are, therefore, a total of four predictions for each variable assessed.

● Selection of time horizon
It was decided that climate change over a 100 year+ timescale was the preferred subject to address. This was because, over a much shorter timescale, year-to-year weather variations will tend to mask the underlying climate changes. Over a much longer timescale projections of climate change becomes very uncertain so that the reliability of estimated impacts seriously declines. So a 100 year, or so, period of study seems appropriate between these two limiting factors.
To overcome the year-to-year variability problem, changes in variables were defined in terms of the change in the 30-year average value from the period 1960-1990 to the period 2070-2010 (as is commonly done in IPCC modelling). So the actual timeframe is 100 years of which 20 years is expected to be small compared with other uncertainties in the prediction, so most of the results of the project could be assumed to apply to changes over the next 110 years without much loss of accuracy.

● Identification of key changes in climate that will affect pavement performance
Taking into account all four project predications, the following changes in climate can be expected to affect pavement performance in the study period and area (Europe north of the Alps):

- The annual maximum temperature might rise between 1 and 12 °C with greatest rise in the West (particularly France) and less in Eastern and Northern Europe.
- For the vast majority of areas studied, the frequency of rapid air temperature changes will remain the same or reduce.
- In the Nordic and Baltic countries (Norway, Mid-Northern Sweden, Finland, Estonia, Latvia, Lithuania) the annual cold sum (number of hours when air temperature is less than 0 °C multiplied by the number of degrees below freezing) will decrease significantly. In Southern Sweden and Poland there will also be marked reductions though not as great as in the countries previously listed.
- The change in number of hour-degrees per year higher than 25 °C will be less than 1000 for the UK, Ireland, the Nordic countries, and most of the three Baltic States

and in the Alps. The change will be greater (as much as 4000 hour-degrees) in Germany, particularly in the south, parts of the Czech Republic, Slovakia and France.

- In all areas, except the very north of Norway, Sweden and Finland (Lapland), the number of freeze-thaw cycles is expected to reduce.
- For most of mainland Europe and the British Isles total rainfall will change little. Only Scotland, northern Poland, the Baltic and Nordic States will see increased rainfall (or snowfall). Greatest increases are expected in the Atlantic coastal areas of Norway and Scotland but proportionally to current rainfall levels, the increase there will be similar as in other parts of northern Europe – 20-30%. The Alps will also experience an increased precipitation.
  Rainfall intensity will increase in most areas.

OUTCOMES

It is noted that the life cycle of the pavement is much less than the time span over which climate change will have a statistically dependable influence on pavement performance. Only for the pavements with longest life or for the lower layers that may not be touched during future rehabilitation and reconstruction, do road designers need to change their practice at present.

However, if current practice is not to be progressively changed at times of major pavement rehabilitation during the next 110 years, then the effects of these changes on pavements constructed, managed and trafficked as at present might be:

- In areas where rainfall is unchanged then subgrades and aggregate layers should be drier on average, because warmer temperatures should increase evaporation. Even in wetter areas, the increased rainfall intensity is likely to result in greater run-off so increased net infiltration to the subgrade and aggregate should be small or even negative. A small improvement in pavement support is therefore anticipated in most locations.

- Temperature and rainfall increase will be a challenge for asphalts. Softer materials more prone to rutting and stripping can be expected.

- In those countries that rely a lot on having frozen roads during winter, the length of the frozen period will decrease in the far north with a briefer spring thaw – a mixed problem and benefit. To the south, in much of the Nordic area, frozen road structures may disappear altogether in some years. Periods during the winter when the surface layers aren't frozen will become normal. Spring thaw problems will be likely to become less problematic, but many thin and unsealed pavements will need upgrading to provide a reliable, high, bearing capacity all winter long.

- In coastal and low lying areas raised water tables may be experienced due to points at which flood waters collect or due to raised sea levels. Road raising or special reinforcement techniques will be needed locally to address this problem.

The appropriate responses to these changes in pavement performance:

- will be fairly dependent on the climate change model & scenarios used,
- will be relatively easy to handle given the rapidity with which pavements are renovated relative to the timescale over which climate is expected to change,
- will be achievable, in most cases, by routine material formulations that can be employed at the next reconstruction/rehabilitation event,
- will need new design criteria regarding temperature and return period of storm flows to be developed (regionally specific),
- will need more attention paid to drainage systems, particularly to make them self-cleaning and easily inspectible,
- may necessitate different resurfacings on 'perpetual pavements' than originally planned,
- are likely to include, in the mid and southern parts of the Nordic countries, stabilisation of unsealed pavements, overlaying by bound layers or operational management solutions based on continuously monitored condition, and
- are likely to be over-ruled by the responses needed to satisfy user and funder demands and to deal with changes in use consequent on demographic, technological and economic changes (some of which are a consequence of climate change).

Detailed information about the project is available at [4], [5], [6], [7], [8], [9], [10], [11], [12] and [13].

The project reports can be downloaded from the following websites:
http://www.eranetroad.org/, www.cedr.fr and www.fehrl.org.

4. RIMAROCC – Risk Management for Roads in a Changing Climate

4.1 Project Facts

Duration: 01/10/2008 – 31/07/2010
Budget: EUR 300,000

Coordinator: Bo Lind, Swedish Geotechnical Institute
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Partners: EGIS, France
DELTARES, the Netherlands
Norwegian Geotechnical Institute (NGI), Norway

4.2 Background and objectives

Risk management for roads with regard to climate change is an area subject to genuine and long-lasting uncertainty. Uncertainty stems from a number of sources, such as climate models and our inability to accurately project the level of future emissions. There is also uncertainty in the way climate will affect the road system, e.g. the physical structures, maintenance and demand levels. Efforts should be made to understand this uncertainty and ensure that it is factored into decision-making. It is expected that some of the uncertainties will diminish over time, for example as a result of the ongoing improvement in climate models while others will remain for many years.

RIMAROCC provides a systematic method for risk management based on three questions;
- What can happen?
- How likely is it to happen?
- If it does happen, what are the consequences?

In a risk analysis, it is crucial that one does not miss any scenario or eventuality – thus risk identification is a key step in the framework. A non-identified risk can make the whole analysis worthless, whatever effort is put into the other risks.
The RIMAROCC method is designed to be general and to meet the common needs of road owners and road administrators in Europe. The method seeks to present a climate change adaptation framework for roads to help ensure that road networks are more resilient to future climate change. The method is based on existing risk analysis and risk management tools for roads within the ERA-NET ROAD member states and others. Work dealing with risk analysis and climate change is taking place in many countries. The proposed method is designed to be compatible and function in parallel with existing methods, allowing specific and functional methods for data collection, calculations and co-operation within each organisation to be maintained. The method is also in line with the ISO 31 000 standard on risk management.
The RIMAROCC method consists of seven steps and is a cyclic process to continuously improve the performance and capitalise on the experiences.

The method has been tested in practical case studies in four countries – and at different scales including, network scale (e.g. 100 – 1000 km network of primary roads), section scale (e.g. 20 – 100 km road section) and structure scale (e.g. a bridge).

4.3 Methodology and outcomes

The following methodology was adopted in the project:

● Critical climate factors

Through a literature review and a series of workshops with climate experts a list of the main climate parameters impacting on roads were identified. They include:

- extreme rainfall events (heavy showers and long periods of rain)
- seasonal and annual average rainfall
- sea level rise
- heat waves
- drought.

It was noted that combinations of critical climate variables can cause other or increased risks e.g. intense rainfall after a drought period causes more slippery roads than intense rainfall after a wet period.

● The RIMAROCC Framework

The RIMAROCC Framework is designed for road risk management on all decision levels and on all geographical scales of pertinence.
Its main objective is to facilitate the production of a Risk Management Study by or for a road authority. The method can be used to mitigate threats, reduce vulnerabilities and minimise the consequences of an event. The RIMAROCC Framework consists of seven steps each with a number of sub-steps

Step 1 - Context Analysis

By establishing the context, the authority responsible for the climate risk management study (risk manager) articulates its objectives, defines the external and internal parameters to be taken into account when managing risk, and sets the scope and risk criteria for the remaining process.

Step 2 – Risk Identification

The risk manager should identify sources of risk, areas of impact, unwanted events (including changes in circumstances) and their causes and potential consequences. The aim of this step is to generate a comprehensive list of risks based on events that might stop, degrade or delay the normal operation of the road system, or create trouble or damage in the exposed area.

Step 3 – Risk Analysis

Risk analysis involves developing an understanding of the risks. The risk analysis provides input to risk evaluation and serves as a decision basis for whether risks need to be treated, and for selecting the most appropriate risk treatment strategies and methods.

Step 4 – Risk Evaluation

The purpose of risk evaluation is to assist the risk manger in making decisions, based on the outcome of the risk analysis, about which risks need treatment and the priorities for treatment implementation. Risk evaluation involves comparing the level of risk found during the analysis process with criteria established when the context was considered. Based on this comparison, the need for treatment can be considered.

Step 5 – Risk Mitigation

Risk mitigation involves identifying, appraising and selecting one or more options for modifying the non-acceptable risks. A combination of the identified measures can be transformed into a strategy for the coming years in order to cope with climate change and keep risks acceptable. This step also includes securing financing as well as documenting in an action plan how the chosen adaptation measures will be implemented. Risk mitigation is a strategic step which may involve players from several departments: roads, civil security, finance and others

Step 6 – Implementation of Action Plan

In this step the action plan is presented in detail; responsibilities for implementation are addressed; resources are allocated; performance measures are selected. When all the details are in place, the action plan is implemented. This is a strategic step which involves players from several departments: roads, civil security, finance, etc. Network and territorial scale analyses require information on which geographical units of the organisation should be involved. This also applies to stakeholders contacts.

Step 7 – Monitoring, Review & Capitalisation

Since risk management is a learning process this step aims to monitor and review the implemented actions and to capitalise on the knowledge gained within climatic events and implementation of action plans. If conditions change, re-planning starts within this step.

● Case studies

Four case studies were run. They were developed to illustrate four different scales: structure (e.g. bridge or very short road section), section (e.g. a motorway section between two interchanges), network (e.g. > 1000 km of interconnected roads), and a territory (e.g. a road network and its associated territory). These case studies show in concrete terms how the method can be implemented, what the possible adaptations of the overall methodological framework could be as well as the method, scope and limitations.

Detailed information about the project is available at [14], [15], [16], [17] and [18].
The project reports can be downloaded from the following websites: http://www.eranetroad.org/, www.cedr.fr and www.fehrl.org.

5. SWAMP – Storm Water Prevention, Methods to Predict Damage from the Water Stream in and near Road Pavements in Lowland Areas

5.1 Project Facts

Duration: 01/10/2008 – 31/05/2010
Budget: EUR 231,100

Coordinator: Michael Larsen, Danish Road Institute, Denmark
e-mail: mil@vd.dk

Partners: Swedish National Road and Transport Research Institute (VTI), Sweden

5.2 Background and objectives

Researchers predict significant changes in climate during the current century. These will have multiple effects on society. For example a greater frequency and intensity of flooding is expected in many parts of Europe, in particular in central and northern Europe. Flooding poses a great threat to roads, and may in severe cases lead to massive obstruction of traffic and damages to the road structures themselves. In many countries, design guidelines for new road related constructions have changed in response to the anticipated future climate. Given the uncertainty of what to expect of the upcoming climate, it is difficult to give specific recommendations on how to change dimensioning, valid for all European countries. Some countries have adopted a nationwide uniform modification of e.g. the design flood, while others have suggested a climate factor that varies with the geographical (or rather climatologically) region of the country.

Changing the entire existing road network is very costly, and most likely not necessary. Identifying the weakest parts of the road network is the first and most important part of a climate adaptation strategy. The SWAMP project addresses the critical issue of finding the parts of the road network that are most vulnerable to flooding, using a geographical information system as a basis. These parts are referred to as blue spots. It is believed that most resources should at least initially be spent on relatively few blue spots. Additionally, one should perhaps think twice before rebuilding or upgrading structures. In many situations the worst socio-economic costs, which appear to be related to obstruction of traffic, may be avoided simply by using early-warning systems combined with effective communication to the road users. The project deals with the issue of how to limit the effects of flooding, or if possible avoid flooding, at the blue spots.

Given the variability of road and drainage system constructions, and the differences in geology and climate across national borders, a general European guide is at the moment not feasible. The SWAMP project aims to present the crucial issues to consider when creating national or even regional guidelines for inspections and maintenance. The suggestions are geared towards lowland areas that are relatively flat and mildly undulating landscapes, and do not explicitly cover steep, sloping areas.

The project also gives:

- Guidance and instructions to engineers and people in charge of inspection, maintenance and repair.
- Useful information to decision makers responsible for renewal of the drainage system with the aim to reduce future flooding and damage of the road network.
- Practical suggestions on how to perform field work in a systematic way over the season, and also how to prepare the road system before, during and after a heavy rain event.

5.3 Methodology and outcomes

The following methodology was adopted in the project:

- Questionnaire and data collection for blue spot identification
- The Blue Spot concept
- Inspection and maintenance – guide to reduce vulnerability due to flooding of roads

● Questionnaire and data collection for blue spot identification

A questionnaire was send out to road authorities with the aim of providing answers to the following questions:

- Are there any guidelines with information about inspection and maintenance to prevent flooding?
- Are there any models or maps to predict flooding?
- How often is the drainage system inspected?
- How often is the drainage system maintained?
- What is done to prevent flooding?
- What is done after flooding?

Results show that most countries have written guidelines for inspection of national roads and bridges though these guidelines are very diverse and treat different aspects of the road drainage system.

Most countries have inspection intervals prescribed by some kind of national guidelines although the frequency of inspections of roads and bridges also vary from country to country.
Regarding maintenance frequency, it was obvious from the answers that several factors contribute to the risk of flooding:

- clogging of the drainage system
- root intrusion in pipes
- vegetation growth and sedimentation in ditches.

Cleaning of ditches and pipes are generally done when needed. This is however not regulated at certain time intervals in most countries.
The results suggest that cleaning and maintenance are the most important actions to perform to prevent flooding. This includes actions such as cleaning of culverts, removal of clogged material, debris, vegetation and sediments along road verges to allow for sideways drainage.

The respondents remarked that:

- It is important to identify areas prone to flooding and consider other design options for repair and reconstruction of vulnerable road sections
- Maintenance is sometimes done only as a reaction to a flood event. There is a need for a clear strategy to prevent flooding.
- Lack of funding is limiting inspection and maintenance.

The most typical damage after a flooding event is clogging, erosion and replacement of pipes. The results shows that repair work can be done more effectively to prevent future problems, suggesting a need for more effective processes for the management of repairs.

Two important conclusions were identified from the questionnaires:

- There is a need to be able to identify and prioritise road sections prone to flooding, since maintenance and funding apparently cannot cover the entire road network
- There is a need for a clear strategy, stating how to inspect and maintain the areas in question in order to prevent flooding on vulnerable road sections.

It is recommended that road authorities pay more attention to these questions to meet the present maintenance and repair needs and those anticipated in the future as a result of climate change.

● The Blue Spot Concept

The blue spot concept is a chain of procedures that can be used by road owners, operators or consultants to systematically analyse, adapt and protect the road network with respect to flooding. It involves computer methods executed at office PCs, followed up by targeted field inspections and actions. The starting point is a screening method (the Blue Spot Model) that can be used on the regional scale to find blue spots. In the screening process all depressions in the map material are identified. This is done by allowing rain to fall on the model land surface while not allowing for infiltration into the ground or evaporation to the atmosphere. Hence, every drop of rain will flow along the land surface until it reaches a volume of free water collected in a depression. If these volumes are larger than $10m^3$ and close to a road, they are considered as threats and are included in the next analysis.

The second level is a calculation of rain sensitivity for each individual depression found in the screening. It is done by assuming no drainage from depressions and assuming impermeability of the catchment 20, 40, 50, 60, 80 and 100%. In this way a risk map can be drawn showing the amount of precipitation needed to fill low-laying areas.
The third level consists of a 1D-1D hydrodynamic model of surface reservoirs and depressions which is used to find pathways, catchments and ponds in a risk area. In this way calculation of both water flows on the surface and in the drainage systems is taken into account giving a more accurate calculation of flood risk.
In addition, the risk of flooding due to sea level rise is mapped by incrementing the sea level and tracking how far inland the sea water reaches. Dykes act as barriers as long as the water level does not exceed the upper limit of the dyke.
The risk of flooding from water level rise in rivers can be calculated in the same way as the sea level rise. The water level in a river can be incremented to a given level and the water level rise can be tracked inland.
In general, at least a level 2 analysis is recommended for all blue spots.
The blue spot concept is intended for use at large and important roads in non-urban setting.

● Inspection and maintenance

Reducing vulnerability to flooding at a blue spot consists of two steps. The first focuses on information retrieval, considerations of redesigning the drainage system as well as directions concerning which elements of the drainage system should be considered at a blue spot. The second is more practically oriented, and gives information about what to look for during a site inspection.

- Considerations for Managers of Road Infrastructure
The management staffs need to work with information retrieval, in order to evaluate if a redesign of existing drainage systems is necessary, and finally determine a blue spot specific action plan for inspections and maintenance. The information related activities to be done should focus on:

- Information required for the Blue Spot Model simulations
- Background information for the site
- Current status of the drainage system
- Feasibility of monitoring (early-warning) systems
- Information storage in databases (e.g. information about maintenance and repair work, damage to road and drainage, flooding events etc).

- Inspection and Maintenance Activities

It is essential that blue spot locations are inspected and maintained regularly to prevent flooding. The activities needed in doing this are:

- Plans for inspection and maintenance
  It is important to have a plan of how and when to carry out inspections. A blue spot inspection plan is normally created by the "management office". Field personnel are responsible for undertaking inspection activities. It is proposed that inspection routines are performed annually and in connection with extreme situations, before, during and after events.
- Inspection of drainage systems
  The inspection is divided into blue spot catchment (i.e. the upstream part), the downstream recipient, the side area drainage, and the road water drainage. Suggested actions include tables with different drainage elements, inspection frequency, what to look for, and proposed actions.
- Maintenance and repair of drain systems
  The idea with maintenance and repair is to restore the intended function of the drainage system. In some cases this includes a changed design after damages to avoid future problems. The maintenance activity follows the timing of inspection. Repair work is done when damages are discovered. The maintenance activity starts with the road surface and then moves towards road edges, sides and the sub-surface drainage.

Detailed information about the project is available at [19], [20], [21] and [22].
The project reports can be downloaded from the following websites: http://www.eranetroad.org/, www.cedr.fr and www.fehrl.org.

PART II – Outcomes of workshops at final conference

A final conference was held to present the final results of the four projects and debate how those results could be implemented by road authorities. After the introduction of the RIMAROCC, IRWIN, SWAMP and P2R2C2 projects by the project coordinators, two separate break-out sessions for the four projects were held.

1. Workshop I – RIMAROCC and SWAMP

Workshop 1 facilitated discussion regarding the RIMAROCC and the SWAMP projects.

The workshop highlighted that both the RIMAROCC and SWAMP projects have provided useful tools to enable road authorities to:

- build evidence of the likely risks of climate change across road networks;
- to inform robust decision making and the prioritisation of limited resources;
- ensure consistency in the ways in which climate risks are assessed across Europe.
- to support a move towards proactive rather than reactive risk management to reduce vulnerability rather than acting after an event to deal with the consequences of climate impacts;

The projects were felt to have helped increased understanding of the risks of climate change to road networks, the challenges faced in assessing these risks and processes to support action planning to increase the resilience of road networks in future. The value of road authorities applying these methodologies to test the approaches in practice and help support ongoing refinement was noted.

It was highlighted that the two tools can be used in a collaborative way - for example the RIMAROCC method was used to prioritise the flood risk across a network within the SWAMP project following initial assessment of the high priority areas using the Blue Spot Model.

It was highlighted that urgent action is needed on adaptation – the impacts of climate are already being felt and authorities cannot afford to wait for a disaster to occur to spur action. A number of options were explored to help facilitate development of a culture to support and enable action on adaptation including:

- legislation and penalties for a lack of action
- addressing counterproductive policies that hinder action of adaptation
- reviewing funding models to ensure that consideration of adaptation is built in
- building a better understanding of the costs and benefits of different actions
- raising awareness of the consequences of a lack of action
- the need to take note of, and act on, the want for action from the public.

There is still much to learn and the findings of the projects should be used to inform the direction of ongoing research to address gaps identified through these preliminary studies.

1.1 RIMAROCC

Discussion on the RIMAROCC project highlighted the value of the methodology developed in supporting the assessment of climate risks. Some of the key benefits of the approach highlighted included:

- The flexibility of the methodology, with for example sub-steps that can be omitted dependant on the level of data available. The approach can be applied at all operational levels and supports a cyclical process to refine risk management and monitor performance;
- The compatibility of the approach with existing risk assessment methodologies used across Europe;
- Supporting both a proactive and reactive approach to climate risk management (mitigating vulnerabilities and minimizing consequences)
- Providing a process for, and evidence, to inform the prioritization of responsibilities and resources

Although the approach was used to support the assessment of climate risk to main roads it was highlighted that the approach could also be applied to rural roads.

The importance of considering the appropriate scale of assessment was discussed. The types of data that are appropriate will vary across the different spatial scales, with more qualitative information used at the network scale with a move towards quantitative information as the spatial scales decreases.

1.1.1 Recommendations for possible future development

It was felt that there would be value in the development of an approach to support robust assessment of the economic costs of action at different scales, to help road owners to provide more compelling argument on the costs and benefits of action.

1.2 SWAMP

The SWAMP project was felt to have provided an innovative, flexible and accessible approach to help road authorities to identify areas of flooding risk across the network, to enable road authorities to focus on vulnerable locations and identify where action should be taken to reduce the vulnerability.

One of the key findings of the project was that maintenance is the primary cause of drainage problems rather than the original design, a view that was supported by the workshop delegates.

1.2.1 Recommendations for possible future development

- The approach could be further developed to include consideration of groundwater
- To consider the value in developing the approach so that it enables an assessment of 'blue routes' across a network rather than 'blue spots'.

1.3 Recommendations for road authorities

A number of key recommendations for road authorities emerged from the discussion:

- To make use of the tools that are now available to support:
    - Robust assessment of the risk of climate change to road networks to support decision making;
    - The effective prioritisation of resources;
    - A move to long term proactive planning to reduce vulnerability rather than relying on reactive emergency response to deal with the consequences after an event has occurred.
- Consider the authorities attitude to climate risk – what risks are acceptable, where should systems under duress be protected etc
- Use a range of different emission scenarios to inform research to ensure decisions are as robust, and adaptation options appropriate in light of the uncertainty in future levels of green house gases,
- Educate the public further about the risk of climate change to the road network and the actions that they can take in light of these
- Develop robust and consistent data collection processes and databases where the benefits outweigh costs;

1.4 Barriers

Discussion during the workshop identified a number of barriers to the development of the approaches and to their implementation in future:

- **Climate modelling:** the poor spatial resolution of global climate models was highlighted as a challenge as was the level of uncertainty in climate modelling, which makes it difficult for decision makers to develop a strategy to deal with climate risks. A move towards probabilistic climate modelling, such as that introduced by UKCP09 in the UK, helps to clarify the uncertainty that was faced and therefore support more robust assessment of the future risks of climate change.

- **Uncertainty in future emissions pathways:** meaning that it is difficult to recommend a single emission pathway to use for planning purposes. There is a need to plan for a range of different futures due to the uncertainty in the level of future emissions dependant on how successful current and future efforts to mitigate green house gases are.

- **Counterproductive policies:** some policies may present challenges in addressing the risk of climate change to road networks– for example the EU Water Framework Directive, which limits the amount of water that can be discarded from a site, and may limit actions that can be taken to reduce the risk of flooding at Blue Spot Sites identified.

- **Lack of funding/current economic climate:** the level of funding for maintenance and inspection of roads has been reduced in many circumstances presenting a potential barrier to the introduction of new approaches which require initial investment. Although it is likely that there will be some initial investment required, it should be highlighted that the approaches, once implemented, will support the prioritisation of resources and therefore more efficient and effective use of limited resources available.

- **The challenges in developing generic guidelines:** The importance of information on local circumstances in assessing the risk of climate change was highlighted which presents a challenge in the development of generic guidelines that are applicable in all European member states.

Workshop II – IRWIN and P2R2C2

Workshop 2 facilitated discussion regarding the P2R2C2 and the IRWIN projects.

2.1 IRWIN

IRWIN has developed an improved, more reliable winter road maintenance index. Most current winter indices make use of meteorological data. IRWIN's winter index makes use of RWIS data, which improves the accuracy of the index. This is because of the density of the data (provided that a sufficient number of RWIS stations has been installed), the short time interval between weather recordings and the proximity of the RWIS stations to the road. By linking it to climate change scenarios, it also provides a useful tool to project expected changes in future maintenance needs.

IRWIN's local winter index is designed for use in specific areas (local road network scale) as an assessment aid in present-day as well as future climate scenarios.

2.1.1 Recommendations for road authorities

IRWIN's local winter index is a useful tool for local governments, winter maintenance contractors and roads owners to plan their day-to-day and annual winter maintenance operations, to project future maintenance needs and to estimate resources that would be required for, for instance, snow removal and de-icing.
The index requires good quality RWIS data. This necessitates the installation of sufficient RWIS stations to produce these data. Ideally, long, uninterrupted time series would be required. The need was expressed for archiving RWIS data into a central European database, similar to what is already being done in the USA.
The index also requires historical maintenance data so that current and projected maintenance needs can be estimated by using climate analogues for maintenance actions. Also here, there is a need for archiving historical maintenance data.
The IRWIN principles can be adapted for other applications related to climate, such as maintenance actions associated with strong winds, heavy precipitation, flooding, freezing and thawing, etc. The data input requirements would essentially be the same as for winter maintenance: good quality historical RWIS data would be required, as well as a historical record of road maintenance associated with these weather parameters, and appropriate climate scenarios for projection into the future.
The IRWIN index may still require some work to turn it into a user-friendly and transportable tool for implementation elsewhere. However, according to the project team, replicating IRWIN elsewhere can be done fairly easily, provided that quality RWIS data as well as maintenance records are available, and climatologists are available to provide specialist input.

2.2 P2R2C2

P2R2C2 produced a set of 10 reports; the final report providing an overall summary and guidance to road owners on how to deal with the likely impacts of climate change on road pavements.
P2R2C2 also produced maps, based on two emission scenarios and climate models, which can be used by road owners to identify the long-term climate factors that may impact on their road networks.
The project team identified actions that would require immediate attention, as well as actions that could be phased in over time. Immediate actions include:

- Ensuring that proper and timely routine maintenance is effected to drainage systems;
- Updating design standards for new climates:
    - Redefining appropriate temperatures for materials and structures in order to prevent rutting in bituminous bound layers;
    - Developing drainage designs to cater for higher flows;
- Considering a programme of stabilisation of unsealed pavements in the Nordic/Baltic region;
- Raising road levels at low spots (or “blue spots” as defined in SWAMP); and
- Giving greater attention to crack sealing (note: the study indicated that incidences of top-down cracking were likely to increase as a result of climate change).

The project team concluded that if the above recommendations are implemented, no insurmountable problems should be expected as a consequence of climate change. Key to the above is to keep water out of the subgrade and the pavement structure by the provision of adequate subsurface and/or above-surface drainage structures and, most importantly, to ensure that proper and timely routine maintenance is effected to both the drainage structures and the pavement structure (e.g. crack sealing).

Warmer winters in the Nordic and Baltic areas may cause unsealed pavements to become hazardous and/or impassable as a result of thaw-weakening. P2R2C2 recommends that a gravel road improvement programme should be considered by which to upgrade unsealed pavements in order to provide a reliable, high, bearing capacity all winter long.

2.2.1 Recommendations for road authorities

P2R2C2’s aim was not to produce a tool that road owners could use, but rather to provide information and advice to road owners on how to prepare for, and protect road pavements from, the effects of climate change.
The project produced several useful outcomes, which were amplified during the Conference:

- The need was identified for road owners to break the habit of customarily specifying historically ‘trusted’ designs that had offered good performance in the past, since there is no guarantee that these designs will continue to provide similar performances in the future.

- Design standards may have to be adapted so as to satisfy conditions that will become prevalent during the structural lifetime of the pavement. In addition to traffic loading, up-to-date climate-related factors (e.g. temperature regimes and moisture conditions) should be considered in the design of new, rehabilitated or reconstructed road pavements. This may have some implications for road contractors (e.g. use of different asphalt gradings and storage of different binder types at the asphalt plant).

- Not enough emphasis can be placed on the importance of preventative maintenance. Early interventions by means of routine or periodic maintenance are more cost-effective than deferred treatments, which eventually may require some form of rehabilitation or even reconstruction. Under normal circumstances, if road maintenance is delayed, the cost of repairs and rehabilitation increases exponentially: a delay in road maintenance by 3 to 5 years could increase the required repair costs by between 6 and 18 times. With climate change, and more specifically as a consequence of extreme weather events, the costs of deferred maintenance may escalate even further. Deferred maintenance will also impact on road user costs and the safety of road users.

- Design tools, engineering solutions and techniques for rendering pavements more climate change resilient are readily available. There is as yet no need to adapt CEN standards. However, greater information sharing and education on adaptive solutions should be promoted both within the structures of the road authorities and amongst road owners, including local authorities.

PART III – Implementation strategies

1. Workshop feedback on implementation

This section presents key discussion points from the plenary session (final session) of the conference. The session focused on getting feedback from the conference participants on the specific projects and determination of the most appropriate way of utilising the projects' recommendations and ensures that the tools and outputs are implemented across Europe. The conference participants provided the following general comments:

- Road authorities should "break the habit" of designing road infrastructures as they have always done and the tools and models identified in the four projects could be very useful in doing this. There is a great scope for the implementation of the results of the four projects across Europe.

- Actions need to be taken now rather than later. There is the need to look critically at the policies and legislations that are in place that prevent the road authorities from taking actions, and there should be an urgency to have new policies and legislations that will enhance actions from a climate change perspective.

- As the implementation stage is the most difficult in a typical research cycle a lot of effort needs to be exerted in making sure that the research results are not kept too long "on the shelf". A continuous encouragement and dialogue between CEDR members is required to overcome the hesitation of road authorities when facing the inevitable risks of implementing the innovative approaches proposed in these four projects. A commitment to organise, for example, a follow-up conference could go a long way in ensuring that the tools and models are put to use. The aim of the conference, which could be held in a couple of years' time, would be to receive feedbacks from CEDR members about how implementation is progressing in their respective countries. It will also enhance and encourage exchange of experiences between the national road authorities.

- It was noted that implementation has to be at national level though the consortium in each of the projects was multi-national. Exchange of information and experiences should however continue between the different road authorities across Europe. Close working relationships are also encouraged with other existing networks e.g. PIARC Technical Committee on Road Pavements.

- The role of CEDR's Technical Groups on Adaptation and Mitigation in the implementation phase cannot be over emphasised. Although these groups have not really been involved in the programme to date, they hold the key in making sure that the results are implemented in a harmonised way across the CEDR members.

2. Implementation of project results

2.1 RIMAROCC

The output of RIMAROCC is a systematic approach to manage risks. Although the project adopted a fairly universal best-practice approach to address risks, it has been customised to address specific risks associated with extreme weather events (e.g. extreme rainfall events) and long-term climate change effects (e.g. sea level rise). The approach allows for socio-economic analyses to provide road owners with compelling arguments on the costs and benefits of actions.

The methodology proposed in RIMAROCC is of a sufficiently flexible nature that it can be implemented in local as well as in regional/national road networks. It provides guidance on how to address and manage climate change associated risks at both project level (predominantly quantitative data) and network level (predominantly qualitative data).

It is recommended that the principles of RIMAROCC be implemented in prefeasibility and design studies to identify viable and cost-effective solutions, and that it be fed into regional and national studies to identify and prioritise critical problem areas that could hinder the functionality of the network or parts thereof. The approach used in RIMAROCC is compatible with existing risk assessment methodologies used across Europe, which facilitates its integration into existing risk assessment and risk management approaches.

As increasing the resilience of road systems to climate change is all about assessing the risks of climate change and then using this information to support robust decision making, developing and implementing tailored action plans to respond - the RIMAROCC risk assessment methodology provides a good overarching approach. The other three ERA-NET ROAD initiated projects then have the potential to be used to support this approach to help assess the risks of climate change in more detail.

The methodology of RIMAROCC is sound and, hence, its implementation across Europe should be promoted in order to mitigate the risks associated with climate change in a rational and cost-effective manner.

2.2 SWAMP

The outputs of SWAMP are (i) a chain of procedures to identify and mitigate so-called "blue spots" (to be extrapolated to 'blue routes'), namely areas and/or essential road links that are most vulnerable to flooding as a consequence of extreme rainfall events, sea level rise and/or river flooding, using geographical data as a basis; and (ii) national/regional guidelines for the inspection and maintenance of drainage systems.

SWAMP provides road owners with an innovative, flexible and accessible approach to identify areas of flooding risk across the network, enabling them to focus on vulnerable locations and to identify and prioritise areas where actions should be taken to protect the serviceability of the road network.

The implementation of the methodologies of SWAMP should be promoted across Europe in order to mitigate risks.

2.3 IRWIN

The output of IRWIN is a more accurate local winter index which improves the reliability in predicting present and future needs for winter maintenance as well as their associated costs.

The index can be implemented in countries where winter maintenance has historically been, or is becoming an issue that has to be dealt with. The winter index can be used as a planning and budgeting tool for preventative maintenance, maintenance scheduling and resource levelling. It also provides better information on extreme events, such as heavy snowfall and strong winds, which may impact on the serviceability of the road network.

In order to implement IRWIN, information from Road Weather Information Systems (RWIS) is required, as well as historical data. Both Sweden and Finland are in the fortunate position to have RWIS installed at fairly close spacing, at least in the southern parts of the country, and they have already sufficient archived historical weather data available to fully implement the winter index developed by IRWIN, which will enable them to reap the benefits thereof. In order to reproduce and maximise the benefits of IRWIN to other countries and regions, strong motivations should be formulated for the establishment of RWIS similar to those positioned in Sweden and Finland. After two consecutive 'hard' winters in the northern parts of Europe, with associated road and airport closures, the motivation for the implementation of the basic infrastructure required for IRWIN should be evident. That said the inter-regional transfer and applicability of the linkages between historical data and maintenance operations (a key ingredient of IRWIN) would still have to be explored.

The output of IRWIN is, however, not only a winter index, but also a methodology on how to integrate historical data, climate data and climate scenarios to provide information on current and future maintenance needs. The methodology does not only apply to winter maintenance. It can also be employed to improve the reliability of predictions on hot weather, strong winds, heavy precipitation, flooding, freezing and thawing events. The same methodology can be applied, but would require a different set of outputs from the RWIS.

If climate change is to be taken seriously, as it should, the measurement and archiving of all pertinent road weather information should become a priority. The archiving of RWIS data in a central database, similar to what is being done in other countries such as the USA should be strongly considered.

2.4 P2R2C2

P2R2C2 provides a long-term perspective on climate change related effects that would impact on the integrity of road assets. The true value of the study does not reside in the long-term (100-year) prediction of the effects and impact of climate change, but rather with the assumptions made in the study that, when appropriate actions to reduce the risk of climate change have been phased in over time, these would negate the long-term effect and impacts on road infrastructure. With respect to the latter, the following issues were raised:

- Road owners need to continuously adjust their material and structural design methods to take into account changing realities caused by climate change effects. Hence, road owners should accept that there is no longer a guarantee that the technological and engineering solutions which offered them adequate performance in the past will provide similar performances in the future. This applies to surfaced roads all across the European continent as well as to low-volume unsealed roads in, for instance, the Nordic countries;

- Drainage systems should be upgraded and roads realigned, where warranted, to accommodate the consequences of extreme rainfall events; and

- Greater attention and resources should be devoted to preventative maintenance, with specific focus on the maintenance of drainage structures and the sealing of cracks in road pavements.

3. Synergies between the projects and recommendations

In essence, each of the four ERA-NET ROAD initiated projects address the same four basic questions, namely:

- What will happen?
- How likely is it to happen?
- If it happens, what are the consequences?
- How can it be mitigated?

The above questions are addressed in the four ERA-NET ROAD initiated projects from different perspectives, but they all provide basic building blocks which, when integrated, do contribute towards the formulation of a holistic approach that would provide guidance to road authorities on how to deal with the effects and consequences of climate change and, more importantly, on how to mitigate potential risks that could impact on the serviceability of European road networks or sections thereof.

Since climate change is fast becoming a reality, pragmatic approaches to deal with the effects and impacts of climate change should become entrenched in the decision-making matrix of all road owners in Europe, and provisions should be made (i) to augment maintenance budgets to protect current assets (e.g. basic preventative maintenance of road, bridge and drainage structures), and (ii) to institute mitigation actions to protect the European socio-economic fabric from the effects and impacts of climate change by providing all-weather access and protecting the road-based communication network. All four ERA-NET ROAD initiated projects provide some of the necessary methodologies to support the above although some effort will be required to integrate them into a holistic system.

Synergies between the four projects should be sought at the level of integrated asset management and decision support systems, with the latter supporting either project or network level decision support.

European decision support systems should be developed and adapted to incorporate the climate change associated risk concepts embraced by RIMAROCC.
These systems, however, need to be supported by reliable data. The development of SWAMP at a multi-national and perhaps European level should be explored. For practical reasons, this should start at the level of the Trans-European Networks (including possible application to the rail network). Both IRWIN and SWAMP provide useful methodologies by which reliable data can be obtained and uncertainty can be reduced. At the same time, the outputs of IRWIN and SWAMP, within a broader framework, could also feed into forecasting models for incorporation in pavement, bridge and drainage management systems, and therefore also in integrated management systems.

However, some additional work will be required. It should be ensured that any work is based on the latest climate projections and emissions forecast to help ensure robustness. For example the UK Climate Projections (UKCP09) help to support robust decision making by providing information on a range of possible futures and the strength of evidence to support each made possible by the probabilistic approach to modelling adopted. UKCP09 provide more transparency on the level of uncertainty faced and therefore help decision makers to take a flexible approach based on the level of risk they are willing to accept. IRWIN also posed the challenge, within a broader framework, to implement a dense network of road weather information systems across Europe to capture (and archive) relevant weather data. Any decision would be flawed in the absence of reliable data.

The analysis of the four projects also leads to some more general comments.
The outcome of the programme demonstrates that in some cases, projects may be more relevant at a regional level than at a fully-European nature. Whilst all the project partners attempted to cover the breadth of Europe, it is clear that a regional focus might have proved more relevant in some cases. In the overall context of the ERA-NET ROAD process, it is recognised that the individual needs of every road authority cannot be met in each and every project but that overall there will be a balance. What authorities do not gain on one project they would expect to gain on another? However, whilst that concept applies overall, there is a case that at an individual project level some national needs might not be met. In building future programmes, the balance between individual national needs will be something to be addressed.

The climate change call had very broad ranging objective. Taking into account the relatively modest size of the programme and these diverse needs, it is not readily apparent how the projects were coordinated as a programme. In this case, there was very little overlap and there was an advantage that each was able to pursue very different avenues of activity. At this early stage in the development of knowledge on the impacts of climate change, there is no harm in this approach. It could be argued that scattering the seeds widely makes it more likely that some will take hold. However in other areas, and as this subject advances, a more coherent approach should be taken.

The obvious question is if the objectives could have been better achieved with one single large project. There are clear economies of scale and a larger project could lead to wider geographic participation, however as described earlier this would have reduced the ability to persue very different approaches.

In the context of thematic calls, more emphasis should be placed on the objectives of the topic and not only on effectively managing the projects. ERA-NET ROAD is based on need for road authorities to have results and not just on managing the projects. More emphasis should be placed on examining and exploiting the outputs of other projects funded at both national and international levels. The final conference demonstrated some of the broad range of activities being carried out on this topic. Whilst the individual project participants did make some important connections with other activities, this was not optimal for the programme. It is suggested that in similar cases, more coordination and networking is carried out at a programme level rather than project level.

The overall conclusion of the conference is that ‘road owners are starting to get to grips with climate change’ but this programme is just a first step.

Conclusions

Four research projects were let in 2007 by the "Road Owners Getting to Grips with Climate Change" Programme Executive Board (PEB) of the ERA-NET ROAD Programme. These ERA-NET ROAD initiated projects, IRWIN, P2R2C2, RIMAROCC and SWAMP, focused on issues such as winter maintenance, impacts on road pavements, risk assessment and flooding. The objective of the research programme was to investigate issues of climate change adaptation that would provide tools for road authorities to identify and prevent future problems to road infrastructure.

At the conclusion of the programme, a final conference was organised to present the findings and the recommendations. This event took place in Bergisch Gladbach Germany and exposed practical outputs that can be applied across Europe, and is important in facilitating the understanding of this research across the funding member states.

The purpose of this report has been to bring together the findings and recommendations from the four projects and show how road authorities can implement the recommendations from each of the projects in an efficient manner.

Adaptation of the road networks to climate change is one of the important issues facing road authorities in Europe. The impacts of climate change are already been felt and as such urgent actions are needed. The tools and models developed in IRWIN, P2R2C2, RIMAROCC and SWAMP will go a long way to help road authorities:

● identify areas of flooding risk across the network, focus on vulnerable locations and identify where action should be taken to reduce the vulnerability

● plan day-to-day and annual winter maintenance operations, project future maintenance needs and estimate resources that would be required for, for instance, snow removal and de-icing

● prepare for, and protect road pavements from, the effects of climate change

● identify and understand the risks of climate change to road networks and implement action plans that maximise the economic return.

Some key overarching recommendations are:

● to ensure that assessment of the risks of climate change on infrastructure is built into the wider risk management processes of road authorities (using the tools and methodologies developed to support this process)

● to highlight the benefit of the tools in supporting the development of a robust database on the likely impacts of climate change on infrastructure. The different tools could be applied flexibly by road authorities depending on the geographical context, climate etc of the country

● to exploit the value of such a database to raise awareness of the of likely costs of climate change to ensure the buy in of key decision makers and help such groups to make informed decisions to effectively improve future resilience.

To maximise the value of this programme, it should be necessary to organise a further conference after two years to review the progress on impememtaion by each road authority.

While understanding the complexity and difficulties involved, it is felt that more time and resources should have been allocated to the "climate change issue" on a programme (and not project) basis. Although the four projects were all part of the overall programme, they were run very much individually and as a result their focus on different types of climate risks/countries involved etc. This obviously offers some advantages – e.g. their ability to be able to develop and test different approaches but also reduces the synergies. The programme at the end was a bit fragmented and probably could have delivered more than the results obtained.

More emphasis needs to be laid on the implementation aspects of the results. Either this is imbedded as part of the outcome of the projects or a special call is announced specifically to implement the results at selected places/countries in Europe. It seems there is no defined strategy of how to proceed with the available results. And as it was indicated by the participants of the final conference, there needs to be a concerted effort to ensure that the tools and models are used across CEDR member countries.

Where do we go from here? Obviously the issue of climate change will not disappear overnight. A lot more still needs to be done to help road authorities tackle this issue. A good way of ensuring that this remains a top priority is the involvement of CEDR's Working Group on Climate Change. First and foremost, the research results should be disseminated to other CEDR countries not directly involved in the programme. Secondly, this WG should be at the forefront of helping road authorities implement the project results. Thirdly, implementation becomes easier when an implementation agent (organisation, WG etc) is identified at the early stages of a project/programme. In an ideal situation, the implementation agent should have a close working relationship with the project team and advice on how to package the research results for maximum benefits to the users. It is felt that this role should be played by CEDR's Working Group. Early involvement of this Working Group could also have helped in selecting appropriate methods for transferring the tools and models developed in the projects. Active involvement of stakeholders (Working Group consisting of representatives of CEDR members) also builds trust which is a very important element of successful implementation.

The ERA-NET ROAD concept which encourages cross-border trans-national cooperation between National Road Administrations in Europe is an initiative which should be continued in the future as it gives the road authorities the possibility to tackle issues of great concern to them. It is clear that this particular programme has been a success as it not only included a number of European countries as project partners, but also addressed a topic of utmost importance to all road authorities across Europe. Future programme calls need to follow this trend (most especially with regards to number of participating countries). This will help eliminate or avoid the "not invented here" and "it cannot work here" syndrome.

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