

Project Nr: TR80A 2008:72148

Co-operation level: Common Obligation

RIMAROCC: Risk Management for Roads in a Changing Climate

Start date of project: 01.10.2008

End date of project: 31.07.2010

Duration: 22 Months

### Monitoring Progress Report 3

Reporting period from 05.30.2009 to 01.01.2010

**This report is prepared by the Contractor of the research project  
and presented to the Project Executive Board.**

**Project Executive Board:**

AT,	Federal Ministry of Transport, Innovation and Technology (BMVIT)
DE,	Federal Ministry of Transport, Building and Urban Affairs (BMVBS)
DK,	Ministry of Transport, Danish Road Directorate (DRD)
ES,	Centre for Studies and Research in Public Works (CEDEX)
FI,	Finnish Road Administration (Finnra)
IE,	National Roads Authority (NRA)
NL,	Directorate of Public Works and Water Management (RWS)
NO,	Norwegian Public Roads Administration (NPRA)
PL,	General Directorate of National Roads and Motorways (GDDKiA)
SE,	Swedish Road Administration (SRA)
UK,	Department for Transport, Highways Agency (HA)

**Project Leader:**

SE, SRA

**Programme Executive Chair:**

AT, BMVIT

**Contractors:**

SE,	SGI	(Coordinator)
FR,	EGIS	
NL,	Deltares	
NO,	NGI	

**Objectives**

Describe the objectives of the project stated in the MoU and any modifications introduced later (not more than ½ page):

**The objective of the proposed project is to develop a common ERA-NET ROAD method for risk analysis and risk management with regard to climate change** (we agree with the view in the GfA, that a common *method* i.e. a systematic way of structuring and calculating is more needed at this point than a *model* – a numerically based tool for detailed calculations and e.g. simulations). The purpose is to support decision making concerning adaptation measures in the road infrastructure. To facilitate the work of end users the method will be based upon, or at least be compatible with, general existing methods for risk analysis (and management) within the ERA-NET ROAD funders and other relevant methods. Specific improvements of existing methods will be developed where they are necessary to effectively deal with climate change.

**The project is focusing on Topic 2 in the call, Risk Analysis – with risk assessment, risk management in cost-benefit analysis and level of acceptable risk, and Topic 5, Risk management Options.** This integrated approach will greatly facilitate the consistency of methodological deliverables and the work of end users among road authorities.

A specific attention will be given to both **new** road design and improvement/maintenance/operation of **existing** roads. The project will take into account the present knowledge of future climate evolution (short, medium and long-term) and the design life of roads and structures ; at the same time it will add value and qualities today. The architecture of the methodologies will be designed to facilitate their easy-updating when new knowledge appears and to facilitate the complementary responsibilities of the various concerned organisations.

Appropriate coordination with research organisation responsible for topics 1, 3 and 4 are very worthwhile for effectiveness.

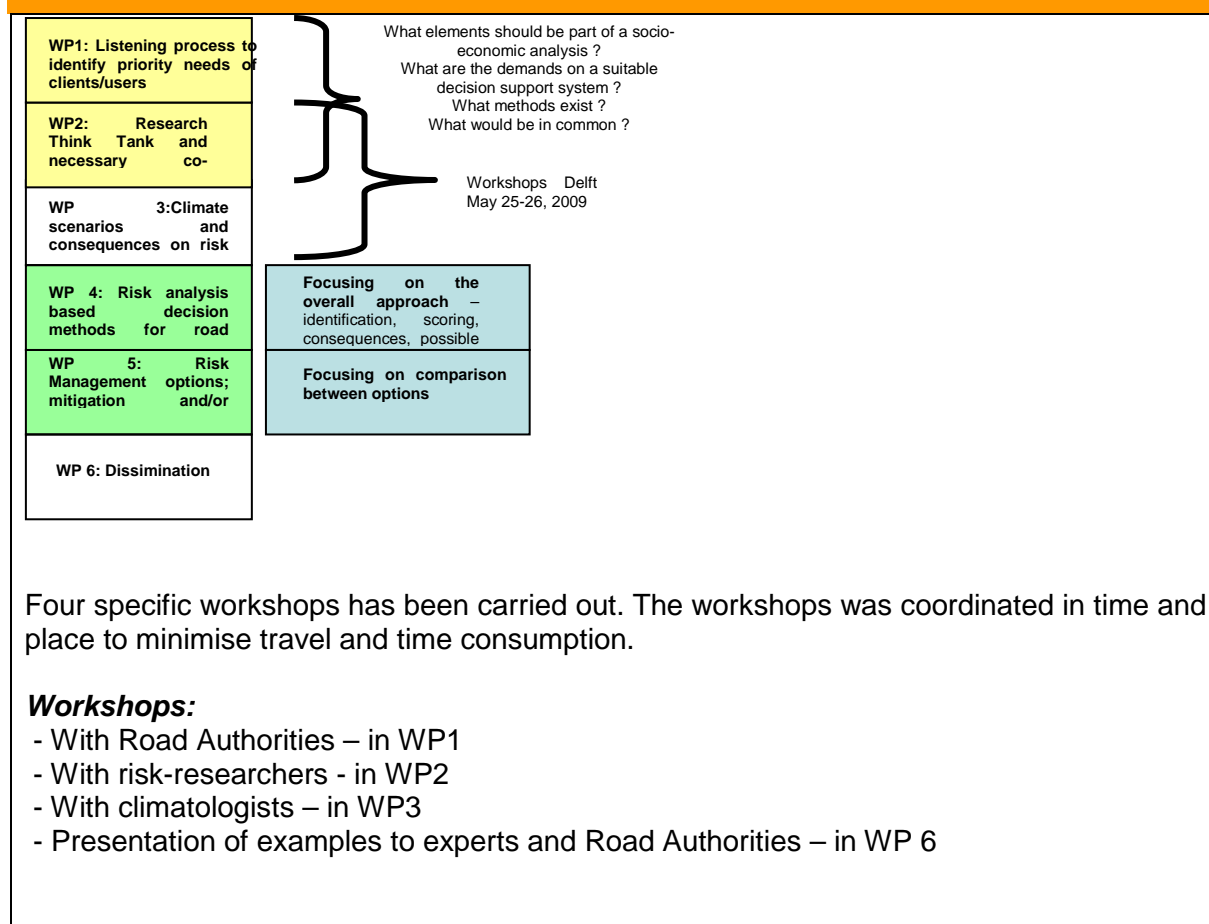
**Technical Description**

Describe the items of technical work, the mode of operation, possible subdivision in Working Groups and how management is organised (no more than 2 pages):

The project is directed by a Project Management Group with representatives from all partners. The project management group will meet regularly when needed, and at least every six months. The specific Electronic Board Room at Deltares is be used to facilitate concurrent engineering, i.e. for identification and classification of risks via expert sessions.

An ERA-NET Steering Group is formed to follow the project.

The project is organised in 6 Work Packages, each with a responsible WP-leader. All WP:s are connected, but specifically W1 and WP2 respectively WP4 and WP5.



## Participation and coordination

### Project Stearing Group (PSG)

Project Manager:

Åsa Lindgren, SRA, Sweden

Members:

Alberto Compte, CEDEX, Spain

Geoff Richards, HA, UK

### Contractors

Chair, Secretary:

Bo Lind, SGI, Sweden

Chalmers Vasa, Hugo grauers gata 5 B

Tel., +46 31 778 65 66

email bo.lind@swedgeo.se

Fax., +46 31 7785940

Members:

France, Michel Ray, EGIS

The Netherlands, Thomas Bles, Deltares

Norway, Frode Sandersen, NGI

### Meetings of the Contractors and PSG:

13-14 October 2008

SGI, Göteborg, Sweden

31 March 2009, Oslo  
25-26 May 2009, Delft

## Report on Results (so far)

Objective/Milestone:	Assessment
<p><b>1 Partner Presentation of our organisations</b> A Project Management Group has been formed : SGI, Bo Lind; EGIS, Michel Ray; NGI, Frode Sandersen; Deltares, Thomas Bles.</p> <p><b>2 WP 1, The Listening process</b></p> <p>Workpackage 1, the listening process, has been completed, including the workshop in Oslo in March 2009.</p> <p>The workshop did focus on key actual needs of the ERA-NET Road partners and the necessary functions of the Rimarocc risk management method. The purpose was weighting the importance of different functions with regard to the needs and the design objectives.</p> <p>The workshop used a Value Engineering approach – that is a systematic process by a team to increase the value of a project.</p> <p>One of the concrete outcomes of the listening process was a list of important functions and design qualities of the Rimarocc methodology. Examples of key Functions and design Objectives are:</p> <p><b>E.g. Key Functions:</b>  F12 - The method should make it possible to identify risk factors (climate factors, infrastructure intrinsic factors, site factors)  F14 - The method should make it possible to determine risk levels and their critical loads (risk factor → graded risk level)  F15 - The method should make it possible to define the level of acceptable risks (acceptable vs non-acceptable risk)  F16 - The method should make it possible to prioritize roads and structures according to the risks (graded list)  F28 - The method should be a framework to calculate socio-economic costs and benefits (costs of physical structures, personal and societal costs)  F29 - The method should be a framework to estimate mitigation efforts/measures (through cost – benefit analysis)  F210 - The method should be a framework to prioritize mitigation efforts/measures (criteria and hierarchy)</p> <p><b>E.g. Key Design Objectives:</b></p> <ul style="list-style-type: none"> <li>Common way of identifying and preventing problems with the road infrastructure due to climate changes</li> </ul>	<p><b>GREEN</b></p>

- Consider specific features of the European countries (risk of flooding, snow, wind ...).
- Already Implemented in existing organisations
- “Method” (i.e. a systematic way of structuring and calculating)
- “Robust” method able to cope with climate change uncertainty and with various scales of project (structure, section, network)
- Dealing with both new road design and improvement/maintenance/operation of existing roads
- Taking account of the present knowledge of future climate evolution (short, medium and long-term) and the design life of roads and structures
- Release of a short report for practical use (rather than a theoretical “Research report”).

## WP 2, Research Think Tank on Risk management

A workshop on Risk management was held in Delft in May 2009.

Main objective of the workshop was getting in depth insight in risk management methods and strategies with relevance for the Rimarocc project. Specifically the three identified methods, from UK, The Netherlands and France, was studied in order to be able to pick the best suitable method for RIMAROCC, or to gather the most appropriate aspects from different methods in order to assembly a new method. Presentation and discussion about the methods give detailed and thorough insight in the methods.

During the workshop a set of questions was prepared and discussed:

- **Main question:** What elements of the discussed methods need to be further explored to become part of the RIMAROCC method? Is it possible to use one of the methods directly? (answer before lunch).
- What features are necessary in the method? In order to be able to:
  - Use different and differing climate scenarios in the same method
  - Use the method in different organizations
  - Fit with end user demands
- How can climate change related risks best be identified?
- How can climate change related risks best be assessed and classified? (Possibly the electronic board room can be used in order to brainstorm on this question)
  - What criteria can be used?
  - What are accompanying indicators with these criteria?
- How can measures for non acceptable climate change related risks best be identified and compared in order to be able to choose the most pertinent option?
- How can identified risks best be continuously evaluated as part of a regularly climate change adaptation check by road owners?

## WP 3, Climate scenarios and consequences on risk approach

The existing view among road administrators on the critical weather conditions for roads in a future climate change has been compiled through a bibliographical review of some major references:

- UK Climate change adaptation strategy
- US report “Potential impact of climate change on US-transportation”
- France: GERICI
- Sweden facing climate change – Threats and opportunities
- Australia: Impact of Climate Change on Road Infrastructure
- Netherlands: Effects of climate change on traffic and transport

## CLIMATE CHANGE ADAPTATION STRATEGY (UK, Volume 1, 31 March 2008)

Overview: The 3<sup>rd</sup> chapter is devoted to climate change trends. The purpose is to “identify climatic trends affecting Highways Agency”. Are distinguished primary climatic variables and secondary climatic impacts. The following listing of variables is provided in the report, without any comment.

Climate variables:

## Primary climatic changes

- Increase in average temperature
- Increase in maximum temperature
- Increase in winter rainfall
- Reduction in summer rainfall
- More extreme rainfall events
- Reduction in snowfall
- Increased wind speed for worst gales
- Sea level rise

## Secondary climatic change impacts

- Longer growing season
- Reduction in soil moisture
- Change in groundwater level
- Flooding
- Reduction in fog days in winter
- Reduction of icy days in winter
- Frequency of extreme storm surges

**POTENTIAL IMPACT OF CLIMATE CHANGE ON U.S. TRANSPORTATION (USA, 2008)**

Overview: In section 2 – Understanding Climate Change, a chapter is devoted to “Climate Changes Relevant to U.S. Transportation”. Based on current knowledge, climate scientists have identified five climate changes of particular importance to transportation and estimated the probability of their occurrence during the twenty-first century.

Climate variables:

- Increases in very hot days and heat waves – highly likely (> 90 % probability of occurrence)
- Increases in Arctic temperatures – virtually certain (> 99 % probability of occurrence)
- Rising sea levels – virtually certain
- Increases in intense precipitation events – highly likely
- Increases in hurricane intensity – likely (> 66 % probability of occurrence)

**GERICI (France, 2007)**

Overview: The hazards taken into consideration in GERICI are called Unwanted Events (UE). Each UE is regarded as a long-term hazard for the infrastructure or its components, as also for continuity of service (traffic) and residents.

The motorway components are subject to detailed expertises intended to identify possible UE vulnerability. Seven main components have been analysed: major hydraulics (bridges), minor hydraulics (catchment area < 2 km<sup>2</sup>) and drainage, engineering structures, equipment, geotechnics, environment, and pavements. The components have been classified in families according to their degree of sensitivity to the same meteorological event. The variation in the intensity of the event makes it possible to establish three typical thresholds for each element: dimensioning level, critical level, breaking level.

Climate variables

- rain (mm/h and mm/24h), changed in flows (m<sup>3</sup>/s) when associated to a water catchment area
- flood (m<sup>3</sup>/s or clearance in m), e.g. critical level if clearance < 0.5 m under a bridge
- wind (km/h), e.g. critical levels if wind speed > 170 km/h for vertical road signs
- snow (snow thickness and snow weight as a combination of thickness in cm, temperature in °C, and wind speed in m/s)
- Frost (combination of number of icy days and average temperature in °C)
- Heat waves (°C), e.g. critical level if temperature > 60°C for road pavements in day time, > 50°C at night (vary according to the bituminous content).

**SWEDEN FACING CLIMATE CHANGE - THREATS AND OPPORTUNITIES (SWEDEN, SOU 2007:60).**

**APPENDIX B1, THE ROAD NETWORK (SRA)**

Overview: As an input to the national *Swedish Commission on Climate and Vulnerability* the Swedish Road Administration has studied the impact of climate change on the Swedish road network. The Echam4 model and A2 emission scenario was chosen as a basis and the time scale 2070-2100.

Climate variables

The specific weather conditions that were considered as most critical were defined as:

- Changes in precipitation - with a 10-40 % increase in large parts of Sweden.
- High flows - increasing frequency
- Ice - more zero-crossings expected. E.g. shortening the life span of a road body.
- Sea level – rising. More erosion and flooding.
- Temperature – rising and affecting e.g. ground frost which is important for the bearing capacity of forest roads during winter.
- Wind – rising number of storm events

Comments:

The Vulnerability for different components in the system is summarised in a table:

<b>Road network components</b>	
Swedish SRA, SOU 2007:60, Appendix B 1.	
<b>Component</b>	<b>Climate related vulnerability</b>
Road	Landslide, Rockfall, erosion
Road	Flooding
Road	Snow and ice hindrance
Road embankment	Deformation and cracks
Pipe	Dam, erosion, flushing away of road
Bridge	Temperature induced tensions
Large bridges	Wind-swinging, wind-load
Hanging bridge	Ice
Concrete bridge	Shorter life span
Wooden bridge	Shorter life span
Low bridge	Dam, erosion, flushing away of road
Bridge-owerburdon	Dam, displacement
Piers	Erosion
Tunnels	Flooding
Ferry-harbour	High and low water level

**IMPACT OF CLIMATE CHANGE ON ROAD INFRASTRUCTURE (Australia, 2004)**

Overview: Austroads and the Department of Transport and Regional Services engaged ARRB Transport Research and CSIRO Division of Atmospheric Research to undertake a project to examine likely future climate scenarios for the whole of Australia during the 21st Century, and investigate the likely effects of this climate change on major road infrastructure, as represented by the Australian National Highway network.

The raw CSIRO Division of Atmospheric Research climate data has been transformed into parameters required by the pavement deterioration models used in the project.

Climate variables:

- Temperature (monthly averaged temperature in °C)
- Rainfall (monthly averaged rainfall in mm)
- Thornthwaite moisture index

Comments:

Climate is represented in the pavement deterioration models by the “Thornthwaite moisture index” (Thornthwaite, 1948), which is a function of precipitation, temperature and potential evapotranspiration. The latter depends on a range of factors including temperature and length of daylight hours. Roads in



areas with higher value for the Thornthwaite index will deteriorate faster than those with a lower value for the same traffic loading. A warmer and wetter climate leads to a higher rate of pavement deterioration, both as function of time and as a function of the pavement load (measured in equivalent standard axles; ESAs).

Moisture and temperature are major influences on road deterioration: moisture affects pavement structural performance; and temperature affects surfacing performance (through bitumen aging effects which include oxidation and embrittlement).

Due to project constraints, it has not been possible to examine the impacts of extreme weather events such as extreme rainfall, extreme temperature or flood frequencies, but it is assumed that these events will also impact on road design, road condition and operation.

### EFFECTS OF CLIMATE CHANGE ON TRAFFIC AND TRANSPORT (Netherlands, 2008)

**Overview:** This exploratory study is a response to the need of the Directorates-General for Passenger Transport (DGP) and Transport and Aviation (DGTL) of the Ministry of Transport, Public Works and Water Management to be able to ascertain whether any or additional policy measures are needed in order to adapt traffic and transport to climate change in time. The study was based on Royal Netherlands Meteorological Institute (KNMI) estimates regarding the way in which climate change is set to develop. The report describes observed effects of climate change on traffic and transport and the possible measures which have been and are being taken.

#### Climate change induced weather conditions:

- Rise of average temperature
- Rise of extreme heat (summer)
- Rise of sea level
- Rise of extreme drought (summer)
- More often low water levels
- Rise of intense rainfalls
- Rise of storms
- Rise of high water levels and flooding
- More mild winters

Effects	Adaptation measures
<b>Infrastructure construction, management and maintenance</b>	
Rutting (melting asphalt) of roads	Improved construction or more repair (research)
Flooding of roads by intense rain fall	Adaptation of design criteria (normative rainshower)
Loss of electric systems of roads	Improve, fall back systems, more repair
Jammed bridge openings	Widening of dilatations (research)
Softening of substructure of roads	Improved construction or more repair (research)
Consolidation of substructure of roads	Improved construction or more repair (research)
Flooding	Dike improvement or compartments, escape routes
<b>Settlement of traffic and transport</b>	
Decrease of availability and capacity of roads	Short period: none, long period: re-route
Rise of importance of weather alarms	Further developments, improve and tune
Rise of number of repairs	Anticipate on volume and timely help
Rise of use of remedial tools and emergency services	Equip for more intense use
Rise of importance of evacuation and emergency plans	Development of demands on road infrastructure
Congestion	Variable effect, continuation of existing policy
Rise of traffic unsafety	No substantial effect, continuation of existing policy
Noise production	Limited effect, continuation of existing policy
Discharge emission and photochemical smog	Variable effect, continuation of existing policy

### SYNTHESIS



The critical climate conditions was elaborated in workshops in Oslo and Delft with the help of climate specialists. The results was compiled into a “state of the knowledge matrix” that is one of the cornerstones for the risk analysis and management. However the matrix is still under development: See also filled matrix in Appendix 1.

Critical climate variables	Major risks to road infrastructure
Maximum temperature and number of consecutive hot days (heat waves)	Concerns regarding pavement integrity, e.g. softening, traffic related rutting, embrittlement (cracking), migration of liquid asphalt. Thermal expansion on bridge expansion joints and paved surfaces Impacts on landscaping
Extreme rainfall events (heavy showers and long rain periods)	Flooding of roadways Road erosion, landslides and mudslides that damage roads Overloading of drainage systems, causing erosion and flooding Traffic hindrance and safety
Seasonal and annual average rainfall	Impacts on soil moisture levels, affecting structural integrity of roads, bridges, and tunnels Adverse impacts of standing water on the road base Risk of floods from runoff, landslides, slope failures, and damage to roads if changes in precipitation pattern (e.g.: changes from snow to rain in winter and spring thaws)
Drought (consecutive dry days)	Susceptibility to wildfires that threaten transportation infrastructure directly Susceptibility to mudslides in areas deforested by wildfires Consolidation of substructure with (unequal) settlements as a consequence More generation of smog
Snowfall	Traffic hindrance and safety Snow removal costs
Fog days	Traffic hindrance and safety More generation of smog
Frost (number of icy days)	Traffic hindrance and safety Ice removal costs
Thaw (number of days with temperature zero-crossings)	Thawing of permafrost, causing subsidence of roads and bridge supports (cave-in) Decreased utility of unimproved roads that rely on frozen ground for passage
Extreme wind speed (worst gales)	Threat to stability of bridge decks Damage to signs, lighting fixtures and supports
Sea level rise	Inundation of roads in coastal areas Erosion of road base and bridge supports Bridge scour Reduced clearance under bridges Extra demands on infrastructure when used as emergency/evacuation roads

### 3 Future Work

WP 1-3 are now elaborated and the results are taken foreword to the building of the Rimarocc method in WP 4 - 6.

#### ***WP 4: Risk analysis based decision methods for road authorities***

A common method/procedure for risk analysis considering climate change are under development which can be adopted by ERA-NET partners, either in complementary to existing methods or if necessary with a new proposed method.

Input is needed from WP1 and WP2. Four case studies will be used where data is collected from each country. They will be based on real climatic data events and simulations at appropriate level. Important to have pedagogical cases. The cases can improve the methodology.

#### ***WP 5: Risk Management options; mitigation and/or emergency plans***

Decision Support Systems, DSS, is an interaction between problem, policy and political stream. Deltares have developed the GeoQ riskmanagement methodology with six risk management steps.

WP5 is very much integrated with WP4. It is not possible to choose between measures without overview of whole risk management approach and vice versa. The needs and demands from WP1 should be part of the analyses e.g. delays, costs, value of a passable road, safety. Facts from WP2, 3 and 4 is needed.

Output of WP5 is a methodology / approach, not a calculating tool / model.

#### ***WP 6: Dissemination***

The project has discussed examples of how to best disseminate results; reports, publications, papers, web-sites, seminars/workshops, participate at conferences.

The goal with WP6 is to present how the worked-out method can be used at different levels. A final seminar/workshop with presentation of case studies should be arranged in July 2010, and the results of the Rimarocc project will also be presented at the TRA conference in 2010 and at other conferences, e.g. "Transportforum" Sweden 2010. There is also planned to write an scientific paper for publishing in an international journal.

From discussions with ERA-NET Road it is concluded that the final report should be a short report with recommendations step by step, like for example the UK method, with references to publications.

An editorial group with one person from each partner will be established to discuss e.g. the format, editing roles, pedagogic, content.

WP6 shall make a report of the case studies. The case studies give feed back to the methodology and comparison between national methods and the one the project present. The best available climate scenarios should be used in the case studies. It is important that road owners give free information to the project.

#### **4 Time table**

An application to extend the project time to 2010-09-30 is sent to the Era-NET Road board.

(all costs in Euro)

**Deliverables list**

Through its publication, the final report will become a public document.

Written reports will be delivered as follows:

Del. No.	Deliverable Name / Report Name	Due date	Actual submission date
1	<b>Progress report 1, December 2008:</b> The report shall present the result from the start up meeting on October 14 (2008). There shall be a time table for the whole project, including the seminars. There shall also be a structure of the whole project and the role of each partner shall be described.		2009-01-28  (draft 2009-01-13)
2	State of the art review : During WP 1 and WP 2 a state of the art review will be carried out, including : <ul style="list-style-type: none"> <li>o Methods for risk assessment (probability and consequences) for various types of climate events and associated road-related events</li> <li>o Methods for calculating and comparing the costs of preventative measures with the costs of damages</li> <li>o Methods for defining the level of acceptable risk</li> <li>o Risk management options by improvement and/or maintenance of present infrastructure</li> <li>o Risk management options by emergency actions.</li> </ul> The state of the art review is limited to tasks 2 and 5 of the GFA.		June 2009
3	<b>Progress report 2, June 2009:</b> The progress report shall present the result from WP1 and WP2, including the seminar with Road Administrators (WP1) and with invited researchers and ERA-NET Road representatives (WP2). Progress report 2 shall also present the result from WP 3 - where relevant climate scenarios are chosen. The report shall give a state-of-the-art review of used methods for risk analysis and risk management within ERA-NET Road members and other relevant methods.	June 2009	June 2009
4	<b>Progress report 3, December 2009:</b> The report shall summarise the project at this point including the results from WP1, WP2 and WP3, and also give an overview of the central work within WP4 (Risk analysis based decision methods for road authorities) and WP5 ( Management options; mitigation and/or	December 2010	December 2010

	emergency plans).		
5	<b>Final report, September 2010:</b> The final report shall present the total project results, including a proposed method for risk analysis and management and examples from final seminar on structural-, section-, network- and area level, and strategies for dissemination.		

## APPENDIX 1

Project Nr. TR80A 2008:72148

Project acronym: RIMAROCC

Project title:

**Risk Management for Roads in a Changing Climate****Handbook, Chapter 1-3****Working DRAFT - not to be cited**

(A Guiding Book)

Start date of project: 01.10.2008

End date of project: 30.09.2010

**Authors this deliverable:**

Michel Ray, Egis

Thomas Bles

Yves Ennesser

Jean-Jacques Fadeuilhe

Frode Sandersen

Stefan Falemo

Bo Lind

Marjolein Mens

**Contributors :**

Version: draft 02

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5.	Territory.....	<b>Fel! Bokmärket är inte definierat.</b>
6.	Network.....	<b>Fel! Bokmärket är inte definierat.</b>
7.	Section.....	<b>Fel! Bokmärket är inte definierat.</b>
8.	Structure.....	<b>Fel! Bokmärket är inte definierat.</b>
9.	Proposal for implementation.....	<b>Fel! Bokmärket är inte definierat.</b>

## Preface

This report is part of the Rimarocc project with the objective to develop a common ERA-NET ROAD method for risk analysis and risk management for roads with regard to climate change in Europe. The project is led by a Project Management Group with representatives from all partners SGI, Bo Lind (co-ordinator); EGIS, Michel Ray; Deltares, Thomas Bles; NGI, Frode Sandersen. The project working group also includes Yves Ennesser and Jean-Jacques Fadeuilhe, Egis; Stefan Falemo and Hjördis Löfroth SGI; Marjolein Mens Deltares,

The Project Steering Group from the ERA-NET Board, Åsa Lindgren (Project Manager), SRA, Sweden; Alberto Compte, CEDEX, Spain and Geoff Richards, HA, UK, have in a constructive way contributed to the project together with other persons from the ERA-NET organisations and other co-workers - they are all gratefully acknowledged.

Our sincere thanks also to all other people that has made important contributions to the project where we specifically would like to mention;

Beatrice Quiquampoix, Egis

Estelle Morcello, Egis mobilité

Stephane Hallegatte: CIRED / Météo France

Eric Brun, Météo-France, CNRSI

Edouard Fischer SANEF, Technical Director Operations

Werenfried Spit, RWS, Environmental advisor

Paul Fortuin RWS, Specialist climate change

Jaap Kwadijk KNMI, Climate scientist

Marjolein Mens Deltares

Unni Eidsvig NGI, Risk assessment

Lars Barring, SMHI

## Definitions and word list

Risk can be defined simply as “an effect of uncertainty on objectives” that reveals itself by ways of undesired events. When one asks, “What is the risk?” one is really asking three questions: What can happen? How likely is that to happen? If it does happen, what are the consequences? (Kaplan & Garrick, 1981). The answer to the first question is called a scenario; the answer to the second is the likelihood. The consequence can be measured for example in number of deaths or cost. Both the estimation of likelihood and consequences deal with uncertainties which is a key aspect of risk. One scenario with its corresponding likelihood and consequence constitute a triplet. All possible scenarios must be included to calculate the risk, so risk is defined as the complete set of triplets (Kaplan, 1997 and Kaplan & Garrick, 1981) or in other words the product of likelihood of an undesired event and the consequences of that event (van Staveren, 2006). In this handbook definitions of important terms are taken from; ISSMGE TC32 (ISSMGE), FLOODsite 2005 (FLOODsite), PIARC C18 (PIARC) and ISO/FDIS 31000.

**Consequence:** In relation to risk analysis, the outcome or result of a hazard being Realized. (ISSMGE).

**Damage:** Direct effects, primarily physical, of man-made or natural events on people and structures and facilities. (PIARC).

**Danger (Threat):** The natural phenomenon that could lead to damage, described in terms of its geometry, mechanical and other characteristics. The danger can be an existing one (such as a creeping slope) or a potential one (such as a rockfall). The characterisation of a danger or threat does not include any forecasting. (ISSMGE).

**Exposure:** Quantification of the receptors that may be influenced by a hazard (flood), for example, number of people and their demographics, number and type of properties etc. (FLOODsite).

**Hazard:** Probability that a particular danger (threat) occurs within a given period of time. (ISSMGE).

**Risk:** Measure of the probability and severity of an adverse effect to life, health, property, or the environment. Quantitatively,  $\text{Risk} = \text{Hazard} \times \text{Potential Worth of Loss}$ . This can be also expressed as "Probability of an adverse event times the consequences if the event occurs". (ISSMGE).

**Risk analysis:** The use of available information to estimate the risk to individuals or populations, property or the environment, from hazards. Risk analyses generally contain the following steps: definition of scope, danger (threat) identification, estimation of probability of occurrence to estimate hazard, evaluation of the vulnerability of the element(s) at risk, consequence identification, and risk estimation. Consistent with the common dictionary definition of analysis, viz. "A detailed examination of anything complex made in order to understand its nature or to determine its essential features", risk analysis involves the disaggregation or decomposition of the system and sources of risk into their fundamental parts.

**Qualitative risk analysis:** An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.



**Quantitative risk analysis:** An analysis based on numerical values of the probability, vulnerability and consequences, and resulting in a numerical value of the risk. (ISSMGE).

**Risk assessment:** The process of making a decision recommendation on whether existing risks are tolerable and present risk control measures are adequate, and if not, whether alternative risk control measures are justified or will be implemented. Risk assessment incorporates the risk analysis and risk evaluation phases. (ISSMGE).

**Risk management:** The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, mitigating and monitoring risk. (ISSMGE).

**Sensitivity analysis:** An analysis to determine the range over which the result varies, given unit change in one or more input parameters. (ISSMGE).

**Vulnerability:** The degree of loss to a given element or set of elements within the area affected by a hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). Also, a set of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards. (ISSMGE).

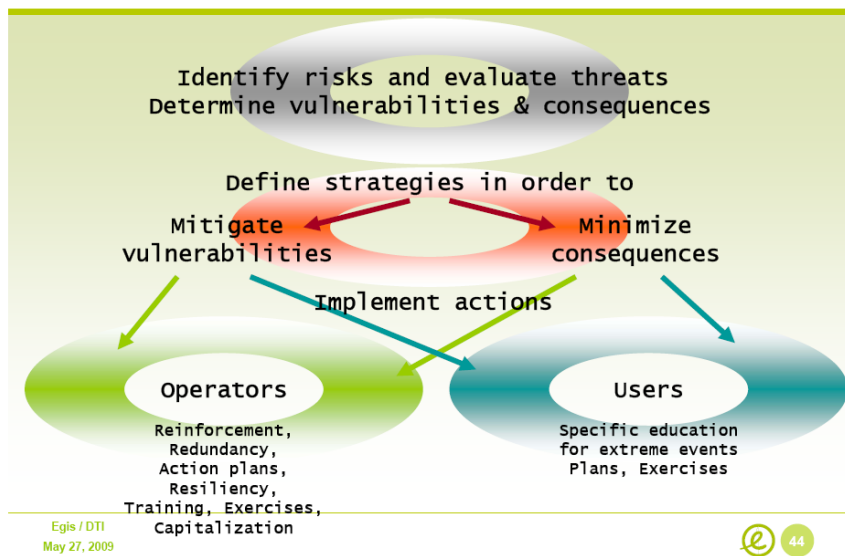
**Vulnerability:** Characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value. (FLOODsite).

In the draft for ISO Guide 73:2009, Risk management — Vocabulary (ISO, 2009), a risk management framework is defined as a set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization. The risk management framework focuses on the implementation of and working with risk management in organizations or within projects.

A possible definition of the risk management process can be written as follows. This is a method or procedure with several steps that are explicitly and continuously taken in order to control the risks within a project or organization with the objective to increase performance. Risk assessment is part of risk management and deals with the identification, analysis and evaluation of risks. For more information a reference is made to ISO 31000.

The Rimarocc method is a matter of Organizing (e.g. who is responsible for what) – Analysing (e.g. risks and vulnerability) – and Prioritizing (e.g. options for non-acceptable risks). The method can be used both to mitigate threats and vulnerabilities and to minimize the consequences of an event, as outlined in the figure below:

## RIMAROCC system



## ***Methods for risk assessment***

Risk management is used to address a wide range of risks of different nature. A wide spectre of methods for risk assessment with different scope and detail level are available to assess these risks. Some are better for comprehensive risk analysis while others are more suitable for detailed studies of a limited system. The risk assessment methods can be divided into groups based on data type, ranging from qualitative to quantitative analysis (van Staveren, 2006).

Quantitative methods focus on numbers and frequencies rather than on meaning and experience. The calculations include statistics to address inevitable uncertainties in models and raw data and the results are presented in probability functions or risk curves. Examples of quantitative methods are *Quantitative Risk Assessment (QRA)* and *Probabilistic Risk Assessment (PRA)*.

Qualitative methods are ways of collecting data which are concerned with describing meaning, rather than with drawing conclusions from statistics. Qualitative methods are primarily used to identify risks and can be used to rank the risks on an ordinal scale, e.g. from “low” to “high”. Examples of qualitative methods are *HazOp*, “*What if?*”-analysis and *checklists*.

Semi-quantitative methods lead to some kind of quantification of risks without using for example probability distributions or data analysis as described at the quantitative method. The quantification is reached by using meaning and experience for scoring the probabilities and consequences. Semi-quantitative methods are useful when on the one hand not many data are available but still a detailed and well thought of classification is necessary with somewhat quantitative content

## **Introduction; the purpose and contents of the Handbook**

### ***The purpose of the Handbook***

This Handbook is intended to be a concise guide to risk management for roads with regard to climate change. The proposed method should enable the user to identify the risks and to implement optimal action plans that maximise the economic return to the road owner considering both construction costs, maintenance and environment.

The Rimarocc method is designed to be general and meet the common needs for road owners and road administrators in Europe. The method seeks to present a framework and an over all approaches of adaptation to climate change. The method is based upon existing tools for risk analysis and risk management for roads within the ERA-NET Road member states and others. There is work going on in many countries with regard to risk analysis and climate change. From a state of the art research three methods seemed particularly interesting and need to be further examined. These methods are the French GeRiCi-project, the UK adaptation strategy and the Deltares approach. The proposed method is designed to be compatible, and function in parallel with existing methods so that specific and functional methods for data collection, calculations and co-operation within each organisation can be kept.

The Handbook is designed to be straightforward and easy to use. More information and background can be found in the “Technical report” from the Rimarocc project where the research and considerations behind the proposed method are presented.

## ***How to use the Handbook***

The Rimarocc project is presented in four reports; State of the art on existing methods for risk analysis and risk management within the ERA NET ROAD countries - applicable for roads in relation to climate change, Rimarocc Technical Report, Rimarocc Case studies and this Handbook.

...  
...

## ***Policy's and responsibilities***

Risk management for identifying preferred options of adaption to climate change is a comprehensive and important work that should be acknowledge within the organisation. The work should be a cyclic process to continuously improve the performance and capitalise on the experiences. The work should be lead by a specific "Program Manager" and sufficient resources should be provided. If this is done – the risk management process should be a success that minimise risks and save money and resources both in a short-term and long-term perspective.

It is important that the risk management work is implemented in the organisation in a distinct way. Key responsibilities for different parts of the process should be clear as well as for data collection and other work. However, it is our experience that the Rimarocc method can be adapted to many different types of organisations. We believe that the risk management process can be flexible and adjustable and use the strategic structures and policies of most road owners and administrations.

## ***Adapting to climate change***

There is a global scientific consensus that the world's climate is changing and the need for action is widely acknowledge. Despite the existing uncertainties regarding the future climate the EU white paper "**Adapting to climate change: Towards a European framework for action**" states that "*The challenge for policy-makers is to understand these climate change impacts and to develop and implement policies to ensure an optimal level of adaptation*" (Brussels, 1.4.2009, COM, 2009, 147 final). There is no time to wait; adaptation need to start now to ensure protection against future climatic risks.

Existing climate models are improved and new more accurate predictions are expected over time. The optimal adaptation strategy is different depending on what model is used. With this uncertainty in mind it is not feasible to find only one optimal strategy but focus should instead be on robustness. Adaptation is a dynamic and reflexive process that interacts with many other policies and measures. Adaptation measures belonging to the groups "no-regret" and reversible strategies are preferable over irreversible strategies. Selecting no-regret strategies brings benefits already in today's climate. When selecting adaptation measures, assess urgency and prioritize the "early impact" risks.

## ***Uncertainty and the need for action***

Risk management for roads with regard to climate change is a work under genuine uncertainties. Uncertainty stems from a number of sources such as, the emission scenarios and the climate models. There is also uncertainty in the way that the climate will affect the road system, e.g. the physical structures, the maintenance and the public relations. Some of the uncertainties will diminish over time while others will remain for many years. However, this should not inhibit decision making but should be understood and considered. There is a constant need for decisions and development of the road transport system. And it is understood that a change in climatic conditions will have significant effects that should be considered.

## ***Critical climate parameters***

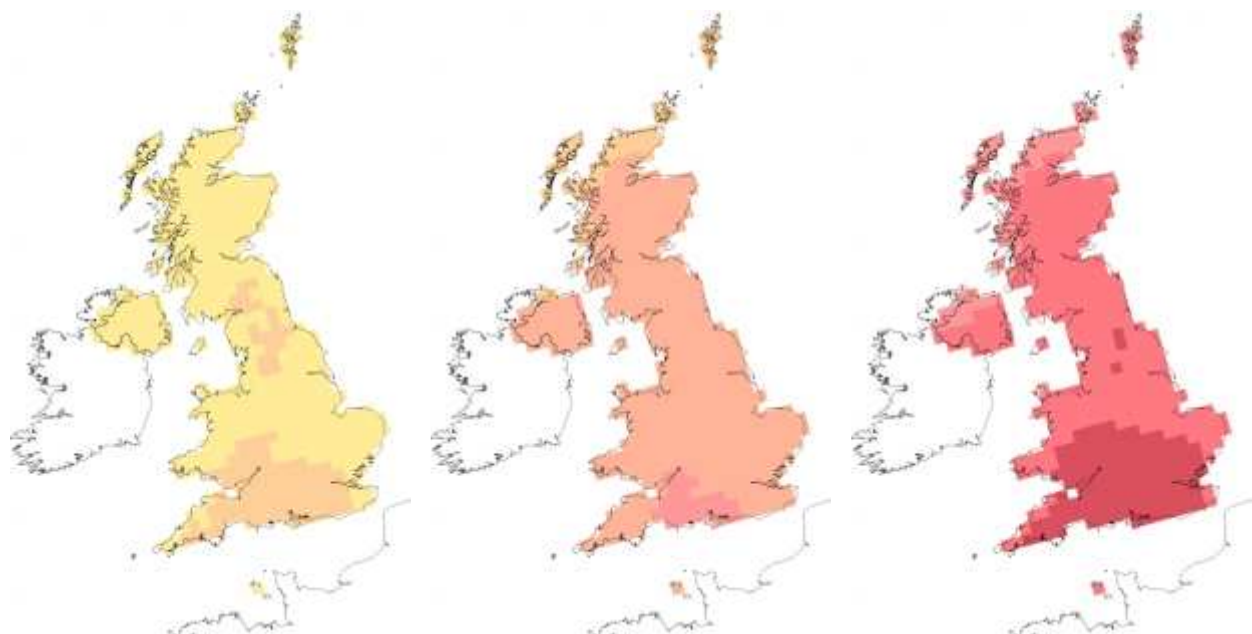
An important step in the development of climate scenarios is to adopt a probabilistic approach and present maps showing the probability for different scenarios. Below we show examples from the UKCP09 project (<http://ukcp09.defra.gov.uk/>) with two variables – temperature and precipitation (includes rainfall, snow and hail), Figure 1-1. The maps show changes suggested by climate models at the 10, 50 and 90% probability levels. The example considers the impact of continued global greenhouse gas emissions on a pathway that is described, in UKCP09, as the medium emissions scenario.

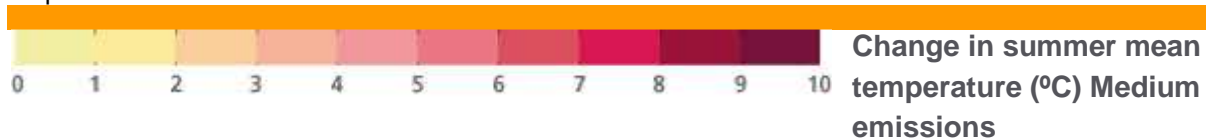
Note that:

- until 2030 (important for maintenance) economic scenario's in general do not produce differences in CO<sub>2</sub> levels so only uncertainties in climate models are important,
- after 2030 (important for new infrastructure) economic scenario's are relevant in assessing the robustness of infrastructure policies.

### **Change in summer mean temperature for the 2080s under a medium emissions scenario**

**10% probability level: 50% probability level: 90% probability level:**  
**very unlikely to be less than central estimate very unlikely to be greater than**





Figur 1-1. Change in summer mean temperature in the UK, (°C). Medium emissions. From, UKCP09 project (<http://ukcp09.defra.gov.uk/>).

The 10% probability level maps tell us that the probability that the change will be less than that shown is 10% – the term very unlikely to be less than to describe this.

The 90% probability level maps tell us that the probability that the change will less than that shown is 90%. In other words, the change is very unlikely to be greater than shown.

The 50% probability level maps tell us that the strength of evidence for the projected change is just as likely to be greater than the values shown, as it is to be less than the values shown – this is called central estimate. It is not necessarily the most likely projection.

Through a bibliographical review of major references and a series of work-shops with climate experts a list of main climate parameters impacting roads have been identified:

#### Main climate parameters impacting roads

- seasonal and annual average temperature
- maximum temperature and number of consecutive hot days (heat waves)
- seasonal and annual average rainfall
- extreme rainfall events (heavy showers and long rain periods)
- drought (consecutive dry days)
- extreme heat
- snowfall
- fog days
- frost (number of icy days)
- thaw (number of days with temperature zero-crossings)
- extreme wind speed (worst gales)
- sea level rise

Present knowledge regarding critical climate parameters for climate change analysis in the transport sector is summarised in table 1-1. The climate events are weighted according to their importance for the road sector and the amount of change is marked by a relative scale from significant increase, ++, to -- to significant decrease --.

*Table 1: Summary of Present Knowledge Regarding Critical Climate Parameters for Climate Change Analysis in the Transport Sector. The climate events are weighted according to their importance for the road sector; 0 irrelevant; 1 of some importance; 2 important; 3 very important; 4 of primary importance. Amount of impact from significant increase ++, to significant decrease --.*





Weight	Unwanted climate event	Critical climate parameter	Amount of change compared to 1961-1990 period (++, +, +/-, -, --)	Availability of predictions: qualitative, quantitative or impossible	Certainty of predictions: likely, very likely, (virtually) certain	Geographical resolution (grid size) / resolution for which it can be used)	Time Horizon (when will it happen ?)	Available data / models																					
4	Extreme rainfall events (heavy showers and long rain periods)	➤ Max. intensity in [mm/h] and [mm/24h]	Intensity: likely (+) Frequency: ➤ North likely ➤ South ?	Qualitative	Likely	50 km (difficult to use smaller grids)  Resolution of 25 km – 12 km will soon be available	No statistical evidence of trends, but likely to be happening today	Regional models + local expertise																					
4	Annual, seasonal and periods ("wet spells") average rainfall	➤ Average amount [mm/ 3 months]	<table><tr><td></td><td>Sum.</td><td>Wint.</td></tr><tr><td>North</td><td>+/-</td><td>++</td></tr><tr><td>South</td><td>--*</td><td>-</td></tr></table>		Sum.	Wint.	North	+/-	++	South	--*	-	<table><tr><td>Quantitative</td></tr><tr><td>North</td></tr><tr><td>South</td></tr></table>	Quantitative	North	South	<table><tr><td></td><td>Sum.</td><td>Wint.</td></tr><tr><td>North</td><td>L</td><td>VL</td></tr><tr><td>South</td><td>VL</td><td>L</td></tr></table>		Sum.	Wint.	North	L	VL	South	VL	L	Main signal perceptible for 250 km grid, but can be refined locally	Already observed.	Global IPCC models
	Sum.	Wint.																											
North	+/-	++																											
South	--*	-																											
Quantitative																													
North																													
South																													
	Sum.	Wint.																											
North	L	VL																											
South	VL	L																											
4	Sea level rise (+ waves and storm surges)	➤ Rise [m]	++ XXI Cent.: (0,2 to 0,6m) No ice cap melting (IPCC assumption)	Quantitative  Qualitative if considering ice cap melting	> 0.2m is virtually certain in 2100	Global but not uniform (may vary according to sea basins)	Already observed (ice cap melting not within a century)	IPCC scenarios (post-IPCC scenarios)																					
3	Maximum temperature and number of consecutive hot days (heat waves)	➤ Average max. [T°C on 24h]  ➤ Maximum [T°C]  ➤ Heat wave duration [number of consecutive days], [hw/year]	++ XXI Cent.: Taver. Global: 1,8 to 4,0 °C (best estim. /scen.). South + Continent. > Nor. ++ Even more for extremes ++ 5 to 30 days	Quantitative  Quantitative  Quantitative	V. Certain in Europe  V. Certain  Very likely	Main signal perceptible for 250 km grid, but can be refined locally, except specific case of cities (higher T°C) and coastal areas (lower T°C)	Already observed (figures available)	Global IPCC models																					

Weight	Unwanted climate event	Critical climate parameter	Amount of change compared to 1961-1990 period (++, +, +/-, -, --)	Availability of predictions: qualitative, quantitative or impossible	Certainty of predictions: likely, very likely, (virtually) certain	Geographical resolution (grid size / resolution for which it can be used)	Time Horizon (when will it happen ?)	Available data / models
2	Drought (consecutive dry days)	➤ Drought duration [number of consecutive days], [d/year]	++ over South Eur.	Quantitative	Very Likely	South. Eur and Med.  More uncertain in N Eur.	Has begun	
2	Snowfall	➤ Max. snowfall in 24h [m/day] ➤ Snow duration at the ground [nb of days]	Int: + Freq: - Duration: --	Qualitative  Quantitative	Likely  Certain	Extr. North Eur  Whole Eur	  Has begun	
2	Frost (number of icy days, Tmax<0°C and frost days, T drops below 0°C)	➤ Minimum [T°C] ➤ Average [min. T°C on 24h] ➤ Frost duration [number of days/year] ➤ Frost index [frost penetration into the soil]	+ ++  --	Quantitative Quantitative  Quantitative	Likely Certain  Certain	Whole Eur. Whole Eur.  Whole Eur.	Has begun Ditto  Ditto	
2	Thaw and frost (number of days with temperature zero-crossings)	➤ Thaw days [number of days with 0°C crossings]	+ or – depending on the regions	Qualitative	Certain in North. Eur.	+ North. and Cont. Eur. - South.	Has begun	
2	Extreme wind speed (worst gales) : extra tropical or convective systems induced	➤ Max. speed [km/h]	+ in North-O Europe ? elsewhere	Qualitative	Likely in North Poor (unknown) in South.	500-1000 km grid (North shift of the storm tracks)	Not yet recorded (Vince storm not representative)	Global IPCC models
1	Fog days	➤ Fog days [number of days with fog]	?	Not yet possible (local effects – vertical resolution)	Unknown		Observed locally (less pollution)	



## Climate impact on roads

*The main climate parameters impacting roads are:*

Critical climate variables	Major risks to road infrastructure
Extreme rainfall events (heavy showers and long rain periods)	<ul style="list-style-type: none"><li>➤ Flooding of roadways</li><li>➤ Road erosion, landslides and mudslides that damage roads</li><li>➤ Overloading of drainage systems, causing erosion and flooding</li><li>➤ Traffic hindrance and safety</li></ul>
Seasonal and annual average rainfall	<ul style="list-style-type: none"><li>➤ Impacts on soil moisture levels, affecting structural integrity of roads, bridges, and tunnels</li><li>➤ Adverse impacts of standing water on the road base</li><li>➤ Risk of floods from runoff, landslides, slope failures, and damage to roads if changes in precipitation pattern (e.g.: changes from snow to rain in winter and spring thaws)</li></ul>
Sea level rise	<ul style="list-style-type: none"><li>➤ Inundation of roads in coastal areas</li><li>➤ Erosion of road base and bridge supports</li><li>➤ Bridge scour</li><li>➤ Reduced clearance under bridges</li><li>➤ Extra demands on infrastructure when used as emergency/evacuation roads</li></ul>
Maximum temperature and number of consecutive hot days (heat waves)	<ul style="list-style-type: none"><li>➤ Concerns regarding pavement integrity, e.g. softening, traffic related rutting, embrittlement (cracking), migration of liquid asphalt.</li><li>➤ Thermal expansion on bridge expansion joints and paved surfaces</li><li>➤ Impacts on landscaping</li></ul>

Critical climate variables	Major risks to road infrastructure
Drought (consecutive dry days)	<ul style="list-style-type: none"> <li>➤ Susceptibility to wildfires that threaten transportation infrastructure directly</li> <li>➤ Susceptibility to mudslides in areas deforested by wildfires</li> <li>➤ Consolidation of substructure with (unequal) settlements as a consequence</li> <li>➤ More generation of smog</li> </ul>
Snowfall	<ul style="list-style-type: none"> <li>➤ Traffic hindrance and safety</li> <li>➤ Snow removal costs</li> <li>➤ Snow avalanches closing roads or striking vehicles</li> </ul>
Frost (number of icy days)	<ul style="list-style-type: none"> <li>➤ Traffic hindrance and safety</li> <li>➤ Ice removal costs</li> </ul>
Thaw (number of days with temperature zero-crossings)	<ul style="list-style-type: none"> <li>➤ Thawing of permafrost, causing subsidence of roads and bridge supports (cave-in)</li> <li>➤ Decreased utility of unimproved roads that rely on frozen ground for passage</li> </ul>
Extreme wind speed (worst gales)	<ul style="list-style-type: none"> <li>➤ Threat to stability of bridge decks</li> <li>➤ Damage to signs, lighting fixtures and supports</li> </ul>
Fog days	<ul style="list-style-type: none"> <li>➤ Traffic hindrance and safety</li> <li>➤ More generation of smog</li> </ul>

## Validity

Climate change research and risk management are both fields under rapid development. Therefore this project focus on finding a robust framework rather than the perfect solution for a fixed moment in time. The framework is developed to be valid in EU countries for the next five to ten years. Knowledge within climate change and risk management will continuously enrich. Some ideas from this framework will remain strong and others will need improvement.

The method is valid for climate induced risks however it also considers other risks and the same framework may be used for structuring risk analysis and management in general for the road system. As a rule the knowledge of road authority is good with regard to which type of risks the road transport system is exposed to and where the risks are greatest. The purpose of the Rimarocc method is to function as a systematic way to develop and implement the response to climate change. It provides a method to identify which activities and structures that may be affected by climate change and a platform for decision makers to evaluate policies, standards and the maintenance and development of the road network.

## **The Rimarocc Framework proposal**

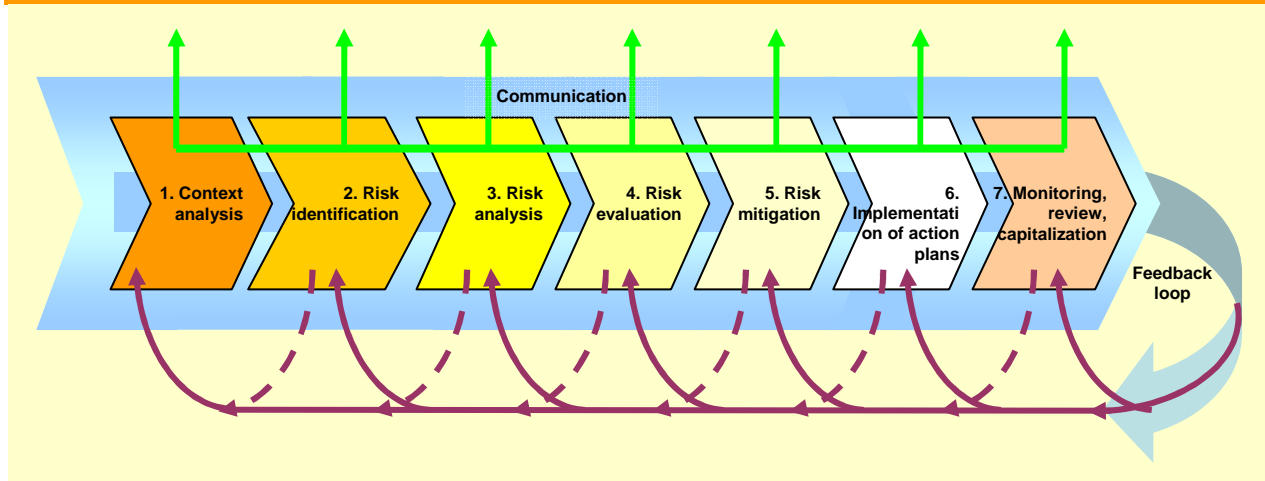
The RIMAROCC Framework is designed for road risk management at all levels. It consists of seven steps which are presented below. This is followed by a thorough description of the general approach, where details on substeps are included. Finally the approaches at four different levels are presented; territory, network, section and structure. Territory covers a geographic area with more than one road owner and is more complex than the Network level, which covers a road network with a single road owner. Section level is used for a stretch of road, and Structure is for single objects or structures such as bridges or sign gantries.

### ***General frame: 7 key steps***

The proposed method is a cyclic process to continuously improve the performance and capitalise on the experiences. It starts with an analysis of the general context where risk criteria are established and ends up with a reflective step where the experiences and results are documented and made available for the organisation. In practice the steps are not always totally separated. There can be work going on in several steps at the same time – but it is very important that the logic structure is kept. There are feedback loops from each step to the previous ones and also a marked loop from the last step as a reflection and as part of the cyclic process.

The permanent communication with stakeholders, external experts and others is very important and marked as (green) arrows throughout the whole process.





### ***Comments on steps and sub-steps***

Key steps	Sub-steps
1. Context analysis	1.1 Establish general context 1.2 Establish appropriate context for particular level 1.3 Establish risk criteria and indicators adapted for each particular level
2. Risk identification	2.1 Identify risk factors 2.2 Identify vulnerabilities 2.3 Identify possible consequences
3. Risk analysis	3.1 Risk analysis : qualitative aspects 3.2 Establish risk scenarios 3.3 Determine impact of risk 3.4 Evaluate occurrences
4. Risk evaluation	4.1 Evaluate quantitative aspects with appropriate analysis (CBA or others)

	4.2 Compare climate risk to other kinds of risk 4.3 Determine which risks are acceptable
5. Risk mitigation	5.1 Identify options 5.2 Appraise options 5.3 Negotiation with funding agencies 5.4 Elaborate action plan
6. Implementation of action plans	6.1 Develop action plan at each level of responsibility 6.2 implement adaptation action plans
7. Monitor, re-plan and capitalize	7.1 Regular monitoring and review 7.2 Re-plan in case of new data or delay in implementation 7.3 Capitalization of return of experience on both climatic events and progress of implementation
Communication and gathering of information	

- 1.
- 2.
- 3.
- 4.
5. Risk mitigation is the step in which is elaborated, negotiated and finalized the action plan. This is a strategic step which concerns actors from several departments: roads, civil security, finance, etc.
6. Implementation of action plan is an operational step: approved action plan is implemented by roads managers at each appropriate level.
7. ....

### ***Working methods – to be completed***

Possible working methods are (no complete list):

- individual:
  - desk studies
  - interviews
- group sessions:
  - brainstorm sessions (group sessions)
  - electronic board room session (acceleration room)