Conférence Européenne
des Directeurs des Routes

Conference of European
Directors of Roads

CEDR Contractor Report 2016-1

Call 2012: Road owners adapting to Climate Change ROADAPT and CliPDaR projects

March 2016

CEDR Contractor Report 2016-1

Call 2012: Road owners adapting to Climate Change ROADAPT and CliPDaR projects

by

David Bárta – CDV (FEHRL)
Eduardo Fortunato – LNEC (FEHRL)
Jānis Barbars – LSR (FEHRL)

CEDR Contractor Report 2016-1 is an output from the CEDR Transnational Road Research Programme Call 2012: Climate Change. The research was funded by the CEDR members of Denmark, Germany, Netherlands and Norway.
The aim of the CEDR Transnational Road Research Programme is to promote cooperation between the various European road administrations in relation to road research activities. The topics covered by this Call were developed by TG Research to fulfil the common interests of the CEDR members.

CONTRACTOR: FEHRL

ISBN: 979-10-93321-14-1

Table of contents

Executive Summary

Infrastructure is the backbone of our society. Citizens, companies and governments have come to rely on and expect uninterrupted availability of the road network. Climate change is an important topic within the context of designing, maintaining and operating traffic networks. Most transport infrastructure is intended to be available (in service) to the public for several decades. The life cycles of assets in transport are long enough to take the full strain that comes with climate change; however, climate impact is experienced on a small scale. Crops are destroyed by floods, timber is felled by heavy storms and infrastructure is devastated by various kinds of extreme events. The adaptation of road networks to a changing climate is one of the important issues that road authorities have begun to address and that needs to be further continued in the near future.

The main objective of the Conference of European Directors of Roads (CEDR) Call 2012 "Road owners adapting to climate change" is to provide road owners with adaptation technologies and the models and tools to support decision-making concerning adaptation measures for the road infrastructure. The ROADAPT (Roads for today, Adapted for tomorrow) and CliPDaR (Design guideline for a transnational database of downscaled Climate Projection Data for Road impact models) projects form an integral part of this 2012 CEDR research programme.

This report provides an analysis of the two projects and provides and overview of the final conference held in Brussels (on 27-28th October 2015). Concise recommendations are given on how to disseminate and implement the products of both projects.

Outputs of the ROADAPT project

Outputs of the ROADAPT project contain tools for risk identification, analysis, evaluation, and mitigation. The set consists of 6 guidelines and 3 case studies. The aim of the **Guideline on the use of data (and data requirements) for the current and future climate for road infrastructure** is to give background information and guidelines for tailored and consistent climate data and information for studies on the impact of the current and future climate for transnational road networks in Europe that are suitable for National Road Authorities (NRAs).

The **QuickScan** methodology produces a first (quick) estimate of the major risks that can be associated with weather conditions both in the current climate and in the future, together with an action plan for adaptation. The list of top risks allows an NRA to consciously and effectively focus on specific areas in their network and/or on specific threats. Focusing on the top risks enables existing resources to be used more efficiently.

The objective of the vulnerability assessment tool is to describe the efficient, existing tools for assessing vulnerabilities within road networks, with a focus on networks managed by NRAs. In addition, a new comprehensive **vulnerability assessment** methodology is suggested, based on and compatible with the RIMAROCC method. Using the vulnerability maps created in the process, it should be possible to combine these with detailed climate change projections. An extensive database that helps with the selection of adaptation measures and strategies for the mitigation of the effects of climate events was designed and set up within the ROADAPT project. The database contains more than 500 measures to support road owners with a decision-making tool.

The method for Socio-economic impacts analysis is well interconnected with the methodology for the QuickScan and the vulnerability assessment, as the selection of the threats to be evaluated is based on their outputs.

Selection of adaptation measures and strategies for mitigation is a 10-step approach for selecting an adaptation strategy containing a database.

Outputs of the CliPDaR project

The deliverables of CliPDaR aim at enabling the road owner to make informed and efficient decisions on whether a proposed climate change scenario is suitable to derive particular adaptation measures or not. The information given enables customised climate change scenarios to be established, which help to answer particular problems regarding future transport infrastructure. This is accomplished by a guideline that helps decision makers through the whole process from the socio-economic scenarios to the adaptation measures to be put into effect. **Ensemble approach** to climate scenarios and the description of the **downscaling of climate data** are the highlights of the CliPDaR project.

Outcomes of the projects and this report:

The research focuses on awareness of the impact of climate change - crushing the stereotype that climate change is just another conspiracy theory. ROADAPT and CliPDaR together with some presentations from the final conference have provided hard evidence that climate change and extreme weather events are becoming more and more common, especially for coastal territories, and generates significant additional cost to infrastructure construction and maintenance. This awareness needs to be spread across the pool of decision makers.

Experience of champions (Nordic countries, Germany, the Netherlands)

Some countries have already set up adaptation strategies or are in the process of developing them. These are mostly countries that have begun to experience extreme weather events on a regular or seasonal basis. Presentations from Denmark, Sweden, Norway, and the Netherlands clearly show that the road to adaptation to climate change is not easy but in the long term it will pay off. It should be noted that climate change mitigation is essential. An estimate from the Netherlands shows that if we do not keep the global temperature rise at 2°C but let it escalate to 5.5°C, the amount of the world's GDP that will be necessary to mitigate the damage will rise from 2% to at least 8% by 2100.

A large part of this report is devoted to recommendations within three main domains – dissemination, implementation and future research. Recommendations are found at the end of each of the project chapters. These are mainly dealing with each particular product or outcome, providing hints on implementation and future research. More general recommendations covering both projects and sometimes stretching outside the boundaries of particular projects are given at the end of this report. These recommendations are sub-divided into specific sections for **dissemination** - awareness creation, and **implementation** - strategy and action plan development, application in transport network management.

Introduction

This report summarises the extensive work undertaken within the CEDR Transnational Road Research Programme entitled "Road owners adapting to Climate Change running from January 2013 to October 2015". The structure of the report is designed to provide information on what has been done (description), what has been achieved (evaluation), and what should be the next steps (recommendations).

This paper covers the deliverables of both projects and provides an overview of the final conference held in Brussels (on 27-28th October 2015). These deliverables and conference presentations are referenced on page 36 of this report and available for download from CEDR and FEHRL websites. At the end of this report, conclusions on the work performed and recommendations are given on how to disseminate and implement the outputs and outcomes of ROADAPT and CliPDaR.

Abbreviations

Abbreviation	Meaning
CC	Climate change
CEDR	Conference of European Directors of Roads (organisation)
CI	Climate index
CliPDaR	Design guideline for a transnational database of downscaled Climate Projection Data for Road impact models (project)
DWD	Deutscher Wetterdienst = German National Meteorological Service
FEHRL	Forum of European National Highway Research Laboratories (organisation)
INSPIRE	Infrastructure for Spatial Information in the European Community (EU directive)
IPCC	Intergovernmental Panel for Climate Change (organization)
KNMI	Koninklijk Nederlands Meteorologisch Instituut = Royal Netherlands Meteorological Institute
NRA	National Road Authority or Administration
PEB	Programme Executive Board
RIMAROCC	Risk Management for Roads in a Changing Climate (project)
ROADAPT	Roads for today, Adapted for tomorrow (project)
SGI	Statens Geotekniska Institut = Swedish Geotechnical Institute
SP1; SP2; SP3	CEDR Strategic Plan (SP1 2005-2009; SP2 2009-2013; SP3 2013-2017)
TEN-T	Trans-European Transport Network
TRA	Transport Research Arena
TRP	Transnational Road Research Programme
ZAMG	Zentralanstalt für Meteorologie und Geodynamik = Austrian National Meteorological and Geophysical Service

PART I

General information about the programme and projects

CEDR Programme on Climate Change, 2012 call

The adaptation of road networks to a changing climate is one of the important issues that road authorities have begun to address, and that needs to be further continued in the near future. The overall aim of this programme is to provide owners with adaptation technologies and the models and tools to support decision-making concerning adaptation measures for the road infrastructure. The programme is based on the following three closely-related objectives:

A) Identification and modelling of climate change effects regarding national highway networks to provide a unified input database,
B) Development and application of risk-based vulnerability assessment of transnational highway networks (TEN-T),
C) Development and application of adaptation technologies.

This programme of research was funded by Denmark, Germany, Norway and Netherlands. Nine proposals were received and, following evaluation by the Programme Executive Board (PEB), two projects selected for inclusion.

- ROADAPT: Roads for today, Adapted for tomorrow
- CliPDaR: Design guideline for a transnational database of downscaled Climate Projection Data for Road impact models

ROADAPT - Roads for today, Adapted for tomorrow

Project Facts

DURATION: January 2013 - December 2015

COORDINATOR:

Thomas Bles, Stichting Deltares, Netherlands; e-mail: thomas.bles@deltares.nl

PARTNERS:

Deltares, Netherlands

SGI, Sweden

Egis, France

KNMI, Netherlands

DELIVARABLES:

- **Guidelines [integrating main guidelines] (May 2015).** "[1]" **These Guidelines comprised:**
- **Part A, No. 1: Guideline on the use of data for the current and future climate for road infrastructure**
- **(May 2015)** "[2]"
- **Part A, No. 2: Climate data requirements of National Road Authorities for the current and future climate (May 2015)** "[3]"
- **Part B: Performing a QuickScan on risk due to climate change (May 2015)** "[4]"
- **Part C: GIS-aided vulnerability assessment for Roads – Existing methods and new suggestions (May 2015)** "[5]"
- **Part D: Socio-economic impacts analysis (WP3); Deliverable No 2 (May 2015)** "[6]"
- **Part E: Selection of adaptation measures and strategies for mitigation; Deliverable No 4 (May 2015)** "[7]"
- **Case study Öresund (May 2015)** "[8]"
- **Case study Rotterdam-Ruhr corridor (August 2014)** "[9]"
- **Case study A24 Portugal (March 2014)** "[10]"
- **Database of adaptation techniques - a spreadsheet (May 2015)** "[11]"

Background and objectives

Infrastructure is critical to our society. Citizens, companies and governments have come to rely on and expect uninterrupted availability of the road network. At the same time, it is generally understood that the world's climate is changing and that this will have significant effects on the road infrastructure. Since road infrastructure is vital to society, climate change calls for timely adaptation. However, there are great uncertainties involved in both the projections of future climate change and related socio-economic developments and estimating the consequences of these changes in transportation needs. In the meantime, there is a constant need for decisions and development of the road transport system.

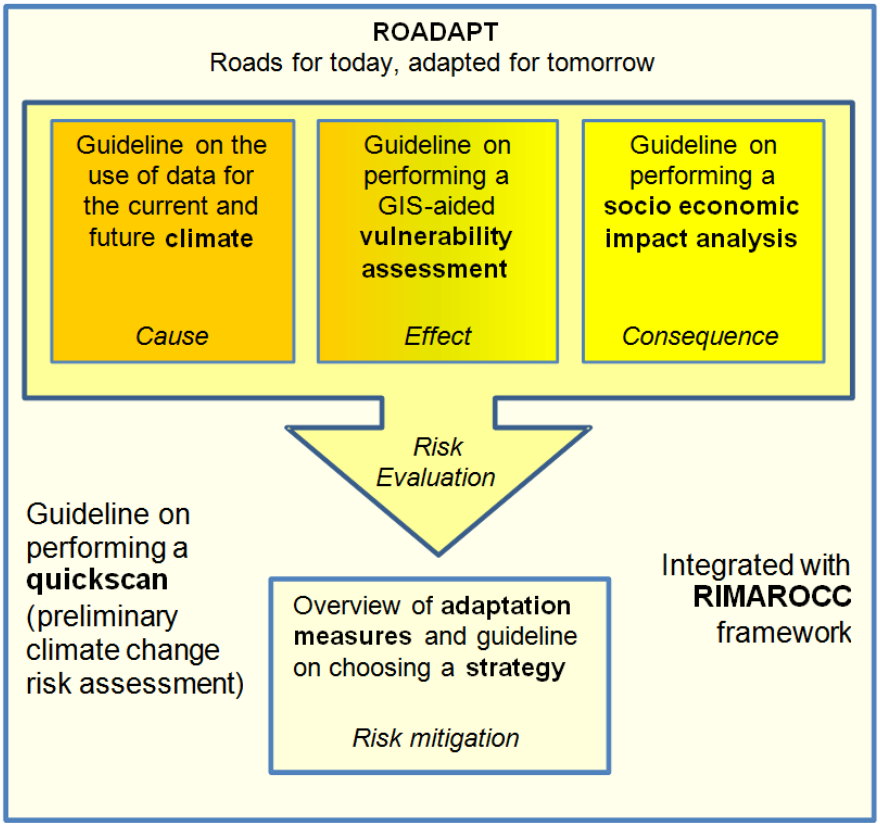

Figure 1: Structure of the ROADAPT guidelines

ROADAPT aims at providing methodologies and tools enabling tailored and consistent climate data information, a good communication between climate researchers and road authorities, a preliminary and fast quickscan for estimating the climate change related risks for roads, a vulnerability assessment, a socio economic impact analysis and an action plan for adaptation with specific input from possible adaptation techniques related to geotechnics and drainage, pavements and traffic management.

Description, evaluation and recommendations of the project

A.1 Guideline on the use of data for the current and future climate for road infrastructure

The aim of this document is to give background information and guidelines for tailored and consistent climate data and information for studies on the impact of the current and future climate for transnational road networks in Europe, suitable for NRAs.

The challenge of climate services for society **is to bridge the gap between scientific knowledge and knowledge that is usable for policy makers, infrastructure designers and impact researchers.** A typical road owner or road engineer in Europe will often require information in addition to scientific papers, such as the probabilities of reoccurrence of extreme rainfall or snowfall and related design loads in the current climate and possible changes in the future. A dialogue is needed to match supply and demand for information provided. This dialogue has already commenced through earlier projects on climate change, infrastructure and road networks. Generally NRAs will outsource the **collection and processing of climate data to researchers or consultancies.**

The A.1 guideline is limited to the provision of climate data, information and knowledge and does not provide information on weather or impacts: these are covered by the other parts of the project guideline. This part also uses information collected in the CliPDaR project.

It appears that there are few international guidelines or recommendations on the use of climate data for international road networks. It is not the objective of ROADAPT to harmonise existing guidelines or develop harmonised guidelines for the use of climate data. However, guidelines are given for the use of climate data in cross-border projects and this information is intended to assist in the provision of more uniform cross-border results of climate change risk assessments.

Part A.1 provides a valuable insight into the existing information on climate on an EU wide scope. Unfortunately, it is perceived that there is a lack of information about the available tools from new Member States, see "[2]" as the information was probably harder to find (perhaps due to language barriers or knowledge about the existing sources). This shows a potential for follow-up work to extend the focus on other countries and find climate change commonalities that could be solved/tackled by similar measures. This could enhance the learning process and transfer of the methodology to an EU-wide scope. Table 2.3 "[2]" demonstrates that some of the data inputs are still not known, while table 2.5 "[2]" tackles the non-harmonised approach among the states. Both provide a clear momentum for the follow-up work to enable EU-wide services in the near future that connect climate change and weather information services with road infrastructure planning and operation and a projection for minimising the information gaps to decrease the level of uncertainty in global but especially in local (regional) conditions.

Recommendations:
The efficient access to climatic data is mostly connected to the existence of a website that brings together various sources of climatic data as one significant part of the whole web database tool (the tool should incorporate all the results of the other parts of the guideline). Such a website can help to give an overview of available data and tools with the advantages and disadvantages of the various datasets and tools, and show good practice around EU. It can work as an inspiration for sharing data and use cases of climate change evaluations; however, it cannot serve as a solution provider as expert knowledge for correct interpretation might be needed.

For a particular area assessment, data from climatic sources, hierarchy of suitable measures to be applied etc can be used. The use of the QuickScan and vulnerability assessments methodologies could be very helpful for including other data inputs into existing databases. The resulting service could be a computation service integrating data from various sources (global climate data, local sensors based on the Internet of Things network), and variables derived from an NRA that is applying the methodology and inserting the values into the predefined web tool.

CEDR (or any database service provider) could provide a membership service for checking the quality of climate data as the input data into the web tool. Also, CEDR could contribute with ROADAPT results to the C3S (Copernicus for Climate Change Services, http://climate.copernicus.eu/) in the coming years.

A.2 Climate data requirements of National Road Authorities for the current and future climate

Climate services include the development, provision and dissemination of climate data, information and knowledge to inform the public, researchers, decision makers (policy and practice) or other specific users. As such, climate services should involve strong partnerships with stakeholders, in this case the NRAs and those providing information and data to these NRAs. Better dissemination and increased relevance require proper knowledge of user requirements. For this purpose, an update was made of the requirements of NRAs presented in the RIMAROCC project (table 1, p. 15 in Bles et al, 2010) "[3]" with the help of a literature review of former projects, a workshop and some case studies.

Table 1.1 "[1]" gives an overview of the threats for road infrastructure as included in ROADAPT and the related climate variables. As expected for design/construction and maintenance, climate data is considered important. For operation, weather forecasts are most important.

To understand user requirements, both information about the services that users require (what do users ask for/need) and information to better understand the requests (why do users ask for these services, how will they use the data/information etc.) are required. Information on "what users ask for" is much easier to obtain than information on "why" users ask for specific information. Information on user requirements related to international road infrastructure was collected through workshops.

Recommendations from ROADAPT project authors:
Most of the climate variables mentioned were directly or indirectly analysed in the RIMAROCC report. The answers provided for ROADAPT raised questions (e.g. importance of climate extremes for design/construction, maintenance and operation of roads) provided further specification of what is needed, especially in terms of extreme events, probabilities, and derived variables such as flooding, storm surge, ground water tables).

In comparison to design/construction projects, much longer time horizons are required for maintenance projects where climate information would be required covering the whole service life. Extreme precipitation is highlighted in the report as a key challenge. It is recommended that extreme precipitation mapping could be one of the EU-wide goals, and a potential follow-up project include a vertical investigation (i.e. mapping of areas with extreme precipitations and their impact (severity) on road constructions).

Climate data with high spatial and temporal resolution is required in many cases for future and current climate conditions. It is difficult to deliver the highest requested resolutions, due to many uncertainties. Additionally, it is not clear whether this high resolution is absolutely necessary or whether a coarser resolution with some indication of spatial differences at the requested resolution is also sufficient. **Pilot studies within a follow-up project could aim at defining a relation between application and necessary spatial and temporal resolution of data. Also, the recommendation on a common reference period** to be given for European countries could be a part of a follow-up project as the type of information for reference periods is not the same. All countries give some information on averages, but these are generally not useful. It would be more interesting to have similar information on the occurrence of extremes for all countries.

There are some national guidelines for taking account of climate change on which climate data should be used, but few reported international standards (although some results of European projects could be used as international standards). In general, experiences from the past are very important, especially for operation and maintenance. For the design and construction for a future climate, it is not possible to lean on experience only. Some modification of the data for the current climate is regularly used. The investigation of the basic requirements for national standards could bring a set of EU commonalities in the sector of climate data and be an important part of a potential CEDR (or outsourced) service provided to NRAs. Also, the way of dealing with uncertainties has been found to be rather diverse - more information on this is seen as needed.

B. Performing a QuickScan on risk due to climate change

The QuickScan methodology produces a first (quick) estimate of the major risks associated with weather conditions both in the current and future climate, together with an action plan for adaptation. The list of top risks allows an NRA to consciously and effectively focus on specific areas and/or threats in their network. This means that focusing on the 'top' risks enables the use of existing resources more efficiently. On this basis, it is also noted that the QuickScan provides a cost effective assessment of risks.

The basis of the QuickScan method is to bring all available knowledge, information and especially experiences of stakeholders together in such a way that a first impression of climate (change) risks can be assessed. This implies that no quantitative and extensive analyses will be executed, but that the outcomes rely on the valid input of relevant stakeholders. The QuickScan method comprises of three workshops where the stakeholders interact and provide input.

The first workshop focuses on the determination of the boundary conditions of the QuickScan, i.e. which climate changes are to be expected, which threats do they influence and what are the consequences should a threat occur. Obviously this step requires at least general knowledge of climate changes to be expected as this form the basis of any threats.

The second workshop determines the risks associated with the identified threats. This is done by making an estimate of the probability of a threat, together with an identification of locations of the high risk threats. The third workshop, meanwhile, focuses on the development of an appropriate action plan for further steps after the QuickScan.

The authors considered it to be very important to use workshops instead of individual interviews and/or questionnaires. A key benefit of the developed QuickScan methodology lies in the mutual exchange of information and increasing joint awareness. These benefits are lost when using an individual approach. Moreover, there will be a high risk of not reaching uniformity in the answers of the different participants. This poses a recommendation for training of relevant NRA representatives to create a group of experts within the Member States who are able to organise similar workshops on a national level to overcome the identified language barrier.

Recommendations:
It is noted that for the proper use and interpretation of climate data for current and future climate, knowledge about possibilities and limitations of climate data is needed when performing a QuickScan. This method could be very useful in bringing local road infrastructure operators together in a discussion that can have well-structured and harmonised results. This action also goes along the existing RIA (road infrastructure assessment) based on the INSPIRE directive so there should be a supportive environment among the Member States. Local piloting within the countries could be a follow-up action of CEDR to enable the collection of diverse inputs from the TENT network which could include the identification of risks and threats, as well as the importance of road sections, scoring evaluation, consequence criteria feedback, risk overview within an EU map and finally the prioritisation of appropriate actions. This follow-up approach could also deliver the overview of various levels of progress among the Member States (from the perspective of data availability, as well as stakeholder willingness to use the QuickScan method) and would be a perfect tool for the monitoring and detection of technologies and vendors to QuickScan the EU market potential. So it could be recommended to **perform transnational quick scans,** especially for the TEN-T network.

C. Vulnerability assessment

The objective of this task is to describe efficient, existing tools for assessing vulnerabilities within road networks, with a focus on networks managed by NRAs and specifically **TEN-T Network roads (http://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/maps_en.htm)**. In addition, a new comprehensive vulnerability assessment methodology is suggested, based on and compatible with the RIMAROCC method. Using the vulnerability maps created in the process, it should be possible to combine these with detailed climate change projections. Using the tools and methods described, it should also be possible to assess the vulnerability to all climate change related threats within the TEN-T road network. Furthermore, guidance to transnational cross border vulnerability assessment and existing GIS data sources is provided.

The desired qualities of a vulnerability assessment method are summarised as:

- Formulas for vulnerability index calculation for each threat (using the same applied method for consistency).
- Results of vulnerability analysis are presentable as a map
- Information on what GIS datasets are needed for the vulnerability assessment of each climatic risk, and where to find data.
- Description of which vulnerabilities can be assessed with world/EU-scale GIS data, and which need detailed national GIS data.
- Guide on how to put together two different datasets at country borders

The output of the ROADAPT Vulnerability Assessment (VA) is a map showing a spatially distributed vulnerability index for the studied threat along a section or a network of TEN-T roads. The degree of vulnerability is presented as a green-to-red colour ramp with values ranging from 0 (no vulnerability) to 100 (maximum vulnerability).

Evaluation:

The methodology is quite descriptive, however is simple to apply and can be used for a wide range of purposes. It **encourages transnational analysis**, and as such support the aims of the **INSPIRE directive (http://inspire.ec.europa.eu/)**. Together with the **RIMA-ROCC Framework (http://goo.gl/GtAhQO)**, it provides a quite robust solution to be used across borders. In comparison with other existing vulnerability assessment (VA) methods, the ROADAPT VA is comprehensive in its approach and thus provides an international well-detailed perspective with a potential to be extended beyond the existing TEN-T network.

The method described should not be considered ready-to-use. It is a proposed draft method for assessing vulnerabilities for multiple climate change-related threats. For ROADAPT VA to be ready-to-use, the method should be tested in case studies. This implies the need/recommendation for pilot testing in all the CEDR member countries to get the valuable feedback for the tool harmonisation and spreading of awareness about its benefits.

However, for ROADAPT VA to be accessible to a wider public, the method should be complemented with ready-to-use vulnerability scoring tables for all climate change-related risks. This implies that there is **a potential of upgrading the existing results** and opportunities for the further development of vulnerability scoring tables, together with feedback from CEDR members.

It is therefore recommended to start a process for the international harmonisation of data from national road databases covering the infrastructure intrinsic factors listed in Annex A "[5]". The authors of the project results propose a series of recommendations towards the real implementation of ROADAPT.

Recommendations:

- Most infrastructure intrinsic factors seem to be available only on a road-owner or national scale. Some vulnerability factors are not at all available as GIS datasets. It could be recommended to **develop guidance for NRAs** on how to overcome the lack of data needed for decision-making which have been identified in the step 9 of the Part E.
- **A project organising pilot testing in all the CEDR member countries** could enhance the real impact (deployment) of climate change threat assessment. This can be complemented with vulnerability scoring tables supplied by the project partners from their countries/NRAs.
- **Publication of the set of metadata** to enhance a common approach of various road authorities when creating EU-wide datasets based on the INSPIRE Directive;
- Based on the EU INSPIRE Directive, **a survey of the actual progress and plans of Member States for harmonised GIS datasets publication** and data analysis infrastructure should be worked out.

D. Socio-economic impacts analysis

The report contains details on how to perform a socio-economic impact assessment due to the consequences of weather events. It is built on the principles that have been developed in the French GERICI project, completed within RIMARROC.

For the ROADAPT project, as there is a high level of uncertainty on the occurrence and real impact of weather events, the authors have considered that the travel time is the main key indicator for impact assessment. When translating the travel time in monetary value, the other indicators are anyway of second order. The **HEATCO project** (Harmonised European Approaches for Transport Costing and Project Assessment at **http://heatco.ier.uni-stuttgart.de/**) recommends harmonised values to be used in Europe.

The work is well interconnected with part B and/or C of the guidelines as the selection of the threat to be evaluated is based on their outputs. The combination of threats is considered by developing a scenario approach, and the results are not an addition of the impact of individual events, but a combination of impacts.

The authors then characterised the potential consequences on the level of service, namely:

- Reduction of speed;
- Delayed traffic due to lane restrictions, for example;
- Access restriction with rerouting or storage of vehicles (e.g. Heavy Good Vehicles).

The guidelines propose three levels of analysis:

- The network level: only the impact on travel time of road network users is estimated;
- The territory level (territory which is irrigated by the network): impact on the travel time on the various linkages which are ensured by the network is estimated;
- A wider area which is described as: the economic system as a whole and which extends the analysis not only in terms of geography, but also in terms of economic activities that can be impacted.

The network level was evaluated with the classical method of Cost-Benefit Analysis (CBA) for transport project assessment (according to the European HEATCO project Deliverable). Local territory levels were evaluated with the analysis of facilities and their accessibility (accessibility maps). Additionally, the economic system as a whole (e.g. demand considerations, perishable goods, just-in-time delivery requirements, quick response) was evaluated with analysis of the structure of flows, organisation of the logistics and calculation of personal income base (PIB) according to spatial analysis. Concerning the objectives, the authors focused on short-term impacts, so classic CBA analysis was used since the two others (territory level and economic system as a whole) are more related to long term impacts.

Regarding the impacts on the different actors (users, operators, society), or type of cost/advantage (time, cost, external factors), the only appropriate methodology is the CBA (network level). The two other approaches are global, but depending on the model used can give an allocation of impacts per the different actors (e.g. personal vehicles, transport of goods, etc.)

The proposed methodology for detailed economic assessment on the network level with its six-step approach, as follows, is clear and comprehensive to anyone involved in transport:

1. Define the events (scenarios) for evaluation (see § 1.1 and 1.2)"[6]";
2. Choose the traffic model to use (see § 2.2)"[6]";
3. Implement the traffic event(s) and/or scenarios in the model and run the model with and without each event (see with traffic modeller, or define simple hypothesis for rough estimations see § 2.2);
4. Calculate the main indicators of total travel time loss, additional travelled distance;
5. Do the global Cost-Benefit Analysis (according to the European HEATCO project findings);
6. Compare the results of different scenarios between them.

The methodology is a simple tool for obtaining an order of magnitude of the impact of an event to the road infrastructure, as well as financial loss due to the decrease in traffic/transport level of service.
Adaptation measures can thus be evaluated from the impact assessment of the corresponding traffic event and then compared to its cost of implementation, hence measures for the economic impact of climate change. The resulting cost-benefit and multi-criteria analysis are the main tools for decision-making.
For groups of measures (strategy or policy), it is possible to combine the corresponding event assessments. But for that purpose, the probabilities of each evaluated event have to be known, which is rarely the case.
This is why simpler methods (without detailed economic assessment) have been defined for risk assessment, using semi-quantitative methods to evaluate the probabilities and consequences of a risk.

Recommendations:
This part of the project methodology is well done and it is recommended to:

- Support its deployment in the form of pilot evaluation of several places ranging from urban areas to highways across European countries within a follow-up project. Systematic transnational collection of data of events and their socio-economic impact will build a knowledge base. This knowledge base will be invaluable in evaluating the cost-benefit of adaptation measures. Currently, such a cost-benefit analysis is hampered by the lack of reliable data on cost and benefits.
- Working out a simple web interface where a local evaluator of a socio-economic impact of an event can insert various variables to get the computation of actual economic burden of a disruption on the road.
- This website could be enhanced with a database storing the requests as user cases across the EU countries, and could serve as an inspirational tool for this good practice.

E. Selection of adaptation measures and strategies for mitigation

This part of the guidelines is very complex (140 pages) and uses the same structure of description for various climate change impacts on road infrastructure performance. The authors introduced a good approach, enabling the reader to get a very quick orientation through the methodology. In particular, through hyperlinks within the Table 1 "[7]", it is possible to effectively identify the theme of interest. It is recommended that this stable structure and navigation be reused in a web database interface providing the knowledge and methodology in various languages to enable useful feedback from the users.

The ROADAPT 10-step approach for selecting an adaptation strategy is based on the following needs with respect to formulating an adaptation strategy:

- To develop a structure for decision-making, corresponding to the need of the road owners. This structure should be consistent and applicable on the level of a road network, section and structure.
- To present an overview of decisions that should be taken in the adaptation process, and factors influencing the choices made by the NRA.
- To find out which techniques to apply, when and why.

A 10-step approach provides for every climate change threat and the 10 steps listed allow the road owner to select an adaptation strategy for the vulnerable road component (asset) under consideration. **Steps 0 to 3 provide background information** on the road owner's needs, impacts and current and future resilience. **Steps 4 to 8 deal with the selection of adaptation measures** and strategies. The selection process involves:

- Selection of a combination of measures that constitute an adaptation strategy.
- Ranking of measures according to the assessment of their consequences for operation and sustainability.
- **Steps 9 and 10 provide an outlook on research** that will help climate change adaptation, also estimating the time-to-market to support compilation of research road maps.

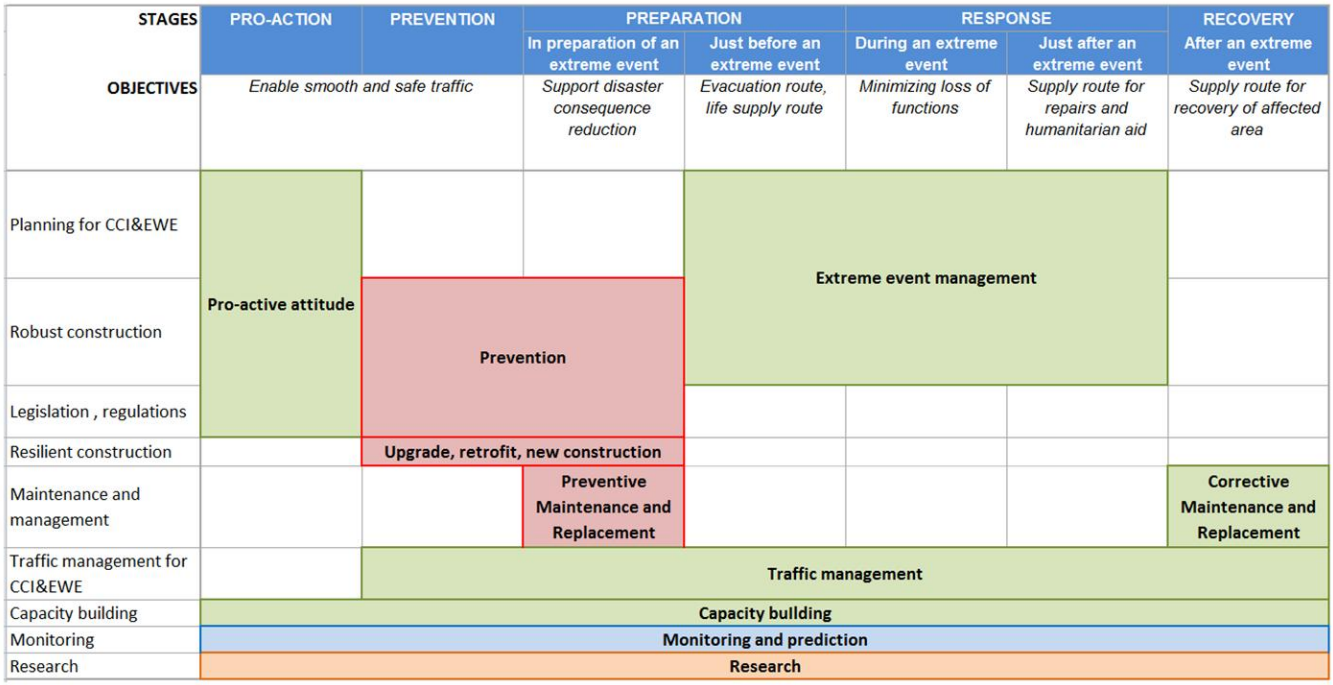

Figure 2: ROADAPT: Policy matrix for adaptation

Recommendations:

The proposed methodology provides a comparison between the RIMAROCC and ROADAPT approaches, and table 2 "[7]" clearly illustrates how and which method to use for a particular adaptation measure. A reader is provided with a complete and comprehensive survey of the relevant steps, as well as the particular part of the ROADAPT methodology to be used. As there are more than 500 measures, the success of the methodology deployment in real use among NRAs consists of an **accessible web tool** that provides quick and structured information that links a threat with appropriate measures. The tool should be as simple as possible to overcome the barrier of hundreds of measures, criteria and ratings. The follow-up project could investigate a potential of methodology deployment in various Member States, **providing specific languages** to overcome the international barrier as well as feedback from various piloting to create, step-by-step, an EU GIS map of climate change threats with successful solutions and measures deployed. This could also be connected with **cost estimates for a particular measure** which could bring positive changes in the technical adaption of road construction as well as a prognosis on the expected cost required by infrastructure over the next 20-30 years. This could significantly complement the existing results of the project, which could improve road adaptation planning and budgeting, influencing the price for toll and other financial tools.

There is also a worldwide phenomenon that could be used to better follow and measure the potential risks and climate change threats and their impacts. **The internet of things** could be developed as an extra part of the follow-up project. The selection of problematic areas of different Member States and the piloting of sensor-based networks to continually monitor the potential threats could bring precious detailed knowledge about the detection technology itself and its cost, as well as the potential

benefits/savings based on the better time response of the road operator and the short-term versus long-term planning of the measures deployed – the hierarchy of quick wins and long-term savings/investments.

The CEDR network could come up with their **own road construction standards** which take into account climate change measures. This could be derived from the existing CEN TC 227 standards and their already defined classes or from the national standardisation work of specific NRA reactions of particular threats (e.g. Denmark, Sweden climate change adaptation policy). As the existing results are still a very high-level issue, i.e. a framework, this standardisation work would fulfil the lower level, detailed and specific levels that NRAs would find beneficial.

CEDR could play a role of integrating and disseminating knowledge and good practice, delivering a consistent map of threats, measures, tools, technologies and GIS maps covering the issue of environmental impacts on road infrastructure in EU.

CliPDaR – Design guideline for a transnational database of downscaled climate Projection Data for Road impact models

Project Facts

DURATION: February 2013 - November 2014

COORDINATOR: Tobias Fuchs, German National Meteorological Service (DWD), Germany; e-mail: tobias.fuchs@dwd.de

PARTNERS: German National Meteorological Service (DWD)

Austrian National Meteorological and Geophysical Service ZAMG, Austria

DELIVERABLES:

- D 1.1: Report on the first workshop 25-27 February 2013, Offenbach, Germany; DWD headquarter (May 2013) "[12]"
- D 1.2 - Report on the outcome of the combined meeting (CliPDaR and ROADAPT), 3-4 April 2013, Langen, Ger-many, DWD Education and Training Centre (July 2013) "[13]"
- D 1.3: Guidelines for the use of Statistical and Dynamical Downscaling results as input for impact models (December 2013) "[14]"
- D 2.1: Report on the workshop held in Vienna at the ZAMG from the 6th to the 8th May 2013 'meeting the operators' (November 2013) "[15]"
- D 2.2: Guidelines on ensemble climate projection data (December 2013) "[16]"
- D 3.1: Guidelines for coping with relatively cold winters/hot summers (January 2014) "[17]"
- Presentation of the CliPDaR findings to the Project Evaluation Board (Final seminar, Offenbach, February, 2014 "[18]"
- An invited presentation at the TRA (Transport Research Arena) 2014 in Paris together with a peer-reviewed publication (Paris, May 2014) "[19]"
- D 3.2: Final Report (June 2014) "[20]"
- D 3.2: Design Guideline - Annex of Final Report (November 2014) "[21]"
- CliPDaR findings, progress and guidelines were presented at over 10 national & international conferences and strongly disseminated among Austrian road authorities.
- In November 2014, a workshop on 'Climate Change and Transport infrastructure' was hosted at ZAMG (together with the Austrian Institute of Technology – AIT).

Background and objectives

As the road sector is very vulnerable to extreme weather phenomena, which can produce large and substantially expensive economic consequences. It is essential to know as early as possible to which extent global climate change exerts impacts on national and European road networks. Appropriate knowledge may be generated from climate projections and specific impact models, which are applied to estimate the future state of relevant parameters for road design and maintenance work. In recent years, it has been recognised that it is essential to assess the uncertainty and reliability of future estimates of climate by using ensemble approaches and downscaling methods.

Within the CliPDaR project, existing approaches and methodologies, which are used to derive climate change scenarios, are discussed and promising strategies are applied to derive changes in hazards to which the European transport industry will be exposed throughout the 21st century. The targets of CliPDaR are the production of hazard maps that depict the evolution of risks to European roads in the future, as well as the provision of answers to a set of questions raised by CEDR. Another central deliverable pertains to guidelines for NRAs that clarify the handling of climate change scenarios, the conclusive interpretation

of risk distribution in terms of probabilities, the detection of flaws in the process of deriving future climate states, which would spoil decisions taken by authorities.

Description and evaluation of the project

The project focuses on the review, analysis and assessment of existing regional Climate Change projections regarding transnational highway networks (TEN-T) needs. In recent years, it has been recognised that it is essential to assess the uncertainty and reliability of given climate projections by using ensemble approaches and downscaling methods.

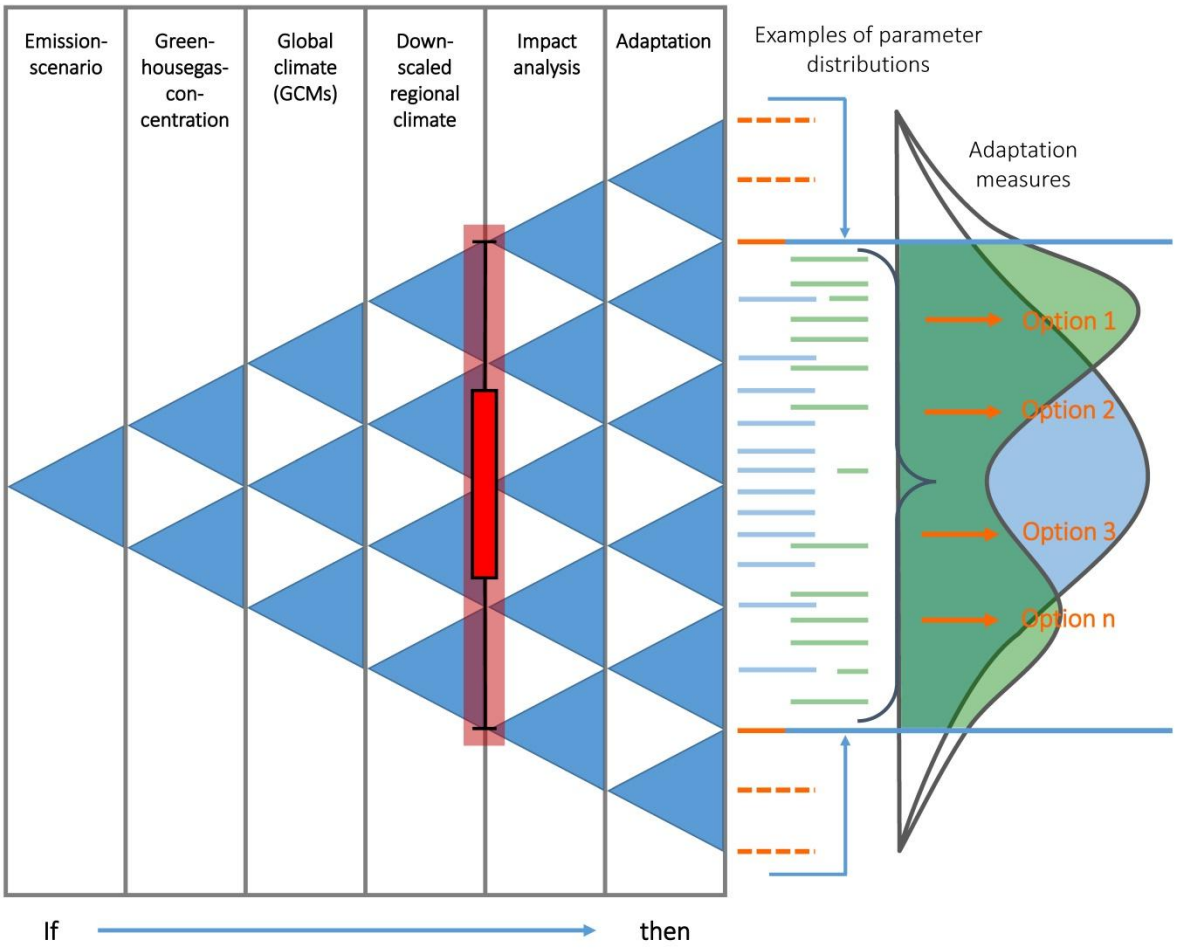

Figure 3: This "cascade-process" is involved when deriving adaptation measures to handle climate change

The assessment of future changes in hazardous situations to transport infrastructure does not only require observational data covering the past, but also information on how climate at the local scale may evolve in the future. GCMs (Global Climate Models) are modelling oceanic, atmospheric and various other processes in the climate system, which are caused by natural forces and driven by man. The spatial resolution of GCMs, however, is too crude to represent local processes, which are essential for transport infrastructure. As such regionalisation is needed – that translates GCM information down to the local scale at which damages actually take place. There are essentially two approaches (statistical and dynamical downscaling) that allow for this and both have been applied throughout CliPDaR.

The research developed during this project discusses two other very important issues:

a) the data in-homogeneities or gaps along national borders, which originate from different past measurement practices but mainly from the fact that different nations tend to develop future scenarios that end at their borders; this practice leads to a break across borders from one nation to another and these breaks can be to the same degree as the climate change signs;

b) the differences between scenarios that can be assumed related to the evolution of life on the planet, and the evaluation of the results obtained with some of them, namely the so called SRES A1B (rather close to what had happened over the past decades), as well as the SRES A2 scenario, which is somewhat more dramatic in terms of the anthropogenic release of greenhouse gases into the atmosphere.

The rutting of asphalt surfaces and 'blow ups' of concrete roads are safety issues that are related to hot days together with tropical nights, which may become more frequent in the future. Longer and more frequent heat waves will also affect, for example, bridges and become a growing concern. Changing precipitation patterns and displacements in the storm track climate (median and variance) may present new challenges to drainage systems and slope support.

Such phenomena are sometimes characterised by one weather element like precipitation totals or wind speed and sometimes described by a multitude of weather elements, e.g. exceeding particular precipitation totals together with temperatures within a certain range. Within CliPDaR, such damaging weather phenomena are described by "Climate Indices" (CIs, e.g. precipitation totals exceeding certain thresholds, temperatures above or below significant values, or combinations) and stored together with the applicable infrastructure elements in a so-called 'Cause-Effect Tensor'. 'Tensor' reflects high dimensionality involving CIs, infrastructure elements, space and time. These CIs – combinations of climate variables or functions of them, which harm road assets (e.g. long-term rain events, heat spells) – were identified in cooperation with road experts, road administrations, people in charge and constructional engineers through interviews, workshops and international meetings.

The selection of days with values of selected meteorological elements that exceed or undercut threshold values represent a practicable approach of the analysis of local scale climate projections with regard to extreme meteorological events. This approach enables the use of CIs that are associated with damages to transportation infrastructure. One output of CliPDaR, which is based on CIs, are maps covering Central Europe, showing the change in the occurrence of hazardous climatic phenomena like landslides, rutting, hot spells and abundant precipitation.

Another CliPDaR challenge deals with the assessment of future cold winters and hot summers in Europe. Hence, further findings of CliPDaR refer to hot summer seasons on the Iberian Peninsula and very cold winter seasons in Fennoscandia. Here also, CIs that correspond to extremely hot or cold seasons are used. Their future distribution is compared to what has been observed so far, preparing the basis for decision-making regarding which counter-measures to be taken.

The final mission of CliPDaR is to create a design guideline setting standards for handling climate change data and downscaling methods used in pan-European traffic infrastructure risk assessment. The design guideline is engaged in the:

- Assessment of statistical/dynamical downscaling to facilitate a proper procedure that deals with the uncertainties of the future climate with respect to the needs of future budgets and maintenance issues;
- Assessment of ensemble simulations and climate projections, as well as the definition of a pragmatic data provision for decision-making. With this information, CliPDaR aims to enable the reader to make informed and efficient decisions on whether a proposed climate change scenario is suitable to derive particular adaptation measures or not.

During the development of this project, emphasis was given to the results obtained in previous or ongoing research projects. The examples given of maps of CI were mainly based on the data prepared by the German joint research programme KLIWAS ("Impacts of climate change on waterways and navigation - Searching for options of adaptation", 2009-2013). In addition, the information and results of other projects such as VALUE ("Validating and Integrating Downscaling Methods for Climate Change Research" and ESSEM COST Action ES1102, 2012-2015) were used. The German Adaptation Strategy (DAS), the Austrian Adaptation Strategy and the IPCC Recommendations (IPCC 2007, 2013) were also taken into account. The Austrian experience in implementation [32] clearly shows that one of the major roles here is played by successful dissemination practices.

Outcomes and recommendations

CliPDaR aims to answer questions related to the interplay (i) between the current climate and road damages, as well as (ii) between a possible future climate and potential damages of road infrastructure. This applies to the generation of highly resolved maps covering Central Europe that shows probable changes of hazards to transport infrastructure (landslides, rutting days, etc.), as well as further analyses referring to the future of hot summer seasons in the Iberian Peninsula or cold winter seasons in Fennoscandia. These findings partly configure the guidelines that determine how climate datasets and mathematical techniques are to be used to derive decision support. This is one of the significant outputs of CliPDaR. The various CliPDaR deliverables are focused on aspects such as how to deal with the results of statistical and dynamical downscaling, build-up of ensembles of climate projection data, the uncertainty of the model chain, the CI approach and a multi-variate technique to identify atmospheric circulation patterns.

The “Guidelines for the use of Statistical and Dynamical Downscaling results as input for impact models” (D1.3 "[14]") especially focuses on the downscaling step necessary to derive local scale climate change scenarios from GCM projections (that produce, by construction, findings that are valid for large geographic areas as continents, but not for smaller regions). In fact, since the transport network in Europe is the topic of interest, a downscaling technique is required that transforms the large-scale information to the road infrastructure. The two main forms of downscaling techniques – Dynamical and Empirical or statistical downscaling – are explained and compared to each other and the parameters that influence them are also discussed. The positives and negatives of the methods for bias-correction are pointed out and specific examples of downscaling problems given. Finally, the report presents a ‘look up table’ that helps to judge which downscaling method was successfully applied to generate regional to local scale projections characterising the possible future behaviour of the target parameter under investigation.

The “Guidelines on ensemble climate projection data” (D2.2 "[16]") introduce and discuss the so-called ‘ensemble approach’. A classification according to practical criteria is done and explained on the basis of examples. The application of the concept is demonstrated and some additional thoughts on the application of the ensemble approach to European transport infrastructure are presented at the end of the report.

The “Final Report” (D3.2 "[20]") has 14 questions and answers, each associated with a brief description of background. The answers to these questions provide information about some important issues related to climate change in Eu-rope and the procedures that should be used to obtain good-quality information. These include: the robustness of the downscaling technique and the kind of downscaling that should be applied; the data that should be used by European NRAs for decision-making; how to obtain this data; the variation of some climate variables in some parts of Europe in recent years; the reliability of the GCMs; the relationship between some climate events and maintenance budgets; the expected climate in some specific regions in Europe; and some hints on future possible landslides.

The “Design Guideline” provided by the project as Annex of Final Report (D3.2 "[20]") is intended to support NRAs regarding the analysis of climate projection data. It is an important tool to help avoid the most current errors dealing with the analysis of climate data and climate projection data. This report summarises the main principles which should be considered to deal with climate models. These principles appear to be a good starting point for users. This report also includes other key aspects: the uncertainty with every step that is necessary to derive different adaptation measures to mitigate the impact of climate change; the need to work with “ensembles” and “ensemble building” and “ensemble statistics”; the advantage of the use of CIs; temporal and spatial aspects of data; reference values for climate change signals; interpretation and communication of climate projections; and application of climate impact models. Finally, some notes related to Regional Climate (RC) Projections prepared by the EU-7-Programme ENSEMBLES (based on the SRES-Emission-scenarios) and the newer Regional Climate Projections of the project EURO-CORDEX, based on the RCP (Representative Concentration Pathways) are presented.

At the 2014 Transport Research Arena (TRA 2014) in Paris, an oral presentation was delivered. Associated with this oral presentation was the preparation of a peer-reviewed publication which was evaluated with a high score. Aside from this, the CliPDaR dissemination event was distributed to scientific communities, practitioners and NRAs at several conferences and workshops.

General Recommendations:

Downscaled climate information (from the European scale to the local scale of a traffic network) is the basis to develop local scale climate change scenarios of what may happen to the road infrastructure and the surrounding environment. Such scenarios are in turn the basis for the planning of adaptation measures to protect the traffic infrastructure against changing climatic challenges. On the other hand, depending on the problem, different local scale climate variables are needed to derive proper adaptation measures.

As general recommendations relating to the application of the results of this project, it is advisable that the CEDR member countries develop regional applications, in order to:

Collect and process the climate data that aims at the absence of in-homogeneities or breaks along national borders.

- Improve the climate change projections.
- Assess the uncertainty along the production chain of the regional climate change projections, which are to be grouped in ensembles.
- Improve the formulation of CIs as a function of space and time.
- Link up the information given by the CIs and the ensembles of climate change projections with exact topographic information, vegetation and soil data and land use change data caused by human activities.
- Create databases that enable us to relate climate change with the damage occurring in the infrastructure.

PART II

Outcomes of the final conference and its workshops

On 27-28th October 2015, the final conference of the CliPDaR and ROADAPT projects was held in Brussels. There were 57 participants from many NRAs, research institutes, industry and EC. The conference agenda, list of participants, and all presentations, are available for download from the **FEHRL website**. The conference was moderated by the CEDR Research Coordinator, Ronan Cunniffe. Below are the highlights of the key presentations and short reviews of four workshops that were held on the second day of the conference.

Plenary sessions and presentations

KEY SPEAKERS

Steve Phillips

CEDR Secretary General - Importance of Climate Change for Road Authorities "[22]"

It was noted that maintenance, multi-modality, ITS and climate change are the main challenges and focus of cooperation for NRAs. This presentation covered the key areas of climate change (CC) in which CEDR is involved:

The CEDR activities views CC from the broader perspective - from a transport system perspective - how it develops to a carbon neutral society but not forgetting the road sector itself; the importance of addressing climate change at the early stage, before the problem becomes too large to be addressed. It was noted that the conference aimed to cover the areas of how the road owners identify and improve the most **vulnerable assets** and risk assessment **methods/tools** to be prepared for the effects of CC. CEDR does not consider its own research programme as a limit to the knowledge generation. It cooperates with the EC and internationally (US, other regions), with industry and is trying to build a programme that is holistic with other challenges in the road sector, thus facilitating better knowledge generation.

Mitigation

Although the two projects are about adaptation to the climate change, we don't have to forget about the mitigation of climate change in the first place. In order to build the road network with the least impact on CO2 and GHG generation, the following need to be considered: where to build (with least impact on environment), what to build (what materials are used); how to build (many research projects are about safety and environmental impact, procurement [see the note below]); how to maintain (better roads - lesser fuel consumption); how to operate (managing the traffic and deciding what vehicles should be supported). The NRA measures on mitigation include the consideration of:

1) Multi-modality
- Cooperation with rail Infrastructure managers and others on better coordination of modes
- Multimodal Travel Information and Planning Services
- Mobility as a Service (MaaS) being investigated
- But notes that 75% EU surface tonne-km of freight are by road - so need our own solutions

2) ITS and traffic management solutions
- congestion management
- cooperative- ITS
- priority for eco-vehicles

3) Promotion of soft-modes (pedestrians, cyclists)
4) Green (and innovative) procurement

The European Truck Platooning Challenge was noted as an opportunity to provide considerable CO2 benefits across European ITS corridors. This has received considerable interest from industry and trucking companies. Further work is required on the challenges of how to get these trucks on the road.

What **CEDR is really looking for** or as Steve Phillips notes:
"Role of CEDR in the light of EU policy and research projects?"

1) Maximise the awareness of the research findings
2) Promote these findings to NRAs and Member States
3) Assist in national application of results (creating national adaptation strategies)
4) Present factual information and guidance to other bodies
5) Implement, implement, implement - implementation is a key area. The first step of deployment is dissemination. CEDR aims for dissemination in all countries.

Answers to these questions or bullet points are at the end of the report - in the recommendations chapter.

Ronan Cunniffe

CEDR Research Coordinator - CEDR Climate Change Research Programme and Plans for the Future "[23]"

The presentation outlined the CEDR Transnational Research Programme (TRP) and highlighted the objectives and steps for past and present climate change calls.

It was noted that ROADAPT and CliPDaR are both continuing the chain of the CEDR TRP on climate change that started in 2008 with RIMAROCC, IRWIN, SWAMP, and P2R2C2. The results of these projects will be carried further into the CEDR call 2015.

The ideas behind CEDR climate change research as a continuum are best described by the titles of those programmes:

An example of this sustainable research approach can be seen in a connection between RIMAROCC (2008) and ROADAPT (2012).

Climate change will feature as one programme under the next CEDR Call for Proposals, Call 2015.The following title has been put forward for the climate change research programme – "Climate Change: From Desk to Road". This programme will have a strong focus on the implementation of existing research into practice.
More specifically, key topics within the call will be:

1. Economic costs associated with integrated climate change decision-making.
2. Driver behaviour: Diagnosing driver decision-making
3. A Transnational approach to water management
4. Embedding climate change into all procurement phases

Marianne Grauert

Danish Road Directorate and CEDR TG - Cross-border Cooperation on Climate Change Adaptation and Mitigation "[24]"

Within the current CEDR Strategic Plan (SP-3) Task I4, the report on mitigation and adaptation issues is due in 2016. It shall be understood that mitigation is global and can be measured and modelled; while adaptation is local and cannot be measured globally. This has to be taken into account when working on cross-border projects with the CC topics - there are two different levels - global and local.

Mitigation WG:
To keep the CO2 at low levels, transport has to convert to electricity and biofuels; in addition to that, more care should be taken about soft modes - pedestrians, bicyclists, and public transport. The group is describing a new way of planning using back casting based on individual goals for GHG reduction.

Adaptation WG:
Many meetings have been conducted which stressed that the window of action is rapidly closing and it is more urgent to be prepared for adaptation. Unfortunately, only a few NRAs have a strategy for implementing CC adaptation. The WG is working on a guideline and template that will help to develop an adaptation strategy and action plan. Awareness across the organisation, commitment on the executive levels, human and financial resources, and focus on implementing afterwards, is required. First a strategy and then an action plan. This then needs to be integrated into the organisation from planning of the road network to the operation and maintenance levels.

ROADAPT AND CLIPDAR PROJECT PRESENTATIONS

Introduction to the ROADAPT project, Arjan Venmans – Deltares "[25]"

The presentation provided an overview of each part of the project, including a description of RIMAROCC; CEDR 2012 and RIMAROCC; ROADAPT project scope; The ROADAPT guidelines.

Introduction to the CliPDaR project, Joachim Namyslo – DWD "[26]"

The structure and description of the CliPDaR project was provided, and a few recommendations on what to focus on in the future:

- Enlarge the region stepwise by consistently including further European countries
- Use new scenarios (RCPs of EURO-CORDEX)
- Avoid the mixing of datasets
- Ensure highest quality of data – no breaks along borders
- Include air traffic and railway transport
- Expand the analysis to further CIs (e.g. damage of bridges, water to street level)

ROADAPT - European guidelines for the use of climate data for road infrastructure, Janette Bessembinder – KNMI "[27]"

The presentation dealt with the following questions:

- How weather/climate affects infrastructure;
- What is climate and climate change;
- Use of climate data for vulnerability studies;
- Uncertainties in climate data.

ROADAPT - The QuickScan Approach, Martial Chevreuil – Egis "[28]"

The presentation provided an overview of the key steps involved in QuickScan, and the requirements for the pool of experts.

ROADAPT - Vulnerability Assessment method, Per Danielson – SGI "[29]"

A description of the GIS-aided VA tool for roads was given. The main highlighted features are:

- Tool to assess all climate-change related threats with the same method
- The focus is on TEN-T network roads
- Possible to use as stand-alone method or with RIMAROCC tool

ROADAPT - Socio-economic impact assessment, Martial Chevreuil – Egis "[30]"

Event definition – from weather event to traffic event to socio-economic impacts, using a risk map; Link with the risk assessment: vulnerability of asset and probability of threat;
Three geographic approaches: network level, local territory level, and economic system as a whole.

ROADAPT - Selection of adaptation measures and strategies for mitigation, Arjan Venmans – Deltares "[31]"

Step-by-step guide on selection of CC adaptation measures and strategies for mitigation was provided: The 10 step approach; ROADAPT guideline Part E; The ROADAPT database

CliPDaR - Application of CliPDaR climate guidelines by Road Authorities, Christoph Matulla – ZAMG "[32]"

Experience in the application of CliPDaR climate guidelines by different levels of road authorities (BMVIT - the federal ministry of transport, ASFINAG - motorway and expressway financing corporation, NÖ-L Roads - federal province roads department, Road Maintenance Depot Hollabrunn) in Austria. The central subject of the presentation is a detailed analysis of the implementation process of new scientific findings regarding road infrastructure in planning, maintenance and reinforcement into the procurement strategies of road authorities on different levels – from road maintenance depos across procurement departments of the federal states up to the ministries of the Austrian government. Several strategies how this implementation procedure may be influenced or even steered are discussed.

National Road Authorities

National adaptation strategies for roads, results of the CEDR Technical Group I4 - Climate Change Adaptation and Mitigation, Christian Axelsen – Danish Road Directorate "[33]"

CEDR TG I4 was dealing with the technical aspects of CC during SP2. SP3 is more concentrated on implementation. SP3 objectives: identify barriers of implementation, overcome these barriers at a non-technical level, increase rate of success. Identified barriers include: resource demanding (cost and labour), political difficulties, force-feeding CC to existing working paradigms (some feel it is a hassle), general absence of organisational-level strategy and awareness. Identified four major areas to facilitate implementation for NRAs: Strategy, Action planning, Awareness, and Methodologies. Denmark and Sweden have their strategy on CC adaptation in place.

Transforming a strategy into an action plan - experiences from Sweden, Eva Liljegren – Swedish Transport Administration "[34]"

The Swedish Transport Administration is a multi-modal (road, rail; to some degree: shipping and aviation) administration. Its CC strategy was developed on the basis of the Danish strategy. There are three subjects in the strategy:

1. **Incorporate CC adaptation in rules and regulations**
   There are approximately 1,500 rules and regulations. It is not possible to incorporate CC in every document which is why inventory was needed of how many documents to be changed, adapted to which scenario, how much will these changes cost, can the changes be financed, what is the time-span for the incorporation of those changes in the documents, what is the time span – how many years it will take to change those documents.
2. **Identify and assess geographical risk areas**
   There are many CC risks in Sweden: in the north, thawing of permafrost under the railways and roadways; in the south – rising sea level etc. Methods used include robustness planning, historical data from natural hazards (flooding events, landslides etc.) and putting them into GIS to see which geographical areas are affected.
3. **Analyse and log CC-related incidents**
   There is a need for guidelines that would answer questions: which investigation method should be used, what type of events should be investigated, how should the incidents be logged; how can the findings/conclusions be taken care of by the organisation?

National Adaptation Strategy and adaptation of infrastructure in the Netherlands, Kees van Muiswinkel – Rijkswaterstaat "[35]"

59% of the Netherlands is vulnerable to flooding. The National Adaptation Strategy (NAS) is being developed and is planned to be in place in the spring of 2016. It will cover all areas like agriculture, health and trading and includes transport and infrastructure and the modes that are managed by Rijkswaterstaat – roads and waterways.

The Delta programme started to address high water protection but the Delta Decision for Spatial Adaptation also looks at climate change adaptation of the urban environment, including infrastructure, drought and heat stress. The Netherlands has to be climate proof and water robust by 2050, which means acting climate proof has to be part of policy and processes by 2020.

The ambition of the Ministry of Infrastructure and the Environment and Rijkswaterstaat is to have a transition to more adaptive long-term thinking and acting to take necessary adaptation measures to prevent future damage. Postponement means higher costs in the future. By taking measures now, benefits increase by avoiding damage; benefits of adaptation measures are estimated to be four times higher than costs on long term. Emphasis has to be on both mitigation and adaptation. The less spent on mitigation, the more has to be spent on adaptation - 2°C vs 5.5°C scenarios with 2% of world's GDP vs 8% GDP for adaptation measures in 2100.

The NAS plans for the Road sector for 2016-2018 are: Existing tools need to be adjusted to take into account the different CC scenarios. Design guidelines and guidelines for water assessments will be adjusted; adapt maintenance strategies for present infrastructure.

Challenges include implementation into daily operations: creating awareness within staff, performing risk assessment for transport and infrastructure and CBA (cost benefit analysis) of measures, relation to asset management and maintenance planning.

Norwegian Roads Adapting to Climate Change, Gordana Petkovic and Lene L. Kristensen - Norwegian Public Roads Administration "[36]"

Norway faces challenges associated with flooding, erosion from rivers and sea; sea level rise; landslides, snow avalanches, road closures due to heavy snow fall. Special interest is about structures and road sections that are expensive and important for society's mobility.

Two four-year R&D programmes "Climate and Transport" and "Natural Hazards - Infrastructure, Floods and Slides" were set up and have provided the information to assess and cope with CC. Projects reveal the importance of cross-domain cooperation – meteorologists, hydrologists, geologists etc.

Climate data infrastructure is in place and accessible. Design manuals have been updated to include CC measures. CC conditions are included in the premise for planning. Now designs account for 200 year flood not 100 year, a robustness factor for drainage, integrated into comprehensive drainage plans. New concept for contingency plans for natural hazards is in place. Challenges in applying CC adaptation measures to road projects: How much of the road network is not adapted? NPRA carries out large-scale surveys from the aspect of redundancy. CC is introduced in these surveys. RIMAROCC has been used and ROADAPT and QuickScan are considered to be possible to implement.

However, the main vulnerability assessment is carried out in contingency plans. An extensive database is available and put on GIS. Natural hazard data are tied with the vulnerability factors thus providing a basis for decisions concerning preparedness. Data is provided by contractors and by local observers (via mobile app).

Workshop 1
Climate Adaptation QuickScan

Moderator: **Martial Chevreuil, Egis**

This workshop focused on the implementation of the QuickScan method for estimating the CC-related risks for roads. The workshop was based on a fictive motorway inspired by one of the case studies from ROADAPT, the motorway in northern Portugal. The A24 motorway linking the Portuguese cities of Viseu and Chaves is a 155 km link opening up the north of Portugal and providing ready access to Spain from the centre of the country.

The moderator simulated three distinct phases of this method on a chosen section of the motorway: a) selection of the relevant climate threats, determination of the relative importance of the particular section of the road, discussion and ranking of the possible consequences of climate threats, scoring of the climate threats regarding their potential impact on each consequence criterion; b) scoring of the probabilities of the threats, evaluation and prioritisation of the climate risks, selection of the risks that can be mapped; discussion on risk acceptability (which risks require action?), c) determination of a CC adaptation action plan, prioritisation of the actions.

The values assigned to the parameters in order to implement the method were suggested by the participants in the workshop, playing the role of the motorway staff.

The main conclusions of the discussion of the QuickScan method can be pointed out:

- In order to make most of the QuickScan, it is necessary to put effort into composing a task group from experts from different fields of knowledge. As underlined during the presentation of the QuickScan method, participants of the workshop should rather include experienced generalists and practitioners of the network. For the first workshop, these fields of experience are, for example, economic evaluation and costs for managing the incidents and repair; traffic management; traffic safety; pavements; geotechnics; hydraulics. While for the second workshop, engineers familiar with the climate-related threats will be required.
- In theory, it would be useful to encompass members of the design team of the infrastructure under analysis. However, as most of the infrastructure under consideration would have been constructed a long time ago, this is not possible. The maintenance team would have in principle access to the as-built database of the infrastructure.
- If required, the QuickScan could be based on preparatory information provided beforehand to the participants.
- In the role playing of this workshop, it was discovered that the ranking of the significance of the threats and their likelihood were inhomogeneous over the panel of participants. This would probably happen in the “real case” as well. That is why it is important for the task group performing the QuickScan to have good knowledge about the road section and the project framework.
- The scoring of the threats is individual and may differ from one to another. The major differences should be explained and discussed to come to a consensus taking advantage of a brainstorming. If a consensus cannot be achieved, average values will be retained.

Workshop 2
Vulnerability Assessment

Moderator: **Per Danielsson, SGI**

This workshop focused on getting practical experience with the VA of various places on the roads within several steps of the guidance. After selecting a main threat and potential sub-threats the participants focused on coming with potential vulnerability factors that can be related to the threat. The next step was to come up with existing GIS data, i.e. specific locations or sources of data that could provide valuable input to the set of existing GIS data. Besides this specific task, the participants also discussed the differences between data that is monitored within the different countries (NRAs), e.g. Danish wind map is very useful for wildfire threat vulnerability. So a black spot map can be derived from this. This example of merging various data showed a potential benefit for future planning and threat awareness when deploying such guidance. The third step then allowed input data to be reclassified into vulnerability factor scores. This part was the most difficult and there were big differences between the results of various groups of participants, from simple reclassification of vulnerability factors to detailed scaling of factors values matched with adequate criteria.

The guidance was found to be very good as it is simple and “easy to use” on the one hand and comprehensive enough on the other. To conclude, there should be a unified view on vulnerability factor scoring so that each threat and sub-threat should be considered and scored in a uniform way.

Workshop 3
Using climate data as a road operator

Moderator: **Janette Bessembinder, KNMI**

From the moderator: Although I had prepared a presentation on "uncertainties" and how to deal with them, I let the audience answer the questions they had about climate and climate change and the use of climate data (also the CliPDaR members were present to help answer the questions). The participants preferred to do that.

The following aspects were discussed during the workshop:
What time period should be used by NRAs when evaluating the climate data? Is it a 10-year span (2001-2010) or 30-year span (1961-1990)?

Natural variability and the standard 30 years need to be captured. For monthly averages, 10 years are enough but for extreme events 30 years are better. Some national meteo agencies update the 30-year data at an interval of 10 years (for 30 years again), so instead of using 1961-1990, some countries can use 1981-2010, for example. Comment from Joachim Namyslo: for climate projections, the 30-year period of 1961-1990 was used. Janette Bessembinder: in the latest **IPCC's 5th report (https://www.ipcc.ch/report/ar5/)**, the period is a last good reference of "normal weather" but engineers anyway want to have updated climate data. Janette Bessembinder: some countries use 20-year periods and in latest IPCC's 5th report it is 1981-2000.

Climate data [projection] should be synchronised with the expected lifetime or maintenance period of the asset. Comment on this: Climate is the statistics of weather and from the statistical point of view, there is no sense to use less than 30 years of data. For some need more data than others.

Suggestion: always check the climate data reference timeframe.

Projections versus predictions - what is the difference? Predictions rely on the conditions of today and try to forecast the actual evolution of the climate in the future, e.g. the next season, next year or next decade. Projections provide information on the statistics in the future of the climate in response to changes in greenhouse gases. Note: this has been described quite well in the ROADAPT guidelines on the use of climate data on p. 15.

Comment from Christian Axelsen: For decision-makers, the main focus is not on averages, it is rather on extremes of the weather. Extremes are the main challenges when talking about the implementation of results of both projects in NRAs. Answer: both ends of probability distribution are showing the extremes. Some ensemble models can also make projections and it is necessary to work with thresholds for the tails of distributions. Need to use common sense when dealing with the outcomes of models (if a climate scientist cannot explain what the model simulations are for the future, always be careful using that information. Janette Bessembinder: Decision-makers are triggered by examples, not numbers alone. Providing existing examples and adding projections on how often or how severe the future events will be under certain scenarios could help decision-makers. Integration of climate and impact/adaptation research (including networking of climatologists and impacted sectors) is essential for providing decision-makers with useful information. Comment from Irina Stipanovic: Dynamic decision-making for maintenance, based on risk assessment. Asset lifetime (see above) should be taken into account. Janette Bessembinder: A dialogue between decision-makers and climatologists would help to determine which scenarios to use for calculations (how robust should it be, which risks are considered acceptable).

Change in wind and snow: make distinction between wind gusts and winter storms (longer duration). Wind gusts (especially in summer and related to thunder and lighting and very intense rainfall) will increase in all cases. For winter storms this is not the

case - around the Netherlands, climate models do not give clear indications of increase. For northern countries it could be different. Intensity and frequency of snow storms could increase.

Final remarks from Joachim Namyslo and Janette Bessembinder: Correlations between climate events and impact events (eg. rainfall pattern versus landslides) need to be addressed in future research. For this further integration and cooperation, is essential at all levels and across borders.

Workshop 4
Selecting adaptation measures

Moderator: **Arjan Venmans, Deltares**
Workshop reporter: **Dr. Alexander Arpaci, Ubimet**

In this workshop the 10 participants were given the opportunity to use part E of the ROADAPT guideline and the database of adaptation measures to select adaptation measures and develop an adaptation strategy in three case studies:

- Heat stress on pavements
- Slides of the embankment; landslides after heavy rain
- Mobility services during extreme weather

The participants were also asked to identify their national top three measures and national research needs. The results of the case studies were discussed and the following comments were given by the participants:

- An impressive amount of information has been collected in Part E of ROADAPT project, and an impressive structure has been set up. This shows the determination and time that was spent on putting it together. At the same time, this represents a challenge - the sheer amount of information can make it quite hard to make the system useful.

Some recommendations for further development are:

- Potential users requested to make database fool proof, user friendly and robust;
- There is a strong need to develop a more user-friendly tool which is self-explanatory and stable. Excel sheets are a good start but are complicated to use. A web-based database with a graphical user interface (GUI) could improve the efficiency of use; lower the level of technical knowledge to use the tool.
- The tool needs to be adaptable (tailored) to users' needs: national/regional, expert level, guide/moderator
- For this purpose, consider breaking it down for different scales/levels. While some of the recommendations and measures are quite large scale or national level, others are very much oriented to the site scale. It would probably help to break it down and make it clearer which information is intended for which level.
- Make the database dynamic – so that user can add own measures
- This is a very good proposal but might make it more complicated due to the level of commitment to maintain the database while integrating new information.

Final notes of the conference

At the end of second day of the conference, two groups of participants - research providers and road operators, were asked by the moderator to provide some final conclusions and notes. These comments are detailed in the sub-sections below.

RESEARCH PROVIDERS:

Thierry Goger, FEHRL

It was noted that these two projects bring real value for money. The customised tool and the solid database supporting the appropriate decision-making process have proven to be with a high potential impact. Now it is time to bridge the gap between this research output and its possible outcomes. In other words, how we can make use of this supporting database tool on a day to day basis? The next step is clearly to run a demonstration so that its implementation can be deployed.

Indeed, such a demonstration focusing on developing a user friendly and expandable decision-making tool would close the innovation loop, bringing the result of effective R&D&I investment into operation.

This second step would fit within the new CEDR ambition to support R&D calls by implementation calls. Thus, we can recommend CEDR considers this topic for an implementation call.

Kenneth Gavin, UCD

It was noted that the research has provided useful and applicable results. It was suggested that the next step could be in the area of demonstration initiatives. These initiatives need resources and cooperation of research providers and road operators.

ROAD OPERATORS:

Dean Kerwick-Chrisp, Highways England

The importance of applied research projects was emphasised to be essential to the transport sector. As a result of the presentations delivered at the conference, information was provided on how to navigate through and understand the key features of the performed research. It was noted that this event is about connecting experts from different professions, and though often the same terminology is used, the words often have different meanings or interpretations. It was suggested that more understanding of these interpretation complexities is required, and that more clarity is needed in how to effectively communicate. Additionally, more comprehension is required in order to bridge the gap between research output and outcomes.

Janis Barbars, Latvian State Roads

Dissemination is a key area of relevance. This includes advice to the top decision-makers and down to engineers. It was recognised that without the support from decision-makers, there will be no funding for real implementation. Networking and cooperation between meteorological professionals and road professionals (climate domain and road domain) is key for delivering quality advice to road domain policy makers. In addition to this, implementation will greatly depend on the success of dissemination and resource availability at the national level. It was observed that CC adaptation policies and tools are already in place in those countries that are facing extreme weather on a daily or seasonal basis (such as the Nordic countries, the Netherlands). Recommendation was given that the first stage of implementation should be the inventory of existing systems: how they are prepared to take into account the meteorological data.

PART III

Applicability of the projects and recommendations for implementation

Applicability of the projects

First of all, the scope of two projects needs to be seen in the perspective of CEDR long term Strategic Plan Task I4 - Climate Change. It is the second link of the chain Getting to grips with the climate change (2008) **» Adapting to Climate Change** (2012) » Bringing research From Desk to Road (2015)] and, as such, the outputs of both projects are strongly supporting this general framework. The methodology is there and the developed tools are to be put into a more robust and user-friendly form (which shall be the next step).

Zooming in on the specific projects, it is clear that CliPDaR is more targeted and focuses on two very specific areas - climatic data downscaling and cross-border cooperation. ROADAPT has a broader scope and has given a very extensive methodology on the evaluation of various climate related threats, bridging these threats with climate parameters, and providing with adaptation measures at different stages of road life cycle.

It has been noted by NRAs that these reports are excellent ways to help them make good decisions. During the plenary session of the second day, representatives of Denmark, Sweden, the Netherlands, and Norway presented their experiences (see the previous chapter). It was not explicitly specified that the ROADAPT products have been used to assess vulnerabilities or risks; however, it was felt that these or similar products have been deployed to come to the results.

Conclusions and Recommendations

Both projects highlight that extensive work has been undertaken and the conference successfully provided information relating to the outputs of these projects. The main conclusion is - ROADAPT and CliPDaR have both met the expectations of and are in line with the CEDR I4 CC Work Programme and have continued the previous work that has been done within this programme. Both projects are ready to be tested and adapted by NRAs and will form a sound basis for the future call within the 2015 CC Call - From Desk to Road.

This section addresses the questions raised at the conference by the CEDR. It also provides recommendations and comments based on the evaluation of the two research project reports.

Questions raised at the final conference by CEDR:
How to **maximise the awareness** of the findings and results of the projects so that policy makers know that the tools are already there? The results of research project reports need to be promoted to the NRAs and Member States. Not all countries

have **adaptation strategies**. The EU requires that the national strategies are ready by 2017. Input can be provided to help these countries create their adaptation strategies for infrastructure.

Implement, implement, implement. How can knowledge generated in these research projects be brought into the policies of different levels: EU and national [suggestion: add a regional subdivision - this would cover cross-border cooperation]. Implementation is key and dissemination is the first phase of deployment. FEHRL should act as a main driver for dissemination. In cooperation with FEHRL members, the EC and CEDR research project results are disseminated at national level. The SAVeRS project acts as an example. CEDR calls for the active dissemination and implementation of the project results.

How can the ROADAPT products help in structuring a strong backbone for the **most economically advantageous tendering (MEAT)**? This question will be carried further to the next CEDR research call. Lifecycle cost analysis should be implemented in procurement. Regarding standardisation - as experience improves, a shift towards a performance-based (less prescriptive) approach can be made, especially in asphalt production. For example, the **LCE4ROADS (http://ecolabelproject.eu/)** project (FP7) could be considered here as it deals among other things with issues connected to the CC mitigation.

Recommendations gathered and proposed by the Report Group:
A dissemination and implementation structure for developing adaptation strategies in a regional setting and on a practical level by road authorities.

Stage:	Awareness	Strategy and action plan development	Application
Event type:	Conferences, seminars	Seminars, workshops	Training workshops
Actions:	Presentations, Speeches, Displays	Presentations, Hands on workshops	Hands on workshops, Field training
	Demonstration projects		
Target audience:	Decision makers, top and middle level managers	Top and middle level managers, field professionals	Middle level managers, field professionals
Geography:	International, regional, national	Regional, national	Regional, national

Awareness and networking
It has been stressed during the final conference that **awareness and networking** are of paramount importance. There has to be pressure from CEDR to include the topic in the agendas of international, regional and national workshops, seminars and conferences; also at the events of international research and professional associations (**TRA**, **IABSE**, **IALCCE** etc.). These agendas should contribute to the **cross domain networking** between, but not limited to, meteorological agencies and road operators. Other domains could include contractors and industries providing technologies for adaptation measures, research and technology providers in biology (vegetation for rainfall water absorption), geology (landslide related risks), and environmental sciences (roadside pollution).

Vehicles for awareness – climate change web site, Web 2.0, souvenirs

CEDR could make a special CC section on the CEDR website to better expose the deliverables of the CC-related research projects established within I4 CC Task Group. Or, alternatively – set up an independent website, managed by the CEDR or some external service provider. Some ideas for webpage naming: climate.cedr.eu, climate4roads.eu, roads2climate.eu, cc4transport.eu, roadaption.eu – depending on the scope of the site (roads only or multi-modal). Top domain could be either ".eu" or ".org". This web page should have connections to the rest of web resources mentioned in this report (pilot use cases, CC databases) but strong distinction should be made to ensure that target audiences are addressed and not scared away by being either too technical or too general.

The information about the website should be distributed to **Web 2.0** (Twitter, LinkedIn, Facebook etc.) and CEDR members should be encouraged to keep links to the CEDR and climate-related sites on their respective web pages. It is recommended that the deliverables of CEDR projects are advertised on the **EU Climate adaptation website (http://climate-adapt.eea.europa.eu/)**.

A big drawback of many project-oriented websites (also on Web 2.0) is a lack of **sustainable support** from the stakeholders. CEDR should make sure that time, resources and funding (including time for **regular updates of content**, domain name payments etc.) needed to run such activities is available for a long period,. If it is decided to close any activity, users should be advised well in advance (at least one month) and pointed to the next available resource of information.

CEDR could consider a series of CC-themed memorabilia (postcards with funny or serious drawings or pictures, USB sticks with website logo, smartphone accessories etc.) to be distributed at transport and engineering conferences and other networking events.

Multi-lingual reports and vocabulary of CC

To facilitate awareness at national level, there is also an opportunity to provide national reports of champion countries in a multi-lingual form to enable information to be shared effectively. CEDR could promote the translation (financed nationally); while CEDR or FEHRL websites could host these reports and posters. A multi-lingual report involving countries bound with a common TEN-T corridor could serve as the first demonstration of such an approach.

Review of PIARC's Terminology Dictionaries of Road Transport and Roads

To further facilitate awareness and efficient networking, a proposal for a review of **PIARC's Terminology Dictionaries of Road Transport and Roads (http://goo.gl/in8UhF)** could be launched - to include terms that are essential for the understanding of CC. At the time of writing of this report, there are only a few terms related to the climate data but no definitions provided.

Strategy and action plan development workshops

To make strategy and action plan development efforts more effective, a series of training and strategy development workshops could be designed. Each separate workshop would target a different level of decision-making; outcomes of the first workshop shall be used as inputs for the second and so on. The last workshop would be for all involved parties and should end with a turnkey adaptation strategy (AS) for each involved country (or at least a clear and detailed roadmap to the AS's).

To address the **creation of adaptation strategies**: the Norwegian Public Road Association's (NPRA) approach shows that knowledge sharing and bilateral learning is a very successful formula to create a viable adaptation strategy (AS) for roads on a practical level. It is recommended that CEDR members develop **regional groups** with leaders that already have established their AS (like Denmark in Scandinavia, the Netherlands in Benelux, etc.) Regions that do not have such leaders can invite speakers from neighbouring countries with established AS. Small workshops are better for addressing targeted tasks. Hence, large-scale events for this particular purpose are not recommended. However, targeted international (EU-level) workshops on AS development could be used to disseminate the knowledge of leading countries and train national and regional climate-road experts.

Discussions with NRAs and researchers revealed that scarce resources make **cross-border seminars and workshops** a less affordable way of cooperation. The Report Group suggests using **webinars** as one form of dissemination and cooperation (also

training, if budgets are low). If travelling long distances is prohibiting, organisers may consider a relay style (just like in 4x100 metre relays in athletics) training activities where the first event is held with the CC adaptation champion and representatives from the country next to it (ideally, if the champion is located in the middle of the region then everyone can join). The next step would involve newly established champions providing knowledge and assistance to the third country and so on until the whole region is covered. Alternatively, the already mentioned EU level training for national climate-road experts could be applied.

Demonstration projects of Vulnerability assessment, QuickScan, data quality assessment, socio-economic impacts analysis (also see the relevant chapters of this report):

Website with pilot use cases

The need for a common multi-lingual website above the database as a tool for providing knowledge, various data and their sources and space for data insertion by the users has been stressed among various participants of the workshop 4. **A website with pilot use cases** could be the most straightforward method of spreading the knowledge and enhance other NRAs to use the guidance and share their efforts and good practice. Also **a board of quality checkers** is needed to ensure that the inputs are supervised and the level of quality is maintained. This supervisory board could be established within the CEDR I4 CC Task Group.

Showcase of technology deployment

The case studies can serve as another level of investigation - selection of representative places across Member States (NRAs) where **the showcase of technology deployment** can serve for in-time detection and information about a possible climate threat, as well as better planning and investment in road maintenance and equipment. The afore- mentioned upgrades of the existing results could be achieved in the follow-up project, which could go more into the implementation and have a practical tool for potential users, not only NRAs or road operators themselves, but the commercial sector of technology suppliers and providers of traffic and transport-related services.

This is perceived as the most potentially visible project (measuring climate change) that goes along with the actual technological trends such as Internet of Things; so it fully supports the idea of broader dissemination, as well as practical deployment.

From the **TEN-T and cross-border cooperation and information sharing** perspective: CEDR could implement demonstration projects on one or two of the nine core TEN-T networks. Probably, the most challenging corridor is **Scandinavian - Mediterranean (http://goo.gl/lfNxRB)**, spanning from the south of Finland down to the south of Italy. The other option (more busy route but not so climatically challenging) is the Rhine - Alpine corridor. One of the key elements of cross-border cooperation is data compatibility. NRAs or road operators will have to work together with meteorological agencies to make sure that the data sets of all involved parties are describing the same parameters. Only then will downscaling work. Consideration of how results can be transferred for use with different transport modes is also required.

NRAs should perform an inventory of their planning, design (including design norms), construction, and maintenance management systems in order to assess the level of readiness to accommodate for climate indices.

CEDR CC Call 2015 and future research

The new CEDR Transnational Road Research Programme call “From Desk to Road” is going to be focused on the implementation and demonstration. Besides dissemination and implementation, the future research needs and activities should not be forgotten. During the conference discussions, it was mentioned that future research should focus on fine-tuning the developed systems with better understanding of relationships between climatological elements and infrastructure assets. For the recommendations from ROADAPT and CliPDaR projects and conference presentations, see the relevant chapters of this report and presentations themselves (references provided below).

All CEDR members should be invited to provide opportunities for pilot projects where the deliverables of ROADAPT and CliPDaR can be tested.

Figure 4: Floods in Sussex, 2000. Picture credits: BBC News

Acknowledgements

Special thanks to our pool of experts for revising, commenting, correcting and giving overall support in the creation of this Final Report:

CAROLINE EVANS, BASt (Germany) and ARRB (Australia);
JANETTE BESSEMBINDER, KNMI (the Netherlands);
GORDANA PETKOVIC, NPRA (Norway);
ISABELLE LUCCHINI AND CATHERINE BIRKNER, FEHRL (Europe);
ARJAN VENMANS, Deltares (the Netherlands);
KEES VAN MUISWINKEL, Rijkswaterstaat (the Netherlands);
JOACHIM NAMYSLO, DWD (Germany);
THOMAS BLES, Deltares (the Netherlands);
MARTIAL CHEVREUIL, Egis (France);
RONAN CUNNIFFE, CEDR (Europe);
HENRIK FRED LARSEN, DRD (Denmark).

References

A list of all deliverables and presentations at the ROADAPT and CliPDaR final conference.

Project deliverables:

[1]	ROADAPT, "Guidelines [integrating main guidelines]," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17283.
[2]	ROADAPT, "Part A, No. 1: Guideline on the use of data for the current and future climate for road infrastructure," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17286.
[3]	ROADAPT, "Part A, No. 2: Climate data requirements of National Road Authorities for the current and future climate," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17287.
[4]	ROADAPT, "Part B: Performing a QuickScan on risk due to climate change," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17288.
[5]	ROADAPT, "Part C: GIS-aided vulnerability assessment for Roads – Existing methods and new suggestions," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17289.
[6]	ROADAPT, "Part D: Socio-economic impacts analysis (WP3); Deliverable No 2," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17311.
[7]	ROADAPT, "Part E: Selection of adaptation measures and strategies for mitigation; Deliverable No 4," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17292.
[8]	ROADAPT, "Case study Öresund," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17285.
[9]	ROADAPT, "Case study Rotterdam-Ruhr corridor," August 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17312.
[10]	ROADAPT, "Case study A24 Portugal," March 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17284.
[11]	ROADAPT, "Database of adaptation techniques - a spreadsheet," May 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17471.
[12]	CliPDaR, "D 1.1: Report on the first Workshop 25-27 February 2013, Offenbach, Germany; DWD headquarter," May 2013. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17382.
[13]	CliPDaR, "D 1.2 - Report on the outcome of the combined meeting (CliPDaR and ROADAPT), 3-4 April 2013, Langen, Germany, DWD Education and Training Centre," July 2013. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17383.
[14]	CliPDaR, "D 1.3: Guidelines for the use of Statistical and Dynamical Downscaling results as input for impact models," December 2013. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17384.

[15]	CliPDaR, "D 2.1: Report on the workshop held in Vienna at the ZAMG from the 6th to the 8th May 2013 'meeting the operators'," November 2013. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17385.
[16]	CliPDaR, "D 2.2: Guidelines on ensemble climate projection data," December 2013. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17386.
[17]	CliPDaR, "D 3.1: Guidelines for coping with relatively cold winters/hot summers," January 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17387.
[18]	CliPDaR, "Presentation of the CliPDaR findings to the Project Evaluation Board (Final seminar, Offenbach, February, 2014)," February 2014. [Online]. Available: http://www.cedr.eu.
[19]	CliPDaR, "An invited presentation at the TRA (Transport Research Arena) 2014, Paris," April 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17376.
[20]	CliPDaR, "D 3.2: Final Report," June 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17379.
[21]	CliPDaR, "D 3.2: Design Guideline - Annex of Final Report," November 2014. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17388.

Presentations at the ROADAPT and CliPDaR final conference

[22]	S. Phillips, "Importance of Climate Change for Road Authorities, CEDR," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17453.
[23]	R. Cunniffe, "CEDR Climate Change Research Programme and Plans for the Future, CEDR," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17454.
[24]	M. Grauert, "Cross-border Cooperation on Climate Change Adaptation and Mitigation, CEDR," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17455.
[25]	A. Venmans, "Introduction to the ROADAPT project, Deltares," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17464.
[26]	J. Namyslo, "Introduction to the CliPDaR project, DWD," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17465.
[27]	J. Bessembinder, "ROADAPT - European guidelines for the use of climate data for road infrastructure, KNMI," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17456.
[28]	M. Chevreuil, "ROADAPT - The QuickScan Approach, Egis," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17457.
[29]	P. Danielsson, "ROADAPT - Vulnerability Assessment method, SGI," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17458.
[30]	M. Chevreuil, "ROADAPT - Socio-economic impact assessment, Egis," October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17459.

[31]	A. Venmans, “ROADAPT - Selection of adaptation measures and strategies for mitigation, Deltares,” October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17466.
[32]	C. Matulla, “CliPDaR - Application of CliPDaR climate guidelines by Road Authorities, ZAMG,” October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17460.
[33]	C. Axelsen, “National adaptation strategies for roads, results of the CEDR Technical Group I4 - Climate Change Adaptation and Mitigation, DRD,” October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17467.
[34]	E. Liljen, “Transforming a strategy into an action plan - experiences from Sweden, Traffikverket,” October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17461.
[35]	K. van Muiswinkel, “National Adaptation Strategy and adaptation of infrastructure in the Netherlands, RWS,” October 2015. [Online]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17462.
[36]	G. Petkovic and L. Kristensen, “Norwegian Roads Adapting to Climate Change, NPRA,” October 2015. [On-line]. Available: http://www.fehrl.org/index.php?m=32&mode=download&id_file=17463.

CEDR Contractor Report 2016-1 (March 2016)

Call 2012: Road owners adapting to Climate Change
ROADAPT and CliPDaR projects

Conference of European Directors of Roads (CEDR)
Avenue d'Auderghem 22-28
1040 Brussels, Belgium
Tel: +32 2771 2478
Email: information@cedr.eu
Website: http://www.cedr.eu

ISBN 979-10-93321-14-1