



Conférence Européenne
des Directeurs des Routes

Conference of European
Directors of Roads

CEDR CONTRACTOR REPORT 2019-02

A large, glowing blue globe is projected onto a screen in a dark room. The globe shows a view of Earth with clouds and continents. In the foreground, the silhouettes of an audience are visible, looking towards the screen. A person is standing on a small stage in front of the screen, possibly presenting.

Climate Change: From Desk to Road
CEDR Call 2015 Final Programme
Report

May 2019

Climate Change: From Desk to Road CEDR Call 2015 Final Programme Report

End of programme report

by

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Abbreviations

AIT	Austrian Institute of Technology
ANPR	Automated Number Plate Recognition
BAST	Federal Highway Research Institute
CBA	Cost-Benefit Analysis
CEDR	Conference of European Directors of Roads
CLIPDaR	Design Guidelines for a Transnational Database of Downscaled Climate Projection Data for Road Impact Models
CORDEX	Coordinated Regional Climate Downscaling Experiment
DeTECToR	Decision Support Tools for Embedding Climate Change Thinking on Roads
DPC	Damage Pattern Category
EEA	European Environment Agency
EPOMM	European Platform on Mobility Management
GHG	Greenhouse Gas
IBDiM	Polish Road and Bridge Research Institute
IRWIN	Improved Local Winter Index to Assess Maintenance Needs and Adaptation Costs in Climate Change Scenarios
MM	Mobility Management
MoDBear	Mobility Management and Driver Behaviour Research
NRA	National Road Administration
PEB	Programme Executive Board
P2R2C2	Pavement Performance and Remediation Requirements following Climate Change
RIMAROCC	Risk Management for Roads in a Changing Climate
ROADAPT	Roads for Today, Adapted for Tomorrow
SuDS	Sustainable Drainage System
SWAMP	Storm Water Prevention – Methods to Predict Damage from the Water Stream in and near Road Pavements in Lowland Areas
TII	Transport Infrastructure Ireland
TM	Traffic Management
TRA	Transport Research Arena
WatCh	Water management for Road Authorities in the Face of Climate Change
WP	Work Package

Glossary

Adaptation Action	Synonym for adaptation measures. An action taken to reduce the adverse risks or maximise the opportunities resulting from the impacts of climate change.
Climate Change	A change in the state of the climate that can be identified by changes in the mean and/or variability of its properties and persists for an extended period.
Climate Projection	A projection of response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols or radioactive forcing scenarios, often based on simulations of climate models
Climate	Average weather, typically across a 30-year period. A statistical description of the mean and variability of relevant variables such as temperature and precipitation.
Consolidation	A process where consignments from one shipper or different shippers are grouped together to a single, large shipment. Normally organised by forwarders.
Cost Benefit Analysis	An analytical methodology for the quantification of the positive/negative consequences of a project in monetary terms over a set appraisal period.
Damage Pattern Category	A term used by RIVA and DeTECToR to refer to a type of damage inflicted on an infrastructure element that can be caused by one or more climate events.
Downscaling	A process where information known at large scales is used to make predictions at local scales.
Mobility Management	A transport demand management mechanism providing the transportation needs of users.
Risk Assessment	A systematic approach for evaluating potential risks, normally with the aim of risk management.
Risk	A combination of the likelihood of an event occurring and the magnitude of the consequences if it occurs. In climate change terms, likelihood is related to exposure to environmental conditions and the vulnerability of the asset.
Risk Level	In some risk assessment methodologies a value to indicate the magnitude of risk is produced. In DeTECToR this is calculated from indicators related to climate, asset vulnerability and potential impact.
Vulnerability	The level of susceptibility to damage or adverse effects resulting from climate change impacts. The vulnerability of an asset depends on its characteristics, condition and surroundings (e.g. geology and landscape).
Whole Life Cost	Analytical methodology for evaluating the total cost of ownership of an asset over its entire lifetime.

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Executive Summary

Climate change presents National Road Administrations (NRAs) with two significant challenges; to reduce their greenhouse gas emissions and that of their supply chain and to maintain the resilience of their network in the face of a changing climate. CEDR has commissioned a number of projects over the past 10 years through its transnational research programme to support NRAs with these challenges. The most recent call in 2015 was entitled Climate Change: From desk to road and funded by Germany, the Netherlands, Ireland, Norway, Sweden and Austria. The projects carried out under this call were DeTECToR (Decision-support Tools for Embedding Climate change Thinking on Roads), WatCh (Water Management for Road Authorities in the face of Climate Change) and MoDBeaR (Mobility Management and Driver Behaviour Research). This report provides an overview of the three 2015 call projects and their findings. Each project is discussed in terms of their aims, objectives and scope, methodology, and main findings and conclusions. The report also describes how the 2015 projects build on the previous CEDR climate change calls in 2008 Road Owners Getting to Grips with Climate Change (IRWIN, P2R2C2, RIMAROCC, & SWAMP) and 2012 Road Owners Adapting to Climate Change (ROADAPT, & CliPDaR) and the synergies between the projects.

In November 2018, an end of programme conference was held in the Utrecht LEF Centre, Netherlands, which brought together researchers, academics, and national road administrations, to discuss the 2015 call projects and importantly how climate change consideration, tools, and knowledge can be implemented and embedded in national road administrations operations. The event consisted of presentations, group discussions, a set of workshops and professional networking. The event was held across two days; the first day focused on the results from the 2015 call, whilst the second day centred on discussions from the CEDR Programme Executive Board alongside speeches from invited guest speakers discussing how they are embedding climate change considerations into their operations. This report highlights the key discussion points across the event and the views of the NRAs on implementation of the project results.

A number of overarching elements, applicable to all projects, were identified during the event, including:

- The need for common climate change adaptation and mitigation goals needing to be defined,
- Setting measurable goals and quantifying climate change impacts and adaptation/mitigation measures,
- Gaining support from decision makers within organisations
- Communicating climate change considerations in a common language and integrating it into standards, organisational policies/statements so everyone (from policy makers to contractors) understands the tangible impacts of a changing climate.
- Adaptive planning and a step-by-step decision-making process whereby given the uncertainty in the likelihood of climate change impacts organisations need to adopt a ‘just do it’ approach and learn from their mistakes, rather than over planning without taken action.
- The need for internal knowledge sharing between experienced and junior personnel. Additionally, the need for sharing knowledge and experiences across an organisation, rather than working in silos.

The report concludes with recommendations for implementing CEDR project findings.

1. Introduction

CEDR has commissioned a number of projects over the past 10 years through its transnational research programme to support National Road Administrations in addressing issues related to climate change. The most recent climate change programme was part of the 2015 call and was entitled Climate Change: From desk to road. The programme, funded by Germany, the Netherlands, Ireland, Norway, Sweden and Austria, aimed to put into practice climate change research and focus on integrating climate change into decision-making. There were four topic areas:

- A. Economic costs associated with integrating climate change into decision-making
- B. Embedding climate change into practice and procurement
 - Implementing existing climate change research into practice
 - Embedding climate change into procurement processes
- C. Developing a transnational approach to water management in the face of climate change
- D. Driver behaviour: Diagnosing driver decision-making (in a changing climate)

Three projects were commissioned covering these topic areas:

- DeTECToR (Decision-support Tools for EMBEDding Climate change Thinking on Roads) covered topics A and B;
- WatCh (Water Management for Road Authorities in the face of Climate Change) addressed topic C; and
- MoDBeaR (Mobility Management and Driver Behaviour Research) covered topic D.

This report summarises these three projects and describes the end of programme event held 19th – 20th November 2018 in Utrecht, the Netherlands. It also discusses the synergies and common themes between the three projects, how they build on the previous projects and provide recommendations on implementation.

2. The Projects

Section 2 provides an overview of the three 2015 call projects and maps out the connections between all the CEDR climate change projects from the 2008, 2012 and 2015 calls.

2.1. DeTECToR

Title	DeTECToR (Decision-support Tools for Embedding Climate change Thinking on Roads)	
Coordinator	TRL(UK)	
Partners	<ul style="list-style-type: none"> • Alfen Consult (Germany) • Heller (Germany) • AIT (Austria) • IBDiM (Poland) • CEC (Germany) 	
Website	https://detector.trl.co.uk/	
Duration	October 2016 – February 2019	

2.1.1. Objectives and Scope

The objectives of DeTECToR were to produce decision-support tools and guidance to help NRAs address two key aspects of climate change:

- A: making the business case for climate change adaptation
- B: embedding consideration of climate change in their operations and procurement

Specifically, the project produced a risk assessment and cost benefit analysis tool that allows the user to identify the level of risk to different routes/assets from relevant weather hazards and understand how this is likely to vary over time due to climate change. It also enables them to compare the whole life costs associated with different adaptation strategies.

The DeTECToR team also produced an online procurement collaboration platform to enable NRAs to share information on their approach to including climate change in procurement and to view examples of good practice. Accompanying both tools are guidance documents providing information and examples of good practice and also manuals to the tools.

2.1.2. Methodology

The project started by gathering information on relevant aspects of climate change and NRA priorities through a literature review and an online survey. The purpose of this was twofold, firstly in order to inform the development of the tools and guidance and ensure it incorporated the latest research and thinking. Secondly in order to produce a useful resource for NRAs summarising relevant climate change research and how it could inform their decision-making. Previous CEDR, EU-funded and national research projects related to topics such as climate change risk assessment, economic appraisal and sustainable procurement were reviewed and summarised in a four-page template. The information

gathered from the literature review was enhanced by information collected through an online survey of European NRAs. The survey consisted of questions about their priorities in terms of types of hazard and assets, the types of asset and meteorological data they collect and the actions they take to embed climate change in their processes. It was completed by 44 people from 24 different countries.

The initial findings, together with the proposed approach for development of the tools, were presented at stakeholder workshop in Brussels. At the workshop NRAs discussed the required functionality of the tools, their preferred format and how they expected to use them. Based on the findings of the literature review, survey and workshop functional specifications were developed for the two tools and submitted to the PEB for their feedback. Once the approach was agreed tool developed started based on the functional specifications.

The risk and cost-benefit tool consists of two modules; a risk assessment module based on the RIVA¹ methodology. This is a semi-qualitative indicator method in which indicators are defined for different factors which affect the risk of a particular asset type being adversely impacted by a specific hazard. These asset-hazard combinations are referred to as Damage Pattern Categories (DPCs). Indicator sets related to climate, asset vulnerability and the effects of an event are identified and scores assigned according to the data. These are combined to give an overall risk score (see Figure 1).

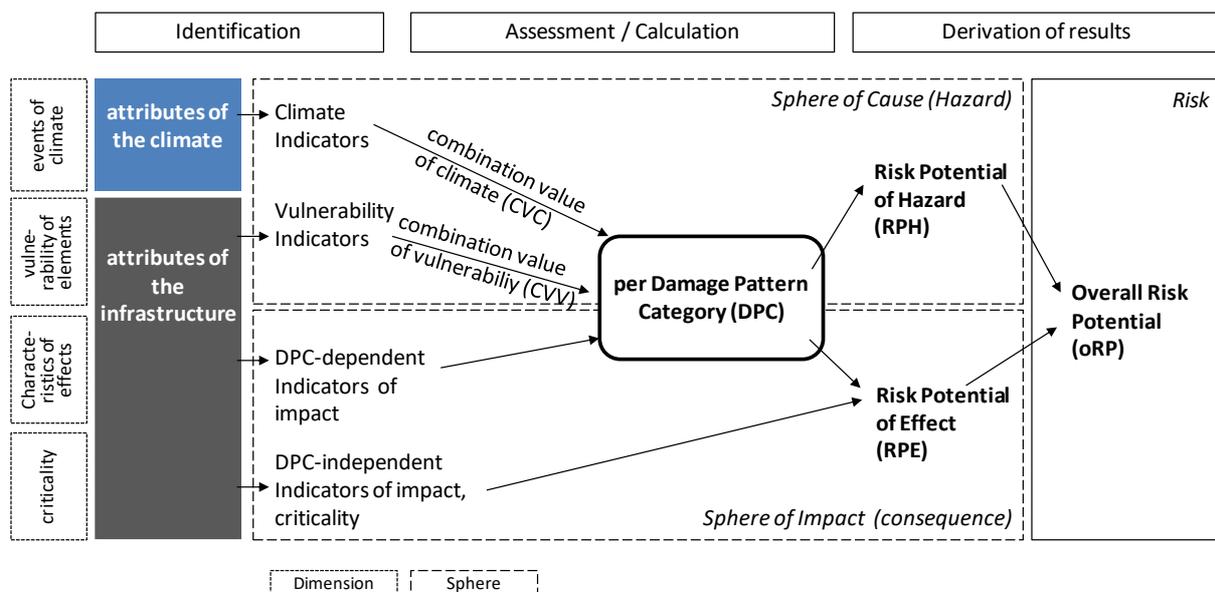


Figure 1. Calculation of risk (based on RIVA)

Climate, asset and cost data is uploaded into the tool by the user and automatically analysed for each section of road. The risk level is mapped onto the network allowing areas of high risk to be easily identified. The risk levels for different time periods and high and low greenhouse gas concentrations can be compared (see Figure 2).

¹ RIVA - Korn, M., Leupold, A., Mayer, S., Krienkamp, F., Spekat, A., 2017. RIVA – Risikoanalyse wichtiger Verkehrsachsen des Bundesfernstraßennetzes im Kontext des Klimawandels. Unter Mitwirkung von: Fischer, K., Guske, K., Sorg, B. Berichte der Bundesanstalt für Straßenwesen. Straßenbau, Heft S 109, 131 S. http://bast.opus.hbz-nrw.de/volltexte/2017/1809/pdf/S109_barrierefreies_Internet_PDF.pdf

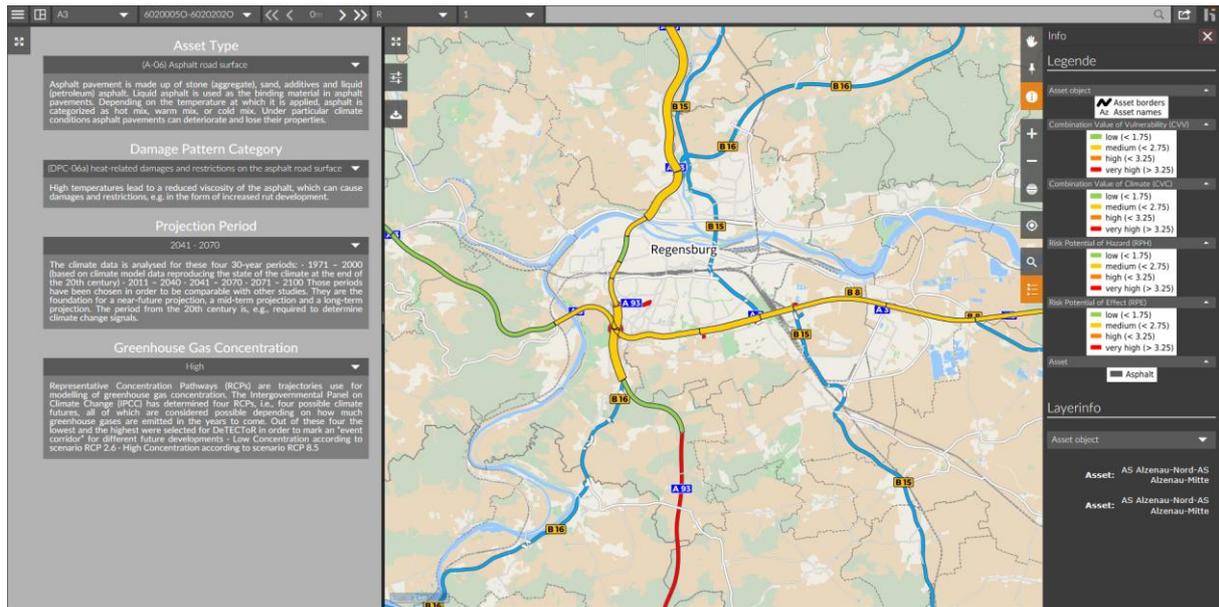


Figure 2. Risk levels for part of the road network in Germany

The second module enables the user to compare different adaptation strategies to address the risk. The costs of three adaptation options are compared to a no-action option over a thirty year appraisal period. The user input data such as the discount rate, cost of repair, design life of the asset and the tool calculates the direct and indirect costs. The calculation takes into account the typical lifecycle of the asset and how climate change can impact on this as well as the level of occurrence of extreme events which cause damage and disruption. The results are again displayed on a network map making it easy to identify the most cost-effective option for different parts of the network.

The tool is designed to be a flexible framework which the user tailors to their requirements and priorities by selecting the DPCs of interest and adjusting the indicators, thresholds and weightings. It is intended that this configuration is carried out once to set-up the tool for a particular NRA and then subsequent analysis is carried out using this configuration so that the results are consistent and comparable.

The procurement tool was designed to encourage NRAs to share information and examples of different approaches. The tool is based on the wiki-approach whereby users can edit and add information themselves, growing and updating the information provided. The tool was initially populated with information from the literature review and pilot studies, but the aim is it is developed by the NRAs themselves and forms a platform to encourage greater collaboration and exchange of good practice: see Figure 3.

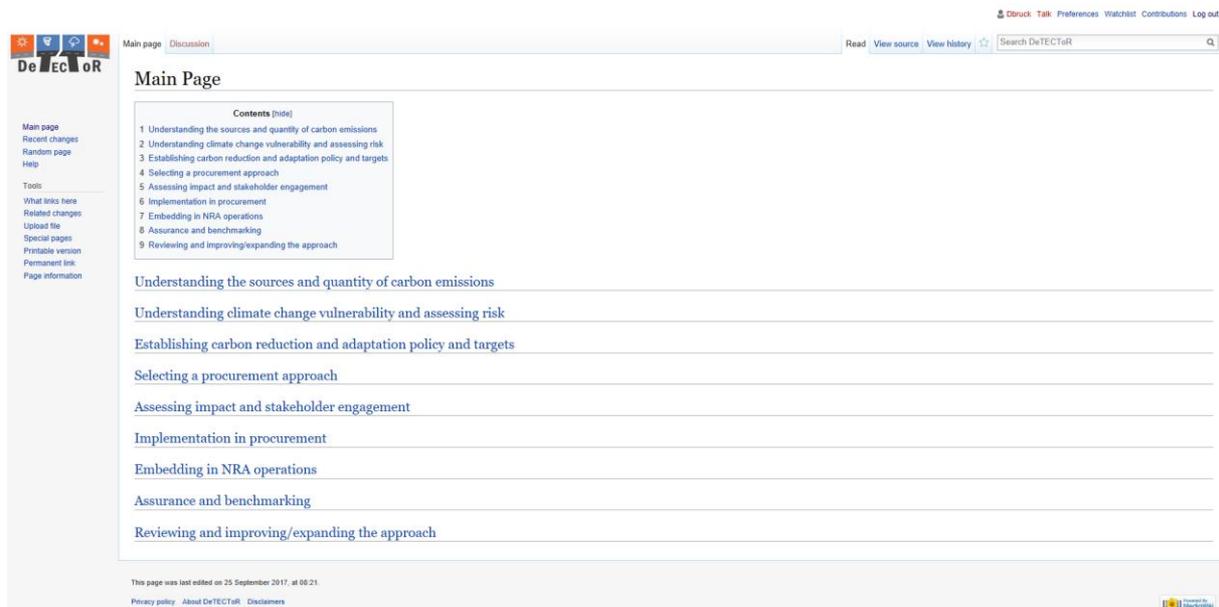


Figure 3. Main page of the procurement online collaboration platform

Pilot studies were carried out to test the tools functionality, ease of use and relevance of the information provided. The risk assessment and CBA tool was tested on sections of the road networks of Germany, Austria and Scotland. Data on climate projections was sourced from CORDEX² and asset data from the databases of the relevant NRAs. The pilot studies for the procurement tool were Norway, Sweden and the Netherlands. Interviews were held with staff from the NRAs to discuss how they included climate change in procurement and the information provided was uploaded in the procurement tool.

Accompanying both tools are guidance documents. The first part of the economic guidance document provides general information and good practice on including climate change in economic appraisal and the second part is a step-by-step manual to using the tool. The procurement guidance document similarly has two parts, the first providing information and good practice on including climate change in procurement and the second a manual for the procurement tool.

2.1.3. Deliverables

Project reports	<ul style="list-style-type: none"> ● Interim Report 1 – Findings from the literature review and NRA survey ● Interim Report 2 – Description of the tool development and pilot studies ● Final Report – Summary of the project and its findings
Software tools	<ul style="list-style-type: none"> ● Risk assessment and cost-benefit analysis tool ● Online procurement collaboration platform

² CORDEX (Coordinated Regional Climate Downscaling Experiment) is an international programme to produce regional climate projections worldwide.

Guidance documents	<ul style="list-style-type: none">• Guidance document on including climate change in economics and CBA tool manual• Guidance document on including climate change in procurement and collaboration platform manual• Summary sheets of research projects
Dissemination	<ul style="list-style-type: none">• Project website, logo and flyer• TRA paper and presentation• Presentation and workshop at the CEDR end of programme event

2.1.4. Main Findings and Conclusions

There were a number of useful findings from the survey including:

- Flooding was universally the climate hazard of most concern and pavements, geotechnics and drainage were the assets considered to be the most vulnerable to climate change.
- Two thirds of respondents don't consider climate change in economic appraisal
- Only a third of respondents have requirements related to carbon reduction in project tender specifications.

The DeTECToR project successfully produced two software tools and guidance documents.

The main outputs of the CBA Tool are:

- Risk levels for different asset and hazard combinations. These can be displayed and browsed on an interactive map or downloaded as a list.
- Estimated whole life costs for different adaptation options, including a business as usual scenario. These can also be displayed on a map or downloaded.

The procurement tool provides:

- Information on including climate change in procurement and examples of different approaches taken by NRAs
- An opportunity to share information and good practice.

2.2. WatCh

Title	WatCh (<u>W</u>ater Management for Road Authorities in the face of Climate <u>C</u>hange)
Coordinator	Deltares (Netherlands)
Partners	<ul style="list-style-type: none"> • ROD-IS (Ireland) • Egis (France) • Danish Road Directorate (Denmark) • KNMI (Netherlands)
Website	no dedicated project website but refer to http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2015/call-2015-climate-change-desk-road/
Duration	October 2016 – May 2018

2.2.1. Summary

European NRAs have long recognised that climate change will have a significant effect on their assets and operations. In the WatCh programme, the challenges specifically related to water management are addressed. This is logical since the damage caused by floods and rain to infrastructure assets is estimated as €600 million annually, making it by far the dominant weather impact.

The WatCh project addresses the requirement for a transnational approach to water management in the face of Climate Change. It provides a “How to do” Manual on water management and the assessment of resilience, understanding and applying the consequences for design, inspection and maintenance.

In addition, the project aims to provide guidance on how to carry out a Cost Benefit Analysis (CBA) as a prerequisite for implementation of the results. WatCh liaised with the DeTECToR project to ensure that the CBA guidelines specifically aiming at water management are compatible with the DeTECToR framework.

A Case Study was carried out to demonstrate how the results of WatCh can be used in practice.

2.2.2. Objectives and scope

Many challenges exist in addressing intense rainfall events into proper design and maintenance of water management systems. These challenges exist both in the field of climate science itself, as well as in the translation of climate projections into proper design and maintenance of water management systems. The WatCh project addresses the most important high frequency causes of road flooding, caused by rainfall and run-off flooding in the area around the road, and heavy rain on the road itself.

The objectives of the project are:

- Developing a manual to determine current and future resilience of the NRAs approach to water management, ensuring optimal maintenance planning and asset management.

- Providing easy access to climate data tailored to determining resilience and providing guidance on how to use these data, plus developing a simple tool to show climate analogues for rainfall extremes.
- Gaining insight in the application of SuDS (Sustainable Drainage Systems) for storage and cleaning of excess water.
- Gaining insight in the alternatives to the costly retrofitting of existing drainage systems.
- Enabling informed decision making on water management, supported by cost-benefit analysis.

WatCh ensured that the research results are useful and ready for implementation in NRAs' standards and procurement practices by paying particular attention to user requirements and integration of the results of the CEDR report on Climate Change adaptation.

The project addresses the most important high frequency causes of road flooding that NRAs have identified in the CEDR report 'Adaptation to Climate Change': pluvial and run-off flooding in the area around the road, and heavy rain on the road itself (rain intensity).

Furthermore, the project considered the drainage facilities that are designed and maintained by/for the NRAs with the purpose to enable a good water management of the road and as such a smooth and safe use of the road infrastructure. As such, both transmitting and storage of water are incorporated.

Drainage facilities include storm water run-off systems, storm water management facilities, culverts, carrier pipes, attenuation ponds, wetlands, and SuDS. Runoff from non-porous and porous pavements was also taken into account, since the run-off is an integral part of ensuring a proper water management system.

2.2.3. Methodology

The main objective of the WatCh project consists in developing a manual to determine current and future resilience of the National Roads Authorities approach to water management, ensuring optimal maintenance planning and asset management. Besides the final manual, the WatCh project provides five other reports and guidelines that all support the manual. They focus on particular scopes:

- What is the current state of practice and approaches of NRAs related to water management and how they take climate change into account: **Country Comparison Report**. As the deliverables of the WatCh project need to be implementable by NRAs, the deliverables build on the current state of practice and approaches of NRAs related to water management and how they take climate change into account. Therefore, the Country Comparison Report provides an overview of existing water management and drainage approaches from guidelines that are used in the NRAs. The countries shown in Figure 4 have been investigated:



Figure 4: Scope of Country Comparison Report.

- How to generate rainfall extremes for current and future climate: **Climate and climate change: protocol for use and generation of statistics on rainfall extremes.**
- How to assess and increase resilience of Sustainable Drainage Systems in face of climate change: **Protocol for Adapting SuDS systems for Climate Change.**
- How to assist the decision-making process: **Socio-Economic Analysis Guidelines.**
- How to implement and demonstrate the manual: **Case study in Denmark.** The case study was conducted with the objective to analyse, test and demonstrate the WatCh deliverables on how an NRA can make use of the step-by-step protocols. The case study has been conducted by the Danish Road Directorate on the M10 road leading into the greater area of Copenhagen. The M10 was chosen as the case study road as it is an existing major road that holds many characteristics targeted by the WatCh objectives.

2.2.4. Deliverables

The main objective of the WatCh project consists in developing a manual to determine current and future resilience of the National Roads Authorities approach to water management, ensuring optimal maintenance planning and asset management. Besides the present manual, the WatCh project provides five other reports and guidelines focusing on particular scopes, see overview below.

<p>Main Deliverable</p>	<ul style="list-style-type: none"> • WatCh Manual - How to determine the resilience of drainage systems and the consequences for inspection and maintenance as well as for the design and assessment of alternatives. (Foucher et al., 2018)
<p>Supporting Deliverables</p>	<ul style="list-style-type: none"> • “Country Comparison Report” - What is the current state of practice and approaches of NRAs related to water management and how they take climate change into account. (Bles et al., 2018) • “Climate and climate change: protocol for use and generation of statistics on rainfall extremes” - How to generate rainfall extremes for current and future climate. (Bessembinder et al., 2018) • “Protocol for Adapting SuDS systems for Climate Change” - How to assess and increase resilience of Sustainable Drainage Systems (SuDS) in face of climate change. (Rooney et al., 2018) • “Socio-Economic Analysis Guidelines” - How to assist the decision-making process. (Tucker et al., 2018) • “Case study” - How to implement and demonstrate the manual. (Axelsen et al., 2018)

2.2.5. Main findings and conclusions

To cope with the expected increase of intensity of rainfall due to climate change, a manual and underlying protocols and guidelines to enable decision making in this field of high uncertainties have been developed. Although the high uncertainties and sometimes limited availability of specific data, it proves to be possible to gain useful climate data for design and maintenance of road water management assets. The project deliverables have been successfully implemented and tested in a case study on the M10 in Denmark, showing that the manual and SuDS protocol are of help to develop an adaptation strategy. The socio-economic analysis framework proved to be useful for both decision making and implementation of the results in the NRAs’ organisation.

2.3. MoDBeaR

Title	MoDBeaR (<u>M</u>obility <u>M</u>anagement and <u>D</u>river <u>B</u>ehaviour <u>R</u>esearch) 
Coordinator	Arup, Ireland (Coordinator)
Partners	<ul style="list-style-type: none"> • Trivector, Sweden • Hasselt University, Belgium
Website	https://cedrmodbear.com
Duration	March 2017 – February 2019

2.3.1. Summary

The MoDBeaR project – Mobility Management and Driver Behaviour Research aimed at understanding the current CEDR policies in place across the CEDR NRAs with respect to mobility management and methods utilised to influence travel behaviour in both the context of the reduction of GHG emissions and to sustain accessibility during severe weather events.

Current Mobility Management policies and practices in place across CEDR NRAs were analysed in order to derive recommendations for NRAs and CEDR for future Mobility Management planning and implementation.

In the context of this project, Mobility Management is referred to as a long-term focussed change of travel behaviour from car driving to more sustainable modes of transport by mainly using soft measures, such as information campaigns and others.

2.3.2. Objectives and scope

The aim of the MoDBeaR project was to generate new research data to understand the current policies in place across the CEDR NRAs with respect to Mobility Management methods utilised to influence travel behaviour, in both the context of the reduction of Greenhouse Gas emissions and improvement of the overall accessibility. As part of this, the MoDBeaR project also looks into the existing Traffic Management practices which tend to be interrelated with Mobility Management.

As part of the project scope, information on attitudes to climate change was requested from all CEDR members: these included Austria, Cyprus, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Netherlands, Norway, Poland, Sweden, Belgium Flanders, Belgium Wallonia, Czech Republic, Iceland, Italy, Latvia, Lithuania, Luxembourg, Malta, Slovenia, Spain, Switzerland and the UK. Portugal and Bulgaria became CEDR members after the start of the MoDBeaR project and were therefore not included in this study.

The complete project consists of four work packages which are:

- **Work Package 1 – Obtaining the Research Data:** the objective of this work package was to carry out both the initial and additional research to gather information and input for further analysis.

- **Work Package 2 – Evaluating the Research Data:** the objective of this work package was to carry out the evaluation of the data collected in Work Package 1.
- **Work Package 3 – Findings Report and Mobility Management Guidance Plan:** the objective of this work package was to develop recommendations for the ideal future policy role of Mobility Management in terms of promoting the use of sustainable travel modes and reducing reliance on cars use for the following scenarios: normal everyday conditions, planned events and unplanned events including traffic accidents and extreme weather events.
- **Work Package 4 – Dissemination of Research Findings:** the objective of this work package was to disseminate research findings in a research findings report, Mobility Management Guidance Plan, dedicated website, presentations, papers and the final workshop.

2.3.3. Methodology

As part of **Work Package 1 – Obtaining the Research Data**, the Initial Research included extracting modal split, vehicle miles travelled and GHG emission data for the CEDR member states from sources such as EuroStat or the European Environment Agency as well as a review of the existing and available information on Mobility Management policies and practices in CEDR countries (data from EPOMM - European Platform on Mobility Management). The Additional Research involved the development of a questionnaire and was structured as an iterative approach. The questionnaire was initially issued to Trafikverket Sweden and Transport Infrastructure Ireland in order to optimise design, language, and content of the questionnaire. Upon improving the questionnaire, it was issued to all CEDR NRAs. Subsequent follow-up calls were carried out to assist with the completion, clarify questions and to obtain further information where necessary. Those research findings were collated in a structured format. The questionnaire represented a mix of multiple choice and open questions.

The objective of the questionnaire was to gain a deeper understanding of Mobility Management and Traffic Management policies, practices and measures applied and used by NRAs. It also aimed to collect some quantitative data with regards to modal split and funding allocations. Thus, the final structure and content of the questionnaire largely was to cover the information gaps identified during the Initial Research stage.

The challenges encountered and the resulting limitations of this methodology were thoroughly analysed and taken into account in the Research Findings Report.

Thirteen CEDR NRAs returned the completed questionnaire (see Figure 5). Upon agreement with CEDR, the scope of the study was reduced to those countries.

The main objective of the **Work Package 2 – Evaluating the Research Data** was to carry out detailed assessment of the data collected as part of the Initial and Additional Research of Work Package 1. This involved next to the assessment and interpretation of the results, a comparison of differences and similarities between the different approaches of the CEDR NRAs to MM and TM, the identification of good practice examples.

The analysis of the data consisted of two steps, which were (1) Data Analysis – Categorisation and Classification, and (2) Data Synthesis – Cross-CEDR trend identification.

Challenges in relation to incomplete and inconsistent data and varying data sources had to be addressed.

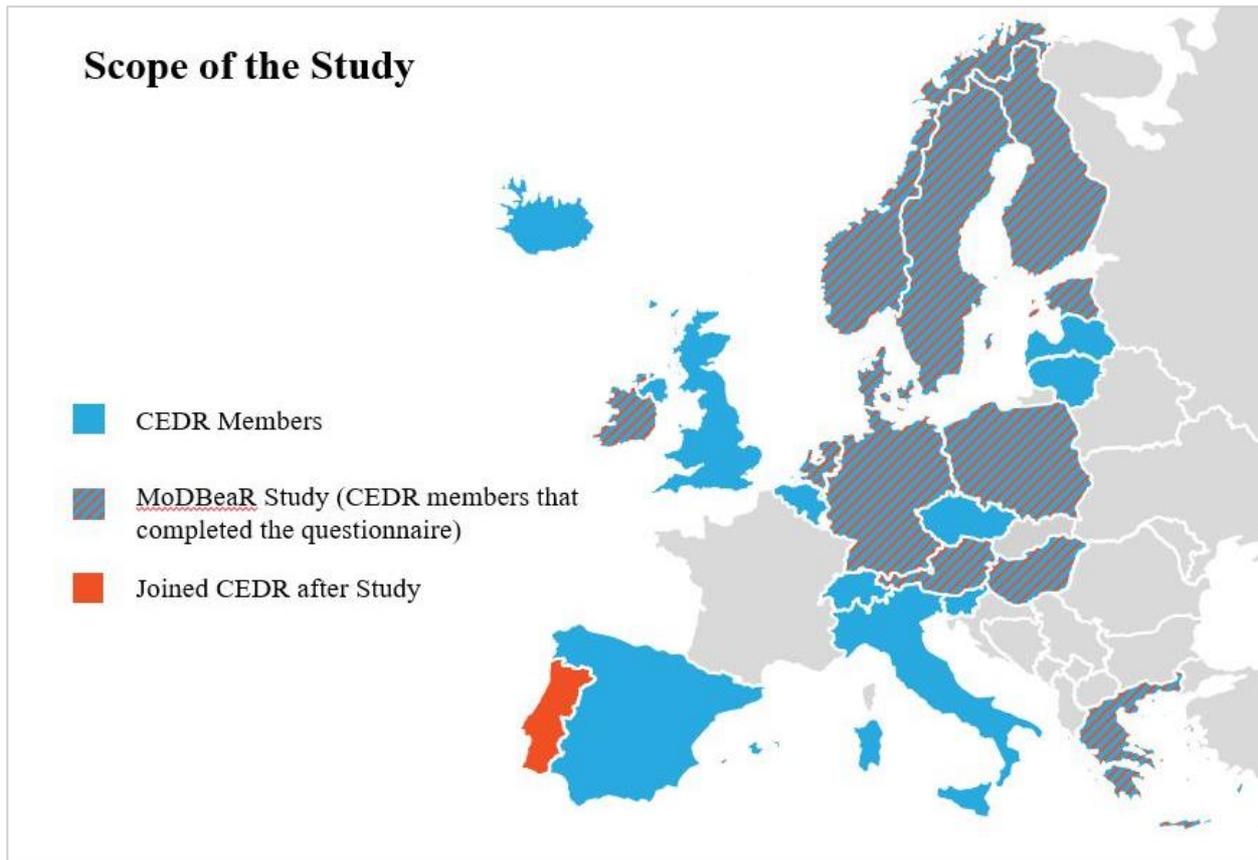


Figure 5: CEDR members included in detailed assessment

The main objective of **Work Package 3 – Findings Report and Mobility Management Guidance** was to collate all findings and develop the final Research Findings Report as well as the Mobility Management Guidance document.

The Research Findings Report collated all the results of the research and identified best practice examples from the different NRAs; divided into Mobility Management and Traffic Management. The report reflects the structure of the questionnaire and present the results for each topic studied as part of the project (Definition, Policies, NRA Role, Measures, Challenges, Funding, Stakeholders). Trends across CEDR members are presented and described for every topic.

The second element was the preparation of a Mobility Management Guidance document (based on any available best practice). It presents high-level recommendations and guidelines for CEDR and CEDR members on how to incorporate Mobility Management implementation into their everyday activities and on how to facilitate their involvement in Mobility Management planning and related policy-making.

Work Package 4 – Dissemination of Research Findings looks to make the results of the project available via two different channels. Firstly, the preliminary results were presented at the end of Programme Event in Utrecht in November 2018. Following the discussion and workshops at the event, final recommendations and considerations were included after verifying them with the present NRA representatives. Secondly, project information and the final project results will be made available on a project website where deliverables can be downloaded.

2.3.4. Deliverables

WP 1	<ul style="list-style-type: none"> • Issue of Test Questionnaire for CEDR NRAs • Issue of Final Questionnaire to all CEDR NRAs • CEDR Responses available in Structured Format • Results of Initial Research (GHG emissions, Modal Split) in structured Format – Infographics per country
WP 2	<ul style="list-style-type: none"> • Assessment complete and summary of Research Findings, including good practice case studies (where available)
WP 3	<ul style="list-style-type: none"> • Draft Research Findings Report (supported by separate Research Structure Report) • Draft Mobility Management Guidance
WP 4	<ul style="list-style-type: none"> • Final Presentation at Summit in Utrecht • Workshop and Discussion of the final Results at Summit in Utrecht • Final Research Findings Report • Final Mobility Management Guidance • Project Website available

2.3.5. Main findings and conclusions

The Research identified that Mobility Management rarely sits within the remit of CEDR NRAs. Despite this, CEDR NRAs are occasionally involved in various Mobility Management projects and programmes, particularly during planned and unplanned road events.

There is often no well-established and universal understanding and definition of Mobility Management within NRAs. Some NRAs tend to associate Mobility Management with Traffic Management.

Some CEDR member NRAs see both Mobility Management and Traffic Management as mechanisms to achieve more effective operations of their transport networks. However, they distinguish between these two concepts on a planning and policy level.

Some CEDR NRAs understand that Mobility Management achieves effective transport network via long-term behavioural change, whilst Traffic Management achieves it with the help of a more short-term network management.

In the actual implementation, however, Mobility Management and Traffic Management are very often confused and NRAs rarely attempt to separate and distinguish between them.

Behavioural change and modal shift as well as reduction of GHG emissions were found to figure as key objectives within Mobility Management and to a lesser extent within Traffic Management in some CEDR member states. However, no prominent interrelation between these parameters was established.

Similarly, fluctuations in the use of the private motorised transport were not found to have been associated with, or predetermined by, any particular Mobility Management or Traffic Management measures used.

There is a lack of a robust and transparent framework for monitoring and evaluation of the effectiveness and cost-efficiency of Mobility Management measures used which results in a poor level of knowledge and understanding of the real value and impact of Mobility Management.

2.4. Synergies between CEDR climate change projects

2.4.1. Overview of the previous CEDR climate change calls

Prior to the 2015 climate change call 'From Desk to Road', there were two previous climate change calls: 2008 Road Owners Getting to Grips with Climate Change, and 2012 Road Owners Adapting to Climate Change. The projects let under these two calls were:

2008: Road Owners Getting to Grips with Climate Change

- RIMAROCC
- SWAMP
- IRWIN
- P2R2C2

2012: Road Owners Adapting to Climate Change

- ROADAPT
- CliPDaR

The six projects are summarised below with icons (see Figure 7) highlighting the types of asset and hazards covered in each.



Figure 6. Photograph from the end of programme event

Project Key

<u>Type of asset considered in the project</u>					
Whole Road	Pavement	Bridges	Culverts	Drainage	Signage
<u>Type of hazard/events considered in the project</u>					
Flooding / Extreme Rain / Storm Surge	Changing Precipitation Patterns	Low Temps / Ice	Fluctuating Temps / Freeze Thaw	High Temps / Heat Waves / Droughts	Strong Winds / Cyclones
Intense Snowfall / Blizzards		Rising Sea Level / Coastal Erosion	Landslide / Mudflow		

Figure 7. Key to assets and hazards considered in the projects

Project: RIMAROCC - Risk Management for Roads in a Changing Climate (10/2008 – 07/2010)

Consortium: *Bo Lind AB (Sweden), EGIS (France), Deltares (Netherlands), NGI (Norway)*

Research Fields: risk assessment, impacts of hazards on infrastructure

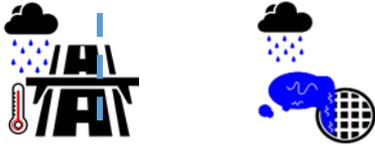


The aim was to develop a climate change risk analysis/management methodology that could be applied to European roads to maximise economic return of optimal implementation measures (construction, maintenance and environmental options). The methodology developed is a qualitative 7 step cyclic framework aligning with ISO 31010:2009. The study resulted in the production of a handbook to support risk assessment (3 sections: basis for climate change adaption; RIMAROCC framework; case studies). Different scales of analysis: territory, network and section were identified. Conclusions relate to the importance of the formal aspects of risk management. Project results have been implemented on motorways in France, Netherlands, Norway, and Sweden.

Project: SWAMP - Storm **W**ater Prevention, **M**ethods to Predict Damage from Water Stream in and near Road Pavements in Lowland Areas (10/2008 – 05/2010)

Consortium: Danish Road Institute (Denmark), VTI (Sweden)

Research Fields: risk assessment

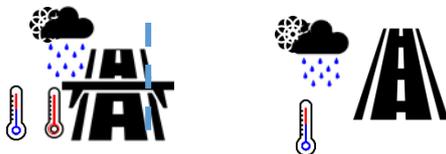


The aim was to develop a modelling framework and screening methodology that identifies flood risks on national highway systems, and provides specific maintenance and inspection guidance to reduce the vulnerability of flood prone assets. The methodology used questionnaires, and data collection (laser scanned elevation profiles, rainfall etc.) which fed into the Chicago Design Storm (CDS) framework, a Digital Terrain Model, and Geographical Information Systems. The results of the project were: an overview of existing inspection guidance in relation to flooding (highlighting areas for improvement); and the development of the Blue Spot Method (procedures that systematically analyses the road network to output flood risk maps highlighting critical areas). The framework analysis has three levels: terrain data analysis, identification and role of existing catchments relative to rain sensitivities, and finally hydrodynamic modelling of surface flow. Guidance documents were also produced for detailing information retrieval and risk reduction maintenance activities. The study concludes that road administrations be flexible when preparing their respective maintenance/inspection guidance documents, and allow room to integrate climate science developments. Project results have been implemented in Denmark to-date but can be used anywhere where high resolution elevation data is available.

Project: IRWIN - Improved Local **W**inter Index to Assess Maintenance Needs and Adaptation Costs in Climate Change Scenarios (11/2008 – 12/2009)

Consortium: Foreca Consulting Oy (Finland), Kilmator AB (Sweden), University of Gothenburg (Sweden),

Research Fields: risk assessment, cost/benefit, adaptation action, impact of hazards on infrastructure, quantifiable indicators



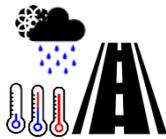
The aim was to develop an improved winter road index to aid assessments (for present day and the future) of climate scenarios. A literature review summarises the state-of-the-art climate models and scenarios (weather and emissions), winter indexes, climate driven road impacts, and calculation methods. A database of historical climate data was compiled and combined with climate change scenarios. The project delivered the IRWIN database, a state of the art climate model and winter indexes, and series of reports. The model and indexes are used to assess the spatial variations of winter maintenance needs, costs, and benefits of winter maintenance strategies. The project concludes that the tools provide stakeholders with accurate information as to where and when

measures need to be taken. The tools result in better: representations/links between climate/weather and road maintenance needs; understanding local weather variations, coverage of extreme events, and comparison of the monetary implications of different maintenance strategies. Project results have been implemented in Finland and Sweden, and is designed to be used across Europe (provided high resolution weather data is available in the correct formats).

Project: P2R2C2 - *Pavement Performance & Remediation Requirements following Climate Change (09/2008 – 03/2010)*

Consortium: *University of Nottingham (UK), ZAG (Slovenia), SINTEF PNP (Norway), VTT (Finland)*

Research Fields: *risk assessment, cost/benefit, adaptation action, impact of hazards on infrastructure, quantifiable indicators, sustainable procurement*



The aim of the project was to study pavement moisture condition differences across Europe due to climate change; and estimate the changes in pavement/subgrade material behaviour across different climate zones to identify risks/vulnerabilities. The study also aimed to define options for responding to identified changes and illustrate them through a cost-benefit analysis. The study's methodology included a literature review, laboratory evaluation of materials, and performing computational studies of pavements structural/hydrological performance to provide road administrators with practical recommendations that can be integrated into existing standards/specifications. Key finding include: temperature and rainfall increases will lead to more defects in asphalt materials; coastal/low lying regions with rising water tables will need to raise/reinforce their structures; thin/unsealed pavements in the Nordic region will need upgrading to cope with future freeze-thaw; and finally, for major asphaltic structures that are not structurally adapted top down cracking is expected, however bottom-up and thermal cracking issues will reduce over time. The project concludes appropriate responses to climate change are achievable through routine material formulation during rehabilitation events; regional specific design criteria is needed for temperature and storm flow return periods; more attention should be given to drainage systems; and that rutting/stripping resistant resurfacing materials should be used for perpetual pavements.

Project: ROADAPT - *Roads for Today, Adapted for Tomorrow (01/2013 – 10/2015)*

Consortium: *Deltares (Netherlands), Egis (France), SGI (Sweden), KNMI (Netherlands)*

Research Fields: *risk assessment, adaptation action, impact of hazards on infrastructure, quantifiable indicators*



The aim of the project was to adapt the RIMAROCC framework (see above) into practical methods for road administrations and operators. The projects methodology followed the RIMAROCC

framework guidance to define risk as a function of probability and consequence. It examined existing tools to develop a GIS-aided platform for generating vulnerability factors and indices, used to inform adaptation/mitigation measures and strategies. The study resulted in the production of guidance documents for: using climate data, the application of QuickScan for climate change risks, performing detailed GIS vulnerability assessments; performing socio-economic impact assessments; and selecting appropriate adaptation strategies. The project results have been implemented in Denmark, Sweden, Netherlands, and Portugal.

Project: CliPDaR - *Design Guideline for a Transnational Database of Downscaled Climate Projection Data for Road Impact Models (02/2013 – 02/2014)*

Consortium: DWD (Germany), ZAMG (Austria)

Research Fields: *climate change modelling*



The aim of the project was to evaluate climate indicators for 20 major cities across Europe to assess the abilities of existing climate models; reproducing current climate conditions using to historical measurements and evaluating climate projections between 2021-2100. The project used models covered under the Cost-Action-Value programme and KLIWAS project to downscale models. The project delivered a series of workshops and guidance documents for: statistical/dynamic downscaling climate models so results can be inputted into impact models; ensemble climate projection data; coping with cold winters and hot summers (return periods of extreme events); and designs for a transnational database of downscaled climate projection data for road impact models. The project concluded by identifying key indicators for hazards to infrastructure, and their repeatability using different climate models.

2.4.2. The links and synergies between projects

There is a clear progression in the themes of the calls over time. In 2008, the four projects focused on understanding and quantifying risk in order to compare different types of risk or different locations. In 2012, there were two more in-depth projects, one (ROADAPT) that directly built on a previous project (RIMAROCC) and one (CliPDaR) that examined a specific area (use of climate projections) where a gap had been highlighted by the 2008 projects. In 2015, the emphasis was on embedding climate change considerations into NRA processes and practical tools and guidance. The most direct links between projects are between RIMAROCC, ROADAPT, DeTECToR and WatCh, but there are also relationships between the other CEDR projects where the principles developed in another project are used or the approach employed aligns with other projects. Figure 8 illustrates the progression over time and the links between projects.

The DeTECToR project risk assessment and cost benefit analysis tool is based on elements of ROADAPT and RIMAROCC. The risk assessment module uses the approach developed in the German project RIVA which in turn aimed to implement RIMAROCC on the German road network. DeTECToR aligns with the network scale analysis objectives described in ROADAPT and supports the implementation of the risk assessment steps identified in RIMAROCC. It also uses elements of ROADAPT’s guidance on socio-economic appraisal in the CBA module and the climate indicator approach from CliPDaR. ROADAPT recommended that any subsequently developed tools have transparency, and are flexible in data

requirements/formats so they can be easily adjusted to meet the individual requirements of different NRAs. The DeTECToR tool took these suggestions forward. The tool is flexible, in that it allows users to redefine or create new indicators, damage pattern categories, modify weightings, use different climate projections (national, international) amongst many other customisable features. Furthermore, the methodology, calculation framework and assessment conditions operating behind the scenes are clearly set out in the accompanying guidance documents, so users of the tool have a clear understanding of its functions and derivations.

WatCh also utilises the socio-economic appraisal approach from ROADAPT in the development of its guidelines for a socio-economic analysis of adaptation and maintenance approaches for water management and when carrying out CBA analysis in the case study. The DeTECToR and WatCh consortiums liaised on the approach to CBA used, so that the projects align. WatCh follows a similar format to the ROADAPT quick scan for its assessment framework and carried out both a quick scan and detailed assessment within its case study. As in DeTECToR, the level of risk is assessed by identifying and scoring criteria related to climate threat, asset susceptibility and consequence. WatCh also references the SWAMP methodology but it was not directly used.

WatCh and DeTECToR use climate projections to compare the current and future risk. Some of the principles identified in **ClipDaR** in relation to using climate projections were used in both projects. DeTECToR used ensembles of climate projections in the risk assessment and CBA tool and created climate indices for different types of infrastructure damage/disruption. Both projects included climate scientists within their consortiums, which is in line with the ClipDaR recommendations for greater collaboration between road engineers and climate scientists. Projects prior to ClipDaR also included climate projections and IRWIN carried out analysis of historic weather data.

SWAMP developed a methodology to identify areas with a high risk of flooding. It uses different levels of analysis similar to ROADAPT.

IRWIN creates a winter index and evaluates how this would change with climate change and the implications for winter maintenance activities. **P2R2C2** provides some insights into how climate change will affect pavements. The types of impacts identified in these projects align with the some of the damage pattern categories used in DeTECToR.

There are a number of other synergies between CEDR projects, in terms of the assets they investigate and the climate change impacts they consider. For instance, the road as a whole is studied in RIMAROCC, SWAMP, IRWIN, ROADAPT, and ClipDaR. The impact of climate change on the pavement structure itself is also explored in RIMAROCC, IRWIN, P2R2C2, ROADAPT, ClipDaR, and DeTECToR. Impacts and risks for drainage assets are addressed under the SWAMP, ROADAPT, and WatCh projects. In terms of climate change considerations RIMAROCC, SWAMP, IRWIN, P2R2C2, ROADAPT, ClipDaR and WatCh assess increased rainfall, flooding and changing precipitation patterns applied to the above assets. Similarly a set of common climate conditions investigated were low/high/fluctuating temperatures in the RIMAROCC, SWAMP, IRWIN, P2R2C2, ROADAPT, ClipDaR, and DeTECToR. Another common theme between projects was the visualisation and geographical contextualisation of results, seen in DeTECToR, WatCh, IRWIN, ROADAPT and SWAMP. The use of climate change projection models was also common to most projects, with a number allowing the use of multiple projections to allow comparison between scenarios and adaptation measures. Other common themes between many of the projects under each call include risk assessments, identification of adaptation options, decision-support guidance and tools and economic assessments of climate change impacts.

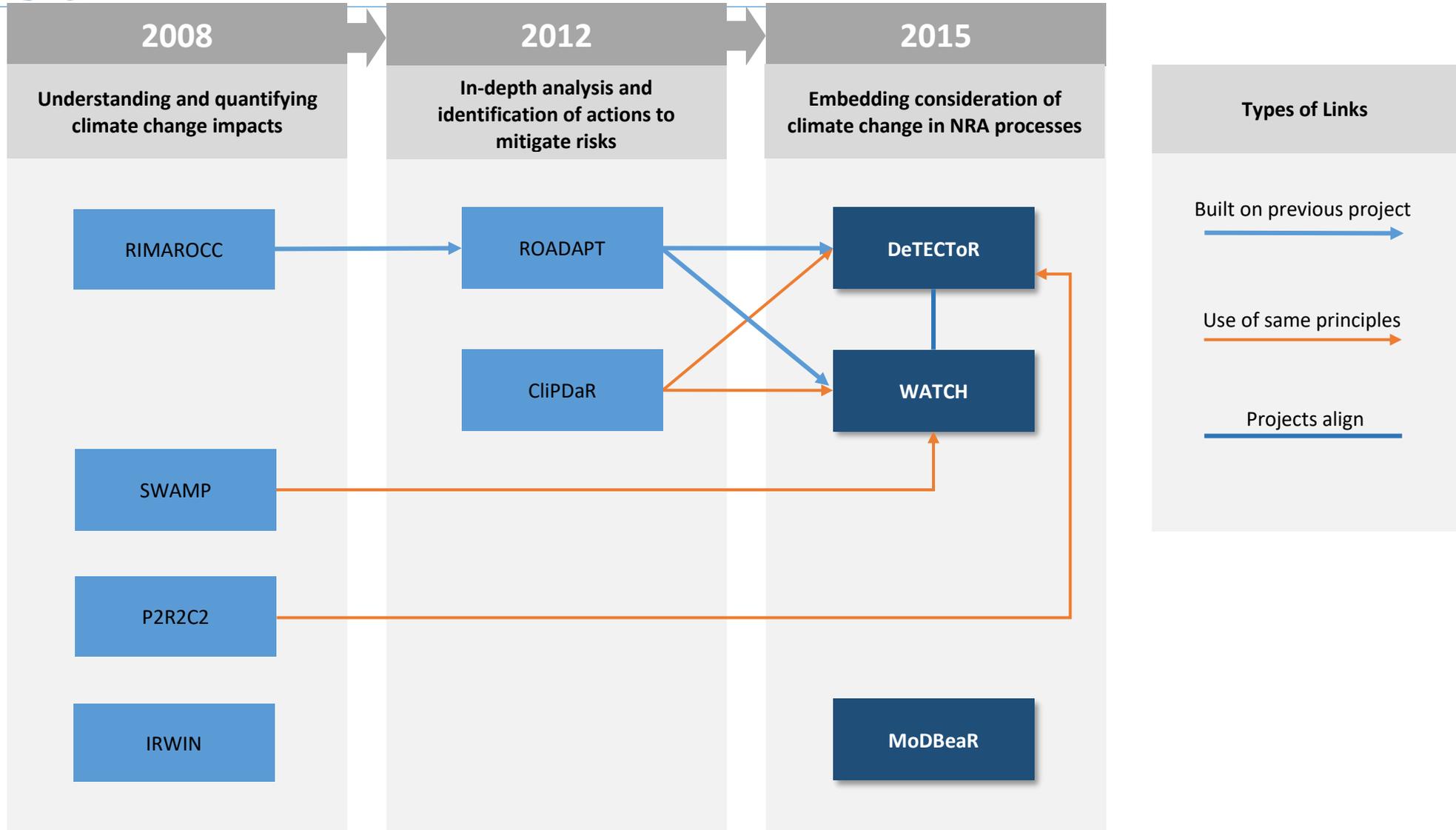


Figure 8. The relationships between the CEDR climate change projects

Whilst ModBeaR does not have any obvious links to the other projects within the three calls, it could be seen as the start of a new theme of planning for and responding to traffic disruption and carbon reduction which could be built on in future calls. There are also some connections with other CEDR calls such as the 2013 Traffic Management call and the 2011 Mobility Call.

2.4.3. Implementation of past projects

A key aim of CEDR projects is to create knowledge and results that can be applied in practice by NRAs. The DeTECToR and MoDBeaR surveys showed that consideration of climate change remains limited across many NRAs. However, there are a number of NRAs who are taking action on climate change and many of these are using CEDR project results as part of this. Whether or not CEDR projects are implemented is unknown, unless an NRA has presented on this topic or published its work. However, it is clear that RIMAROCC, ROADAPT and SWAMP in particular have been implemented by several NRAs.

Rijkswaterstaat used the SWAMP methodology (2011-2014) to better understand their assets vulnerabilities to flooding from sea, rivers, and increased rainfall. Rijkswaterstaat also applied the ROADAPT methodology to their A58 and A20 schemes (2016-2018) to increase the upgrades overall resilience and to derive dynamic adaptation pathways resulting in refined adaptation strategies. Rijkswaterstaat have also been using the ROADAPT methodology (2008-2019) to perform stress tests on their highways to determine the performance levels and acceptable risks of adaptation measures. A core objective of these stress tests is to use the results to inform and define the administrations adaptation strategy for a climate robust network in 2050. Rijkswaterstaat have also been applying the outcomes of the RIMAROCC project in their quantitative and qualitative risk assessments so climate change risks are systematically and consistently assessed across their schemes. The administration also expresses interest in applying the DeTECToR tool, guidance and findings in future innovation projects (2019 onwards).

Transport Infrastructure Ireland (TII) has also implemented CEDR products or has used CEDR generated knowledge as a basis for further research and development of their standards and tools. For instance, as a result of the RIMAROCC and SWAMP projects, TII commissioned studies on flooding impacts to their road networks. Specifically TII have investigated drainage design on their national road network through Irish universities and funded a four year post-doctorate at Trinity College, Dublin. This has increased the administration's expertise in drainage design. TII also funded research relating to the risks of flooding on their network. Following on from the 2012 CEDR call, the results of ROADAPT and ClipDaR encouraged TII to develop comprehensive flood maps of their entire road network and develop a high-level protocol for assessing flood risks, as per the RIMAROCC methodology. The 2012 CEDR call results also led the administration to develop complete sets of drainage design standards which incorporate climate change considerations into drainage design. The results of the 2015 CEDR call led TII to develop and publish a Climate Change Strategy, a Sustainability Statement, and a country specific carbon tool. Furthermore, the administration has recently developed a flood forecasting tool for detailed assessments of motorway sections, alongside a detailed protocol for assessing mitigation measures. TII have also expressed interest in applying DeTECToR principles to their carbon tool for road and light rail projects, ensuring climate change considerations are embedded into their procurement and design processes. The results of MoDBeaR have increased the organisations awareness of mobility management, which they plan to expand on in conjunction with the National Transport Agency. The Norwegian Public Roads Administration have also expressed interest in using DeTECToR products in future products once the tool is finalised.

3. The Final Conference



Figure 9: Opening Day of the final conference.

3.1. Overview of the event

The Final Conference of the CEDR 2015 climate change programme took place on 19-20 November 2018, at the LEF Future Centre, in Utrecht, the Netherlands.

Over 80 attendees from 20 countries participated in the presentations, discussions and workshops and contributed to the success of the event. The attendees were representatives of National Road Authorities, researchers, members of the CEDR PEB, and members of the three project teams. Furthermore, the organisers made sure to invite young professionals in order to engage the next generation which will largely be concerned by climate change issues in the future.

The agenda of the final event can be found in Appendix A. Day one consisted mainly of presentations by the 2015 project consortiums and discussions on the projects. Day two involved presentations by PEB members and guest speakers. The presentations are available on the CEDR website.

The LEF Future Centre is a novel venue with an unconventional set-up that uses wall projections, furniture, colour, images and sound to create a thought-provoking atmosphere. A variety of different spaces facilitates discussions of multiple stakeholder groups. This set-up supports innovative thinking, dynamic group processes, decision-making and contributed to creating lively discussions about how NRAs can face climate change implications.

After the presentations introducing the 2015 call projects, a Q&A session with mountaineer and Mount Everest climber Wim Leenderste from Rijkswaterstaat introduced three concepts that were running as a common thread through the subsequent discussions:

- By introducing the “Sherpa and Specialist” concept, attendees were invited to reconsider their roles, i.e. what impact they can make within their organisations in terms of climate change adaptation and mitigation, and how they can apply the tools that were provided as outcome

of the three projects. Are they Sherpas (i.e. helping the specialists by providing information and guidance) or Specialists (i.e. =providing the specialist skills needed to take the steps required to reach the summit), do these roles overlap, and how can they make an impact on their organisations? The importance of working together as a team in a multidisciplinary way to achieve a common goal was underlined.

- As a second analogy, the Summit (ultimate goal), and basecamps (as steps leading towards a common goal) were used. There are several different possible routes between basecamps. After this session, attendees were invited to come together in groups based on their country, and to define their summit – i.e. the goal to achieve for a country and the NRA. In the subsequent sessions, attendees were invited to think about which steps are needed in order to reach this higher goal.
- Dealing with uncertainty fosters adaptability. All projects have to deal with uncertainty, and especially in the context of climate change the uncertainty is very high. Nevertheless, decisions have to be made, but here this means that all decisions need to be tailored to be able to accommodate changes and the reassessment of options on an ongoing basis.

After this introduction, interactive workshops focussed on the implementation and integration of the research outcomes and tools of the three projects into NRA practice and decision-making. In each workshop, a case study from a CEDR country was presented to initiate the discussions.

3.2. Project workshops

3.2.1. DeTECToR workshop

In the DeTECToR workshop the consortium presented the two software tools produced by the project and illustrated the CBA tool using a case study from Bavaria, Germany.

Procurement tool

The concept of a tool to encourage greater collaboration between NRAs was well received and considered useful. The scope of the tool was discussed including the type of project reviewed and the focus on procurement and infrastructure. One participant suggested it could also be used to encourage greater engagement between NRAs and climate scientists. If climate scientists could also use the tool they could upload information and links to reports which could be useful to the road sector. It was noted that not all information was available in English, but that a link to information in other languages was still of value as it provides users with an idea of what is available so they can seek further information from the providers of the report.

Risk assessment and CBA tool

There was a great deal of interest in this tool as there is currently nothing similar available to NRAs. The main concern was the availability of asset data, but the DeTECToR team explained the flexibility of the tool and that if data sets are missing the indicators and weightings could be adjusted. Similarly, the team explained that NRAs could use national climate projections if they wished. There were discussions around how the tool would be used and how the appraisal period aligned with economic appraisal periods. It was explained that this is a strategic tool that can inform changes in design standards, materials used and maintenance planning. One participant asked if it was worth the effort required to use the tool for a small organisation, but others responded that NRAs can't rely on historic

data anymore to plan for the future and that the asset data required had many other uses so there were multiple benefits in collecting this.



Figure 10. Participants at the DeTECToR workshop

3.2.2. WatCh workshop

The WatCh workshop was organised around two case studies from two NRAs.

The **Danish Road Directorate** supported a case study that aimed at demonstrating how the WatCh manual can be applied by the NRAs. The Danish case study represents a case that is applicable to almost all the NRAs because it deals with an existing motorway infrastructure that is prone to flooding, and as it connects to the capital city Copenhagen, it has high traffic volumes. The presentation took the attendees through each step in the manual, from a high-level analysis to the detailed analysis, and explained how to use it and what elements need attention, and how the results can be interpreted.

Following this there were questions on the implementation of the Watch Manual:

- **Implementation of the Manual.** What are the steps towards implementation, and is there any experience from NRAs? MCAs and CBAs are already carried out on a scheme-wide level but often this does not take the different scenarios and aspects into consideration that are provided by the manual.
- **Individual cases.** Each application of the Manual will lead to different and individual result, and the results are very often not transferable to other projects or other countries. Nevertheless, an analysis based on the manual can help identify sensitive elements of the analysis and this knowledge can be transferred to other projects. Furthermore, experience from the use of the manual can be used as a conversation starter for similar projects.
- **Adaptability to the conditions within different NRAs.** The manual created a flexible approach that can be adopted by all NRAs, and due to varying national conditions the same applications

can lead to different results. With the use of the manual, the NRAs can have an informed discussion about their individual goals and possibly create own tools based on the provided guidance.

- **Importance of Visualisation.** With the objective of sending a clear message about the need for climate change adaptation implementation, the manual can be a useful tool to underline this message. In a subsequent step, the resulting figures can be visualised and be used to convey a clear message in both directions bottom-up (to management level and decision makers) and top-down. This can also help to overcome silo-thinking and to spread the message to related disciplines, e.g. rail.
- **Applicability to other road types,** e.g. non-motorway roads. In low traffic volume roads, the CBA might be less favourable for an upgrade scheme, even if the road provides an important connection. How can the manual be used in those cases?

A second presentation, led by **Transport Infrastructure Ireland**, provided information on flood management on the Irish road network, with a special focus on user guidance. The core objective was to define flood probabilities for different sections of the network and gain understanding which areas hold the highest risk. Furthermore, the research explored how the flooding information can be used best to manage flooding and mitigate damage and disruption of the road network and harm to people, and develop management techniques accordingly. Important elements discussed included:

- **Risk.** The strategic tools help to identify the most vulnerable parts of the network based on different criteria. This ranks different sections of the network in terms of necessary actions.
- **Uncertainty** is inherent to climate change and causes uncertainty in the range of adaptation measures. Therefore, it is important to include a number of different scenarios to gauge the range of possible climate change consequences and the impact on the range of measures that possibly will have to be taken.
- **The guidance provided** needs to provide more specifics and more concrete actions that can be carried out. The purpose needs to be communicated more clearly within the organisation, from management to implementation level, and with other stakeholders as well.

3.2.3. MoDBeaR workshop

The MoDBeaR workshop focussed on Mobility Management Planning and Implementation for NRAs.

The first part of the workshop involved a NRA case study presentation by Camille Delepierre from Trafikverket/Swedish Transport Administration. The presentation focussed on mobility management during the construction phase of infrastructure projects and how accessibility can be ensured. Hard and soft measures are used in combination. Some of the mobility management project examples included: training for building contractors, dialogue with households, test of electric bikes, and meetings with businesses/companies in a specific area.

Other topics raised by Trafikverket are funding issues and the need for organisation development.

After the introduction, the group was split to discuss two topics:

- **Group 1** focussed on policy making and planning for mobility management, which included aspects like definitions, policies, NRA roles, and governance.
- **Group 2** focussed on mobility management implementation, covering aspects such as measures, monitoring and evaluating, funding, and stakeholders.

The key takeaways from the discussion in the two groups were as follows:

- **Knowledge gap, especially on practical steps towards the implementation of mobility management.** There is a clear need for a common national goal for the implementation of mobility management. Goals on different levels, from local to national, need to be aligned. Even if there is a vision for mobility management and concrete ideas about measures that could be useful, NRAs very often lack the knowledge to implement mobility management and do not know how to start working with it, and the (political) conditions to work with mobility management in a meaningful way need to be created first.

The NRAs could play an important role in the educational process about mobility management for local authorities and other national level agencies. Mobility management experts in the NRA could take over this role.
- **Mandate of the NRAs.** In most cases, the NRA does not have a direct mandate to work with Mobility Management. What they can do is, however, the inclusion of mobility management and its objectives in strategy documents to provide guidance, recommendations to and raise awareness to other organisations. In this context, government support for the NRAs is vital.
- **Stakeholder collaboration.** Since not all NRAs have the mandate to carry out mobility management measures, stakeholder collaboration with other national level agencies as well with local authorities is all the more important, for both planning and the implementation of mobility management.
- **Role of the local authorities.** Since the local authorities often know best which measures are needed and useful in a certain area, mobility management initiatives should be led from a bottom-up approach. Different agencies that are present in one area could collaborate on mobility management implementation, let by the local authorities. The NRAs could contribute with funding.
- **Funding.** Especially local authorities could benefit from a NRA-led cross-funding.



Figure 11. Participants of the ModBear workshop

4. Conclusions and Recommendations

4.1. Conclusions

NRAs have similar challenges in addressing climate change issues and there is a clear role for CEDR projects in supporting this. The participants in the end of programme event had clear intentions of using the 2015 call project findings and found them useful. From the discussions the following overarching elements were identified across all the 2015 projects:

- **A common climate change adaptation AND mitigation goal needs to be defined.** This goal can be a common goal between all NRAs on CEDR level but it also needs to find a reflection on national and NRA organisational level. A common goal can foster cooperation between the NRAs, and the dissemination in a top-down approach within each NRA can contribute to streamlining measures and tools implementation.
- **Measurable goals.** Quantitative goals need to be set to be able to measure the actual improvement within one organisation, and each organisation could quantify which results they can realistically achieve. These goals can relate to
 - climate change adaptation/mitigation objectives in term of emission savings, and
 - the use of provided tools for including climate change in procurement processes etc.
- **Decision makers of an organisation need to be on board.**
- **A common language.** The discussion of the Irish NRA focussed on the inclusion of climate change objectives in standards. The need for a clear communication of climate change impacts, inclusion in official documents, adaptation and mitigation measures needs to be phrased in a clear and understandable language. This language needs to be understood at all levels – from policy-making level down to implementation level with e.g. the contractor who is actually carrying out road works. Instead of speaking about the general impacts of climate change, the issue and its consequences needs to be translated into tangible impacts, e.g. to flooding on the road network or resilience of specific infrastructure sections.
- **Adaptability and step-by-step decision-making.** As discussed in the mountaineering session with Mount Everest climber Wim Leenderste, decisions need to be made for the next immediate steps because climate change causes so many uncertainties and it is difficult to plan too far into the future. Conditions can change quickly, and additional knowledge can be produced which can change the optimal option. Every decision needs to allow for as many possible actions afterwards and not tie NRAs to one type of approach. The planning process should hence include the frequency when initial plans should be reconsidered and adapted to changing conditions.

This ties in with discussions made at the final plenary discussions: A hands-on approach is needed. A lot of institutions tend to plan too much instead of doing something. Since the need for active climate change is here now, it was agreed that an approach “just do it” and learning from mistakes should be preferred over over-planning. Especially in the climate change context, with many possible scenarios, no decision can cover them all but needs to be robust enough to cover as many outcomes as possible.

- **Internal knowledge sharing.** There is a need of more exchange of experience within the organisation. Some participants stated they feel isolated in their work and there is a lack of understanding of the issues within their organisation.
- **Evidence based solutions.** Understanding asset location, characteristics, condition and how it currently reacts to different climate conditions underpins robust decision making. This does not only apply when considering climate change, but to effective asset management and risk management in general.

4.2. Recommendations on implementation

4.2.1. Implementation of the 2015 project findings

Some specific recommendations in implementing the 2015 project findings are:

- In relation to the DeTECToR online procurement platform, the following are recommended:
 - Review the procurement information on the DeTECToR online platform and consider how approaches employed by other NRAs could be employed in your organisation.
 - Add information on your experiences and contact front runners for more information on how they implemented their approach.
 - Carry out impact studies, consult with suppliers and gather data to support new procurement approaches which incentivise suppliers to reduce carbon.
 - Carry out pilot studies to trial new procurement approaches.
- Regarding the implementation of the DeTECToR risk assessment and CBA tool within NRAs, the following steps should be taken:
 - Identify the steps required to tailor the DeTECToR risk assessment and CBA tool to your organisation.
 - Decide on the priority Damage Pattern Categories for your network and review the data requirements for these.
 - Appoint someone within your organisation to be the tool administrator to identify the sources of data and modify the indicators to address any gaps.
 - Collect and upload the data for a pilot region.
 - Decide how the use of the tool can be integrated into current asset management and planning processes.
- Review the WatCh manual and use it to identify any gaps in current water management procedures. Consider how the guidance could be applied on your network and if any modifications would be required to tailor it to your circumstances. Use the climate analogue tool to identify which countries are likely to be most similar to your future climate and speak to the relevant NRA about their challenges and approaches. Embed requirements in relation to the use of SUDS within planning and procurement.
- The MoDBear project differed in outcome from the other projects, as it was a research-based project. Rather than developing implementable tools, the current state of the use of Mobility Management within NRAs was analysed. Based on these findings, a guidance and roadmap were developed that NRAs can use when implementing Mobility Management in their processes. Following this initial study, in a continuation of the project the next steps could be

as follows. The Mobility Management Guidance provides a general overview over desirable actions and processes in relation to Mobility Management planning and implementation. This guidance now needs to be refined and tailored to suit individual NRAs and to include variations based on the different national conditions and NRA roles. As the Mobility Management roadmap helps to identify the NRAs current state of the art, more concrete steps can be developed to provide a more hands-on approach, similar to the tools developed in DeTECToR and WatCh.

4.2.2. Recommendations for CEDR regarding future projects

Some more general recommendations on ways to support implementation of CEDR projects are given below:

- The PEBs could be more explicit in the Description of Research Needs about the requirement for step-by-step recommendations on how NRAs can implement the projects findings and results. Whilst project results/tools/methodologies are often implemented and refined through pilot studies during the latter stages of a project, and this is often done in collaboration with an NRA, it can sometimes be unclear how other NRAs can maximise and exploit the knowledge generated.
- Similarly, it is recommended that future calls clearly state how it is expected the research will fit into existing processes or if they expect a change in their procedures to be required. If so, the project reports should discuss how such changes can be made whilst causing minimal disruption to the organisations operations.
- The innovative format of the 2015 end of programme event was well received by participants and successfully encouraged discussions. It is recommended that future end of programme events should follow a similar format and style. Whilst the event provided opportunities for cross-stakeholder discussions and debate, it is suggested that future events should aim to provide more space and time for extended discussions or conversations for the participants. As per the 2015 event, the use of handout templates is encouraged so that the contents of discussions are captured on paper.
- If relevant to a specific project, CEDR could fund implementation workshops (in-person or online) after the main technical elements have been submitted and approved. Ideally such workshops would be organised and run by the project team and would invite interested NRAs to attend. Their purpose would be to explain their research and, in the case of developed tools/methodologies, highlight data requirements and step-by-step procedures on how to use the tool correctly.
- CEDR may wish to distribute end of project surveys to elicit the views of NRA representatives on implementation of the project findings. This could be carried out as part of the end of programme event. A suitably designed survey may help to identify common issues for implementation or highlight the successful elements of projects. This information could be used to refine future project requirements and stipulations, with the aim of making future work easier to implement.
- CEDR may wish to consider the consistency of the call. Although sometimes the projects have had common themes and, in some cases, built on previous projects, often they do not. A review of previous projects to identify the gaps or next steps would help ensure previous research is built upon and that projects complement each other effectively.

4.2.3. Recommendations for NRAs regarding implementation of CEDR results

Some general recommendations on implementing:

- NRAs may wish to agree on their expectations of CEDR research products. Whilst some projects have resulted in ready-made/off-the-shelf tools (such as WatCh and DeTECToR) often further work is required to implement tools/guidance and tailor it to individual circumstances.
- Usually the NRAs most involved in a project get the most out of it. Greater collaborate with the project consortium will ensure their needs are continually addressed throughout each step of a project.
- A key barrier for implementation is the NRAs perspective regarding the quantity and quality of data that is required for inputting into tools/methodologies, and that it would be too costly to compile such information. It is often the case that the NRA will possess the correct data already but it is not centralised and is spread across their organisation/individuals/databases. If projects can clearly highlight the objective benefits of implementing their findings, it would help the NRAs make the case for collecting the required data.
- There can be a gap between mission/vision/objectives and responsible working groups within the NRAs. They don't always match and hence implementation of tools and measures cannot be carried out effectively and efficiently. Stakeholder roles within the organisation need to be clarified, with the most suitable candidates (those who would use the tools for maximum benefit) being identified and ideally have some role/steer in the project.
- Similarly, all the event participants agreed that there is a need for more practical, real-life examples on which measures can be taken. Positive as well as negative examples and case studies can provide a real added value. A focus on technical and implementation aspects is perceived as most useful. Implementation assistance is needed. Those examples should address the people actually working on the implementation who are often engineers. A clear language that is understandable for everyone is needed.
- The above recommendations may require resources and time from NRAs who may already be significantly occupied with their day-to-day operations. NRAs should allow time for the most suitable candidates (often project engineers/designers/planners) to be informed by CEDR research products and carry out internal dissemination. Such time allowance could fall under their existing their research dedications or count towards their employees' professional development. NRAs should, where possible, ensure they are investing in their employees, especially more junior members of staff. These will be the ones addressing the challenges caused by climate change issues, especially considering their increased severity in future years.

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Appendix A: Conference agenda

Climate Change: From Desk to Road

Agenda Day 1 – November 19

12:00 **Registration & Lunch**

13:00 **Welcome and Introduction**

- Marinda Hall (moderator)
- Cees Brandsen, Rijkswaterstaat, Member of CEDR Executive Board
- Vincent O'Malley, Chair, Programme Executive Board, Call 2015 Climate Change

13:15 **Ten Years of CEDR Climate Change Research and the Next Step**

Vincent O'Malley, Chair, Programme Executive Board, Call 2015 Climate Change

- Call 2008: "Road Owners Getting to Grips with Climate Change"
- Call 2012: "Road Owners Adapting to Climate Change"
- Call 2015: From Desk to Road - Implementation of Research

13:45 **Introducing the results of Call 2015 Climate Change: From Desk to Road**

- **DeTECToR**: Embedding climate change into practice and procurement
Sarah Reeves, TRL
- **WATCH**: Developing a transnational approach to water management in the face of climate change, *Thomas Bles, Deltares*
- **MODBEAR**: Diagnosing driver decision-making in a changing climate,
Tiago Oliveira, ARUP

14:30 Coffee Break

14:45 **Climbing the Climate Change Mountain: Wim Leenderste, Rijkswaterstaat**

- Using the "Sherpa & Specialist" concept to plan for Climate Change adaptation
- Definition of roles: how do we use the research tools to adapt to climate change?
Who are the climate change sherpas and specialists?

15:15 **Interactive parallel workshops on each project: Focus on results and Implementation. Includes case study of implementation from CEDR member states**

- **DeTECToR Project workshop**
Implementation focus: integrating climate change into procurement
Leaders: Reinhard David, ASFINAG; Sarah Reeves, TRL
NRA Case study: Germany (case study by the DeTECToR project)
- **WATCH Project workshop**
Implementation focus: Removal of water from roads
Leaders: Billy O'Keeffe, Transport Infrastructure Ireland; Thomas Bles Deltares
NRA Case studies:
 - o Denmark (Case study taken as part of the WATCH project)
 - o Flood management in Ireland
- **MODBEAR Project workshop**
Implementation focus: Mobility management
Leaders: Håkan Johansson, Trafikverket; Tiago Oliveira, ARUP
NRA Case study: Mobility Management in construction projects in Sweden

Climate Change: From Desk to Road

16:45 Coffee Break

17:00 **Plenary discussion**

Each parallel workshop to report their discussions on how to integrate research into practice and decision-making

18:00 Reception followed by dinner

Agenda Day 2 – November 20

09:00 **PIARC activities on Climate Change Adaptation and Resiliency**

Juergen Krieger, Federal Highway Research Institute (BASt), Germany

09:20 **Moving from Desk to Road: Presentation and discussion of NRA case studies**

- **Climate Change Risk Management**
Netherlands - CEDR ROADAPT methodology in the InnovA58 project
Kees van Muiswinkel, Rijkswaterstaat
- **Climate Adaptation Strategy for National Roads**
Poland - Mapping of climate vulnerabilities on existing national road network
Grzegorz Łutczyk, General Directorate for National Roads and Motorways (GDDKiA), Poland; Elisabet Vila Jorda, JASPERS
- **Water Management**
Ireland - Strategy for Adapting to Extreme Weather Events and Climate Change – Implementing CEDR Research into NRA’s Protocols, Guidelines and Standards – Road Drainage Design
Billy O’Keeffe, Transport Infrastructure Ireland
- **Embedding climate change into procurement**
Sweden – Embedding climate mitigation into procurement - reducing CO2 in a lifecycle perspective
Håkan Johansson, Trafikverket

10:45 Coffee Break

11:00 **Moving from Desk to Road: Plenary Discussion**

- What needs to be done and when?
- By whom?
- What further communication is needed?
- What steps can be taken between now and TRA2020?

12:00 Conclusions

12:30 Business Lunch and End of Conference

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