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Decision-support Tools for Embedding Climate Change Thinking on Roads (DeTECToR)

Final Report

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CEDR Call 2015: Climate Change
DeTECToR
Decission-support Tools for Embedding Climate Change Thinking on Roads

Final Report

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Table of contents

Glossary i
Executive summary iii
1 Introduction 1
1.1 Project objectives 1
1.2 Work packages 1
1.3 Deliverables 2
1.4 Report scope 4
2 Summary of project activities 5
2.1 Information gathering 5
2.2 Development of the tools 7
2.3 Development of the guidance documents 18
2.4 Carrying out the pilot studies 18
3 Overview of the DeTECToR tools and guidance 28
3.1 Risk assessment and cost benefit tool and economic guidance 28
3.2 Procurement collaboration platform and procurement guidance 29
4 Pilot study findings 33
4.1 The risk assessment and CBA tool 33
4.2 The procurement collaboration platform 34
4.3 NRA feedback on the tools 37
5 Conclusions and implementation 39
5.1 Project findings 39
5.2 Recommendations for implementation and building on the project 40
6 Acknowledgements 41

Glossary

Term/Acronym	Definition
AADT	Average Annual Daily Traffic
Climate	Climate can be defined as the average weather, normally over 30 years. It is the statistical description of the mean and variability of relevant variables such as temperature and precipitation.
Climate change	A change in the state of the climate that can be identified by changes in the mean and/or variability of it properties and persists for an extended period *(e.g. decades or longer).
Climate change adaptation	The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
Climate change mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs).
Climate projection	A projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols or radiative forcing scenarios, often based upon simulations of climate models. (IPCC)
Cost-benefit analysis (CBA)	An analytical methodology for the quantification of the positive and negative consequences of a project in monetary terms over a set appraisal period.
Damage Pattern Category (DPC)	Damage related to a specific asset type and climate hazard e.g. heat related damage to concrete pavement surfacing.
Environmental Impact Assessment (EIA)	EIA is legal planning requirement carried out to assess the different environmental impacts the planned construction is likely to produce. The 2014 amendment to the European Directive stipulates the consideration of climate change impacts.
Environmental Product Declaration (EPD)	A document providing information about the environmental impact of a product in a standard format. These are often produced by the product manufacturer, but should be independently verified.
National Road Administration (NRAs)	The organisations which manage the construction, maintenance and operation of a countries main roads.
Pavement asset Management System (PMS)	PMS is a systematic and objective tool to manage pavement networks based on rational, engineering and economic principles.
Risk	ISO 31000 describes risk as the effect of uncertainty on objectives. In engineering terms, risk is often described as a combination of the likelihood of an event occurring and the magnitude of the consequences if it does occur. When considering climate change, likelihood is related to exposure to environmental conditions and the vulnerability of the asset.
Spalling	A type of defect where concrete breaks into small pieces, e.g. due to freeze-thaw action.
Uncertainty	A state of limited knowledge with difficulty in describing the current state of future outcome.
Weather	The short-term variation in meteorological conditions, such as temperature, precipitation and wind.

Executive summary

Climate change presents a significant challenge for National Road Administrations (NRAs), both in dealing with its impacts on their network and in finding ways to reduce their greenhouse gas emissions. The DeTECToR (Decision-support Tools for Embedding Climate Change Thinking on Roads) project was commissioned through the Conference of European Directors of Roads (CEDR) Transnational Research Programme to help NRAs address these challenges. DeTECToR focuses on two key areas; developing the business case for climate change adaptation; and embedding consideration of climate change mitigation and adaptation into NRA operations and procurement. A decision-support tool and accompanying guidance was developed for both these areas. The risk assessment and cost-benefit tool produced will enable NRAs to identify the level of risk to different assets from relevant weather hazards and understand how this is likely to vary over time due to climate change. It will also enable them to compare the whole life costs associated with different adaptation strategies. The procurement collaboration platform will enable NRAs to share information on their approach to including climate change in procurement and to view examples of good practice by others.

The first tasks of the project involved gathering and reviewing information to inform the development of the tool and guidance. The information gathered through these initial tasks was summarised in Interim Report 1. Interim Report 2 describes the development of the tools and guidance documents and how the pilot studies were carried out. This final report summarises the whole project and its findings. The detailed guidance and handbook for the tools are contained in the two guidance documents. This report is designed to provide a concise high-level overview of the project.

The risk assessment and cost-benefit tool is an online tool consisting of two modules. The risk assessment module enables users to identify the areas of their network with the highest risk for different types of failure referred to as damage pattern categories (DPC), for example heat related damages and restrictions on asphalt pavement. This is based on the hierarchical indicator method developed by the German RIVA project[1]. Climate, asset and effect indicators and indicator´s thresholds are defined for each DPC and are assigned a score (low, medium, high, very high) depending on data uploaded into the tool. These are then combined to provide each section of road or asset an overall risk score. The second module enables the costs of different adaptation strategies to be compared over an appraisal period. It uses information produced by the risk module to determine how likely a failure event is to occur and the lifespan of the asset and calculates the direct and indirect costs. The costs associated with three adaptation options are compared to the no adaptation scenario to enable the lowest cost option to be identified. This tool was piloted on road networks in Austria, Germany and Scotland. Climate data from CORDEX[2] and asset data from the relevant national road administrations (NRAs) was uploaded into the tool to test the functionality and usability of the tool.

The procurement collaboration platform has wiki functionality. Information and good practice examples have been uploaded into the tool as part of the DeTECToR project, but the aim is

[1] Korn, M., Leupold, A., Mayer, S., Kreienkamp, 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

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

for this to be added to by the CEDR members. This enables the NRAs to share approaches and experiences with each other; expanding the resource and keeping it up-to-date. The procurement tool was piloted with Norway, the Netherlands and Sweden. Interviews were held with the three NRAs and information on their sustainable procurement approaches were uploaded into the tool.

1 Introduction

DeTECToR (Decision-support Tools for Embedding Climate change Thinking on Roads) is part of the CEDR transnational research programme and was commissioned under the 2015 call for proposals 'Climate change: From desk to road'. The project addressed two key challenges facing National Road Administrations (NRAs) in relation to climate change; how to include climate change impacts in economic appraisal (topic A) and how to include climate change in their procurement processes (topic B). The project consortium consisted of TRL[3] (project co-ordinator), Alfen Consult[4], Heller Ingenieurgesellschaft[5], IBDiM[6], CEC[7] and AIT[8].

1.1 Project objectives

The overall objective of DeTECToR was to help National Road Administrations (NRAs) put into practice the latest climate change research and good practice. The project produced a number of decision support tools and guidance documents to enable NRAs to better integrate climate change considerations in economic and procurement decision-making:

- Summaries of relevant research projects, including recommendations and case studies describing how the findings and tools can be put into practice by NRAs;
- An economic decision-support tool that enables climate risk assessment and cost-benefit analysis of different climate change adaptation options;
- A guidance document on embedding climate change impacts into economic decision making, which also provides guidelines and case studies on the use of the economic tool;
- An online collaboration platform tool that will enable NRAs to share their approaches to including climate change in procurement and learn from each other's experiences; and
- A guidance document for embedding climate change mitigation and adaptation into NRA operations and procurement procedures, with guidelines and case studies on using the procurement tool.

1.2 Work packages

The project objectives were achieved through the seven work packages (WPs) shown in Figure 1. The WPs ran across the two topics being addressed, with some sub-tasks addressing specific aspects of topic A (economics) or B (embedment in operations and procurement). Project management and co-ordination was carried out under WP1, and WP7 focused on dissemination and implementation. There were five technical WPs:

[3] TRL - Transport Research Laboratory, UK, www.trl.co.uk
[4] Alfen Consult GmbH, Germany, www.alfen-consult.de
[5] Heller Ingenieurgesellschaft mbH, Germany, www.heller-ig.de
[6] IBDiM - Road and Bridge Research Institute, Poland, www.ibdim.edu.pl
[7] CEC – Climate & Environment Consulting Potsdam GmbH, Germany, http://www.cec-potsdam.de
[8] AIT - Austrian Institute Of Technology, Austria, www.ait.ac.at

- WP2 gathered all the information required to develop the tools and guidance. Activities included reviewing literature, determining stakeholder requirements and mapping out the data requirements.
- WP3 consisted of the development of the two decision-support tools, and was carried out concurrently with WP4.
- WP4 produced the two guidance documents to accompany the tools.
- WP5 applied the tools and guidance in a number of pilot studies, carried out in conjunction with NRAs.
- WP6 finalised the tools and guidance based on the feedback from the pilot studies.

Figure 1. Work package structure

1.3 Deliverables

The DeTECToR project team produced a number of deliverables as part of the project including software tools, guidance documents, project reports and dissemination material. The project deliverables are listed in **Table 1** with short description of their content. All the project deliverables can be downloaded from the DeTECToR project website https://detector.trl.co.uk/

Table 1. Description of DeTECToR deliverables

Deliverable	Description
	Project reports
Interim report 1	This project report summarises the results of the literature review and NRA survey. The research project summary sheets are provided as an appendix and they are also uploaded into the procurement tool). (Based on WP2)
Interim report 2	The second project report describes the development of the two tools and the pilot studies carried out with these. The six pilot studies are described in detail in the appendices. (Based on WP3,4 and 5)
Final report	The final report (this document) provides an overview of the project activities and summaries the project findings. (Based on WP 2-6)
	Software tools
Risk assessment and cost benefit analysis tool	A software tool consisting of two modules. The first enables the user to carry out a risk assessment on different asset types and for different types of climate hazard. The second enables them to assess the cost-benefits of different climate change adaptation measures over an appraisal period.
Procurement online collaboration platform	An online platform with wiki functionality that enables users to view information and good practice examples on including climate change on procurement and upload information on their own experiences.
	Guidance documents
Economic guidance document	This guidance document for NRAs is divided into two parts: • Part A provides information and good practice on including climate change in economic appraisal. • Part B is a handbook for the risk assessment and cost-benefit analysis tool developed by DeTECToR.
Procurement guidance document	This guidance document for NRAs is divided into two parts: • Part A provides information and good practice on including climate change in procurement. • Part B is a handbook for the procurement online collaboration platform developed by DeTECToR.
	Dissemination material
Project website, logo and flyer	A project website was created to provide information on the project and a place where the final deliverables can be downloaded.
TRA 2018 paper and presentation	A podium presentation on the DeTECToR project was given at TRA 2018 Vienna. The paper was published in the conference proceedings.
WCPAM presentation	A podium presentation was given at the World Conference on Pavement and Asset Management 2017 Italy.
EGU 2018 Poster	A poster was presented at the European Geosciences Union General Assembly 2018 in Vienna.
CEDR end of programme event	A project workshop was held at the CEDR end of programme event in 2018, Utrecht.

1.4 Report scope

This final report summarises the activities and findings of the DeTECToR project. The report is divided into the following sections:

Section 1 provides an introduction to the project and sets out the scope of the report.

Section 2 summaries the activities undertaken during the project.

Section 3 describes the project deliverables.

Section 4 describes the results of the pilot studies.

Section 5 summarises the project findings and how they can be implemented.

For more detailed information on a particular aspect of the project please refer to the relevant deliverable listed in Table 1.

2 Summary of project activities

2.1 Information gathering

Information to inform the development of the tools and guidance documents was gathered via a literature review and online survey. The information obtained was also used to produce summary sheets of key research projects as a resource for NRAs.

2.1.1 *Literature review*

Seven basic topics were identified to focus review activities in an effective and meaningful manner. These topics were:

- Impacts of climate change on roads
- Risk assessment methodologies
- Adaptation measures
- Actions to reduce carbon emissions
- Including climate change in road operations (including asset management)
- Including climate change in economic appraisal
- Including climate change in procurement

For each topic area a literature review was carried out of research projects, guidance documents and NRA examples of good practice.

2.1.2 *Summary sheets*

Key research projects relating to the topic areas were identified, and for these projects a Summary Sheet was produced. A template was developed to provide a consistent format for the sheets and to ensure all relevant points were covered. During this exercise 37 summary sheets were created covering completed and ongoing CEDR, FP7 and H2020 projects that address topics such as climate change adaptation, risk management, economic appraisal and environmental indicators. This detailed review allowed specific data/information to be identified which informed the development of the tools and guidance, as well as being a resource for NRAs. The approach taken was to specifically identify the key information relevant to the DeTECToR remit with special emphasis on information NRAs can apply to their practises and operational strategies.

The summary sheets are intended to provide a quick overview of best practices and case studies but also gather more specific information on:

- Data availability and sources
- Methodology
- Key deliverables and outputs
- Recommendations on how NRAs can use the project findings/ outputs
- Examples of the research being put into practice or pilot studies carried out as part of the project

They also include project details such as contact details for the coordinator, partners, programme, and duration of the project. The summary sheets can be found in the appendix of Interim Report 1 and are uploaded onto the procurement collaboration platform.

2.1.3 *Stakeholder survey*

A stakeholder survey was developed to provide:

- Information on NRA priorities regarding assets and their associated climate risks.

- An overview of data availability and use by the NRAs.
- The existing level of embedment in NRA operations and procurement processes.
- Examples of good practice.

The survey was designed to be concise (less than 10 minutes to complete), but also to provide quite specific information on a number of topics relevant to the project. It was developed in an electronic format to maximise the response rate and the link sent to over 100 contacts within NRAs, research organisations and other road climate change experts in Europe. The link was also put on the DeTECToR website and distributed through FEHRL and WRA Technical Committees.

In addition to the survey, a small number of telephone or in-person interviews were conducted with the following stakeholders:

- Polish National Road Administration GDDKiA
- Highways England Procurement Officer
- Trafikverket
- University of Cambridge PhD student

A total of 44 responses were received during the seven week online survey duration period. These came from 24 separate countries (22 European and two outside of Europe (USA and Australia)), with additional responses from separate regions within countries and different roles within NRAs. Details of the interviews and survey results are included in Interim Report 1.

The survey was designed for and targeted at NRAs; however, input from other organisations such as contractors, research institutions and consultants are also important. Responses by type of organisation are given in Figure 2. Around 76 percent of the responses were from the target responders; road administrations.

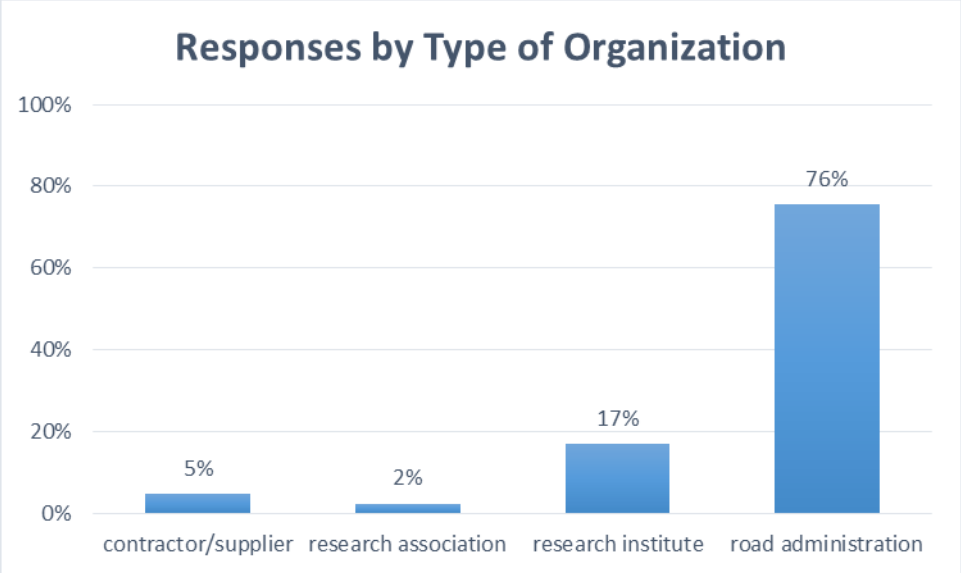

Figure 2. Responses by type of organisation surveyed

The survey responders were asked to identify the types of weather hazards which caused them most concern and which asset types were most affected. Six European climate types were defined and the survey results were reviewed in the context of these. A summary of the results is presented in Figure 3.

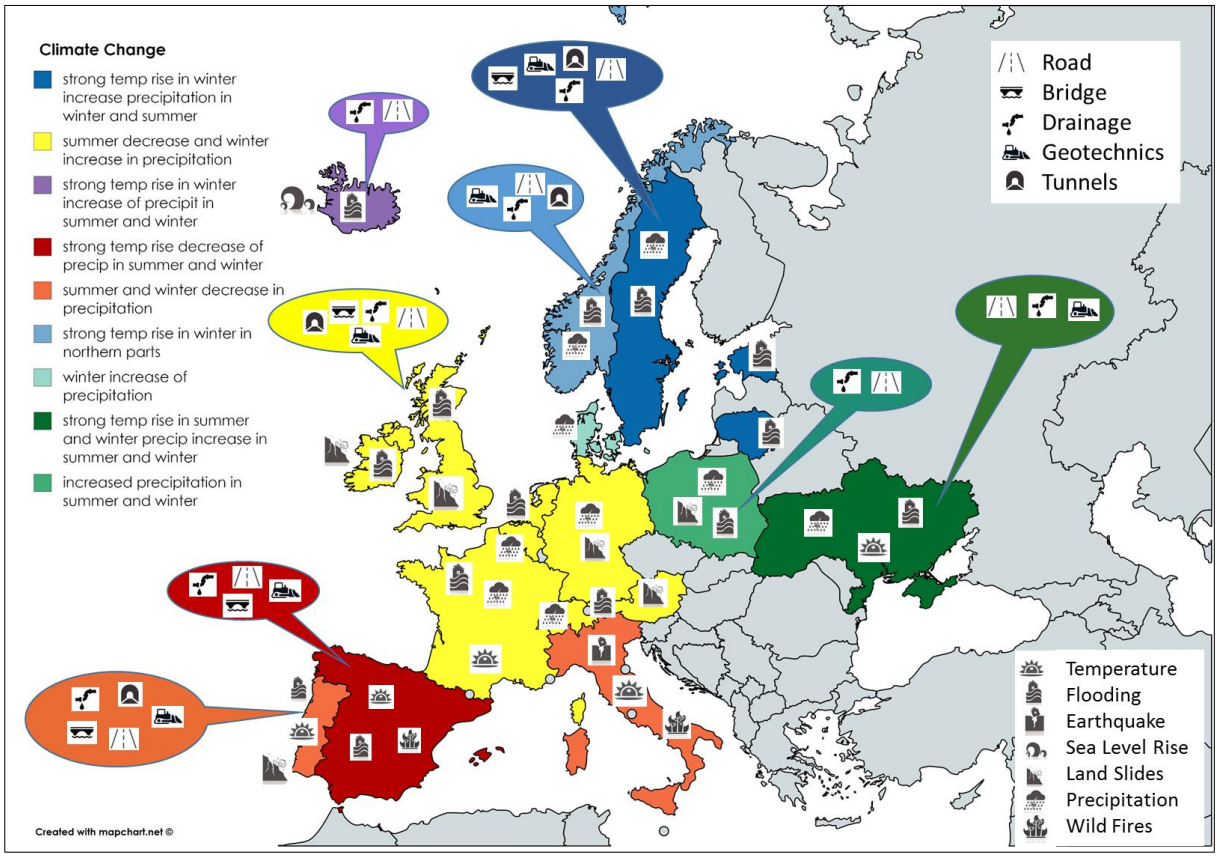

Figure 3. Climate change, asset and priority risks map by region

It can be seen that in southern, central and eastern Europe the major hazards include high temperature and wildfire, whereas in Scandinavia flooding and precipitation are the main priorities. The most vulnerable assets were reported to be drainage, pavements and geotechnics. Of those who responded to this question 84 percent identified drainage and pavements as vulnerable assets. The least vulnerable was pavement lane markings and ITS (5 percent). The major hazards for all assets were identified as flooding, storms, and precipitation, which are in line with the recent climatic changes observed and future projections for Europe.

The major weather hazards for each asset type are:

- Geotechnics – precipitation
- Tunnels – flooding
- Pavements – temperature
- Bridges – flooding
- Road furnishing and equipment and Intelligent Transport Systems (ITS) related equipment, static signs – storms
- Drainage – precipitation

2.2 Development of the tools

The goal of the DeTECToR project was to develop two sets of tools, the first one to help NRAs integrate climate change adaptation into economic decision-making process, and the second one to help them to include climate change in the procurement processes.

2.2.1 *Risk Assessment and Cost Benefit Analysis Tool*

2.2.1.1 Overview

The main goal of the Risk Assessment and Cost Benefit Analysis Tool is to put into practice the latest climate change research and guidance. It applies the findings from previous research projects such as RIVA and ROADAPT to provide information to help NRAs decide on the most cost-effective adaptation strategy for their network. The literature study carried out at the start of the project found that the majority of other projects evaluating climate change risk produced methodologies or guidelines. Those that did attempt analysis on actual assets carried out object based analysis (evaluating the effects of selected weather event(s) on selected assets). The Risk Assessment and Cost Benefit Analysis Tool works on the network level, evaluating all the various assets that NRAs are responsible for in their operations, and so is more directly applicable by an NRA. The development of a decision-support tool to help NRAs carry out their own risk assessments is a significant step forward.

A further objective of the Risk Assessment and Cost Benefit Analysis Tool is the calculation of direct and indirect costs as a result of the impacts of a specified weather event and on a particular asset type. This goes further than previous projects such as RIVA which focused on evaluating risk, but did not include adaptation actions or costs. A unique feature of the Risk Assessment and Cost Benefit Analysis Tool is the ability to compare the costs associated with different types of hazard, and importantly to be able to evaluate the impact different adaptation options could have on these costs.

In this context it is crucial to note, that the targeted users for the Risk Assessment and Cost Benefit Analysis Tool are road engineers within NRAs. The aim was to produce a tool which provides support in their day-to-day business processes. This means developing a tool which is "easy-to-use" is a major requirement for the system design, so the users can work with the tool in an effective way. A second major requirement is consistency of results, so that different options can be compared. The calculated adaptation action costs need to be comparable between all users of one NRA otherwise there is limited practical usage for the entire NRA organisation. Therefore there is a one configuration set for the whole NRA created and maintained by the Content Administrator. The configuration set defines the data and assumptions which the calculations of all users within the NRA are based on. While the internal calculations can be adjusted to different needs, doing so requires understanding of the engineering and climate considerations and may produce quite different results which are not comparable between the individual users of the system. It was deliberately decided to limit the access of the road engineers to the parameterisation of their calculations rather than providing them with the ability to modify the underlying assumptions. This both provides consistency between users and prevents the user being overwhelmed with all the internal details.

Risk Assessment and Cost Benefit Analysis Tool was built based on EVE platform. EVE is an open and flexible platform, developed by the project partner HELLER Ingenieurgesellschaft mbH, which combines existing data and services related to the road network. Various protocols are defined for this, e.g. for road networks, maps, profiles, alphanumeric data, images and documents (Figure 4). To be able to use and merge the data via EVE, the databases or services must implement these protocols. The implementation (the so-called endpoints) can be used in EVE-compatible clients.

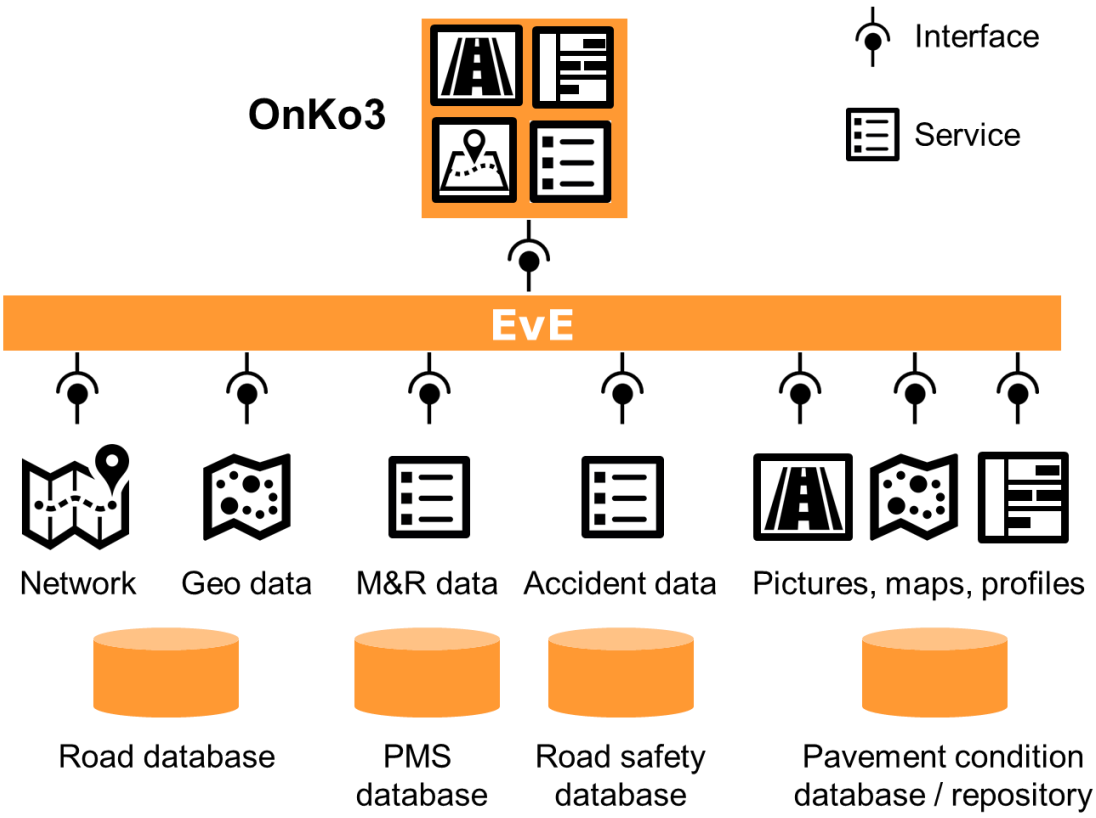

Figure 4: Architecture of the EVE platform

The application provided the following modules (see also Figure 5):

- **Risk Assessment Module**

  The Risk Assessment Module provides an assessment of climate change risks based on asset vulnerability, climate variables and the consequences of failure. This is calculated for damage pattern categories. This module enables the current and future risk levels for different road assets/hazard combinations to be compared regarding projected changes in climate.

- **Cost-Benefit Analysis Module**

  The Cost-Benefit Analysis Module calculates the costs (direct and indirect) for possible adaptation actions for a given asset object. Cost comparison between do-nothing scenario and adaptation actions is presented.

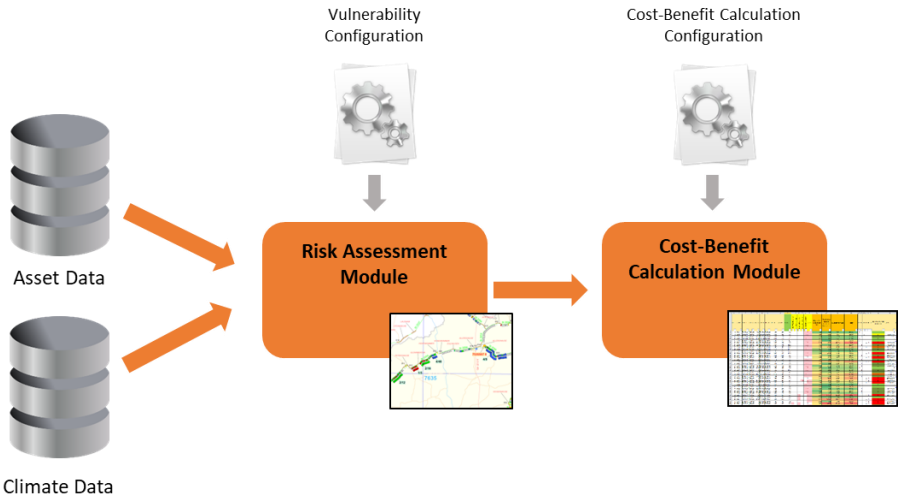

Figure 5: High-Level-Structure of Risk Assessment and Cost Benefit Analysis Tool

The Risk Assessment and Cost Benefit Analysis Tool was implemented as an interactive webpage with services implemented on the server side (Figure 6). The major and most important part of the graphical user interface is the interactive map. The results of calculations are displayed as an interactive selectable thematic layer. As background information, a layer based on OpenStreetMap-project is presented. This layer includes road network, location and names of cities, rivers and water areas, green areas and other additional information.

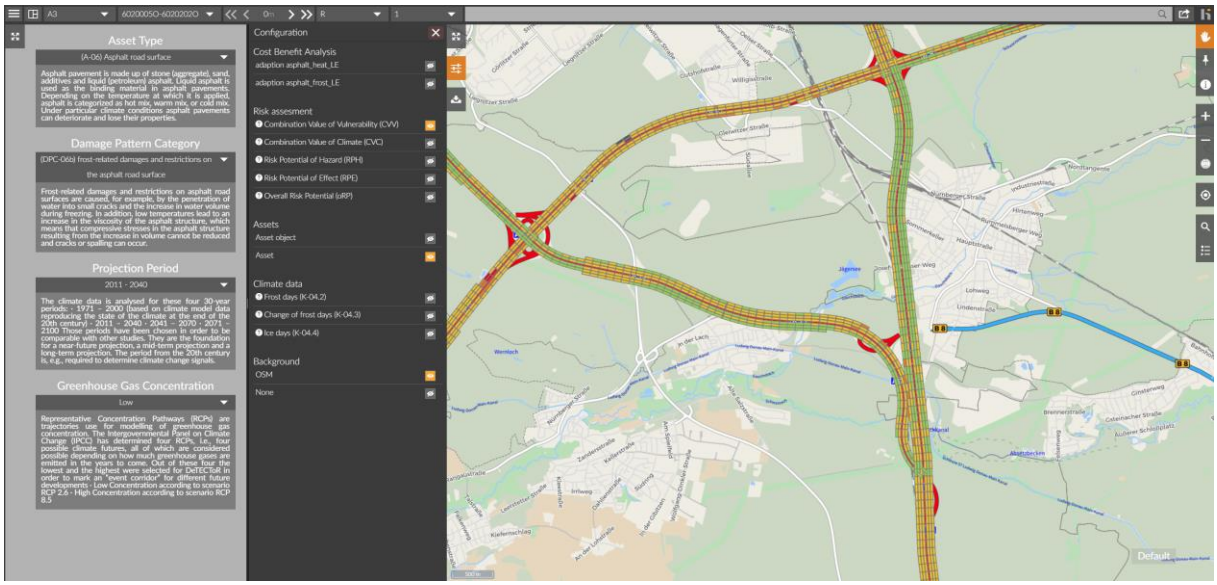

Figure 6: Main window of the Risk Assessment and Cost Benefit Analysis Tool

2.2.1.2 Functions

The Risk Assessment and Cost Benefit Analysis Tool provides various functions for data analysis.

Selection of analyses criteria

The User can select (see **Figure 7**):

- Asset type, e.g. asphalt pavement surface,
- Damage pattern category, e.g. heat-related damages and restrictions on the asphalt road surface,
- Time period (for climate projections), e.g. 2041 – 2070,
- Appraisal time period (for the cost benefit analysis)
- High or low greenhouse gas emissions scenario

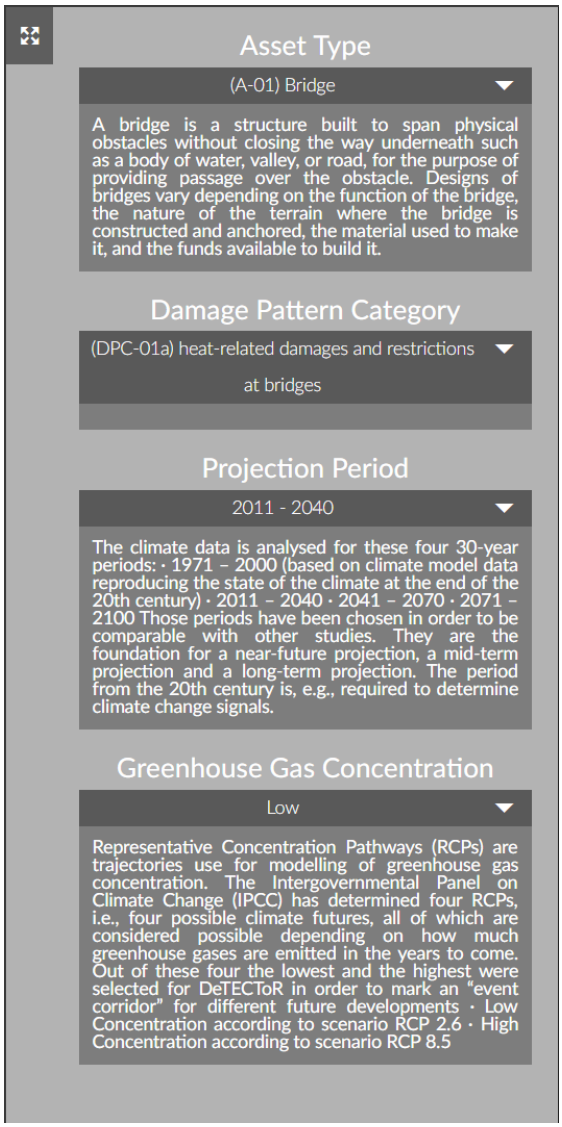

Figure 7: Window with selection of analysis criteria

Browsing of risk level

Depending on the selected analysis criteria and based on pre-calculated risk assessment the tool provides (see Figure 8):

- An interactive thematic layer with the calculated risk level for the selected asset type related to selected damage pattern category shown as a colour on the map,
- Objects show on the thematic layer will provide additional information such as location, road name, vulnerability factors and other relevant data.

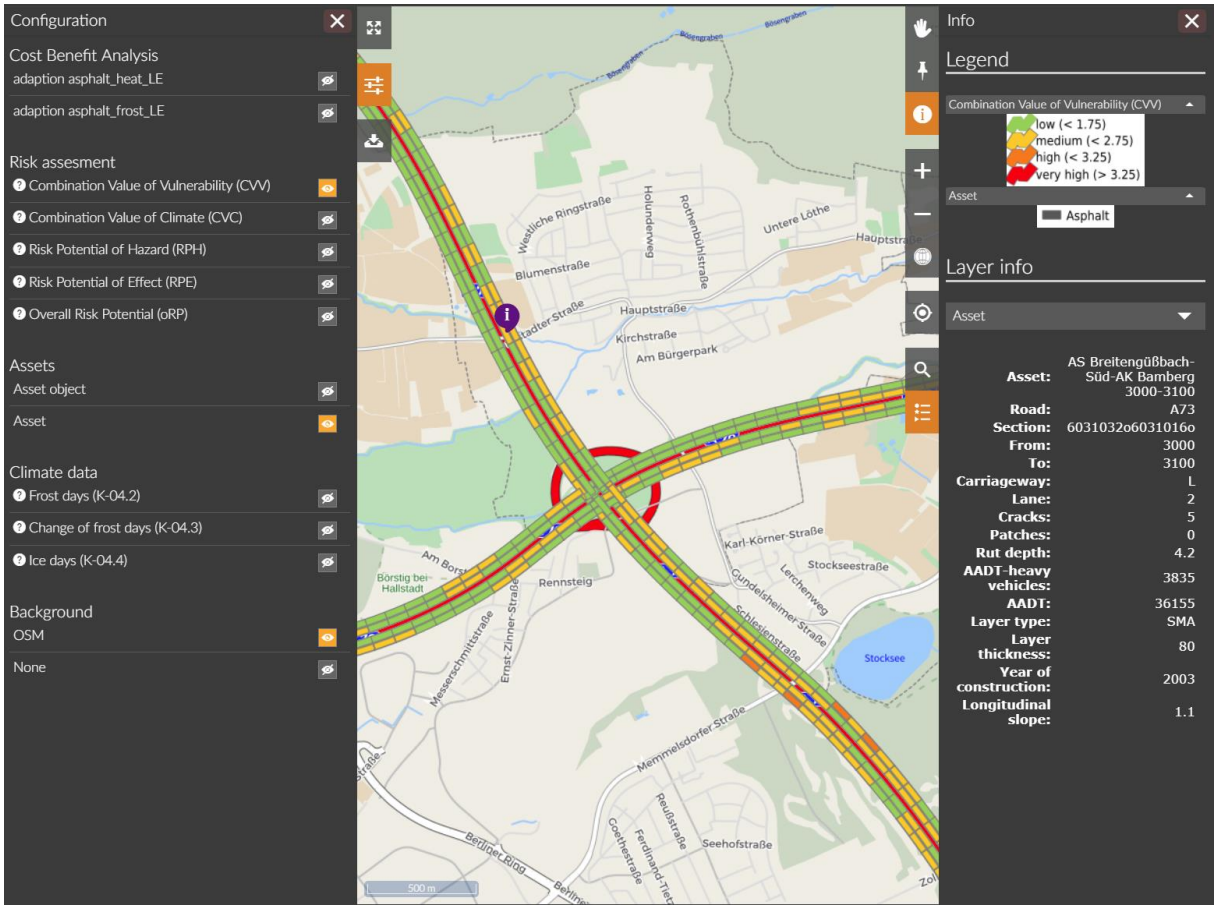

Figure 8: Browsing of risk level

Browsing of proposed adaptation measures

The user selects the relevant asset object on the map and the tool shows the results from the cost-benefit calculation of adaptation measures. Information such as location, adaptation measure type, costs, impact on relevant asset indicators are shown to the user. Three adaptation measures and the do- nothing scenario can by displayed for a selected asset (see Figure 9). The most cost-effective action is highlighted by colour in the map.

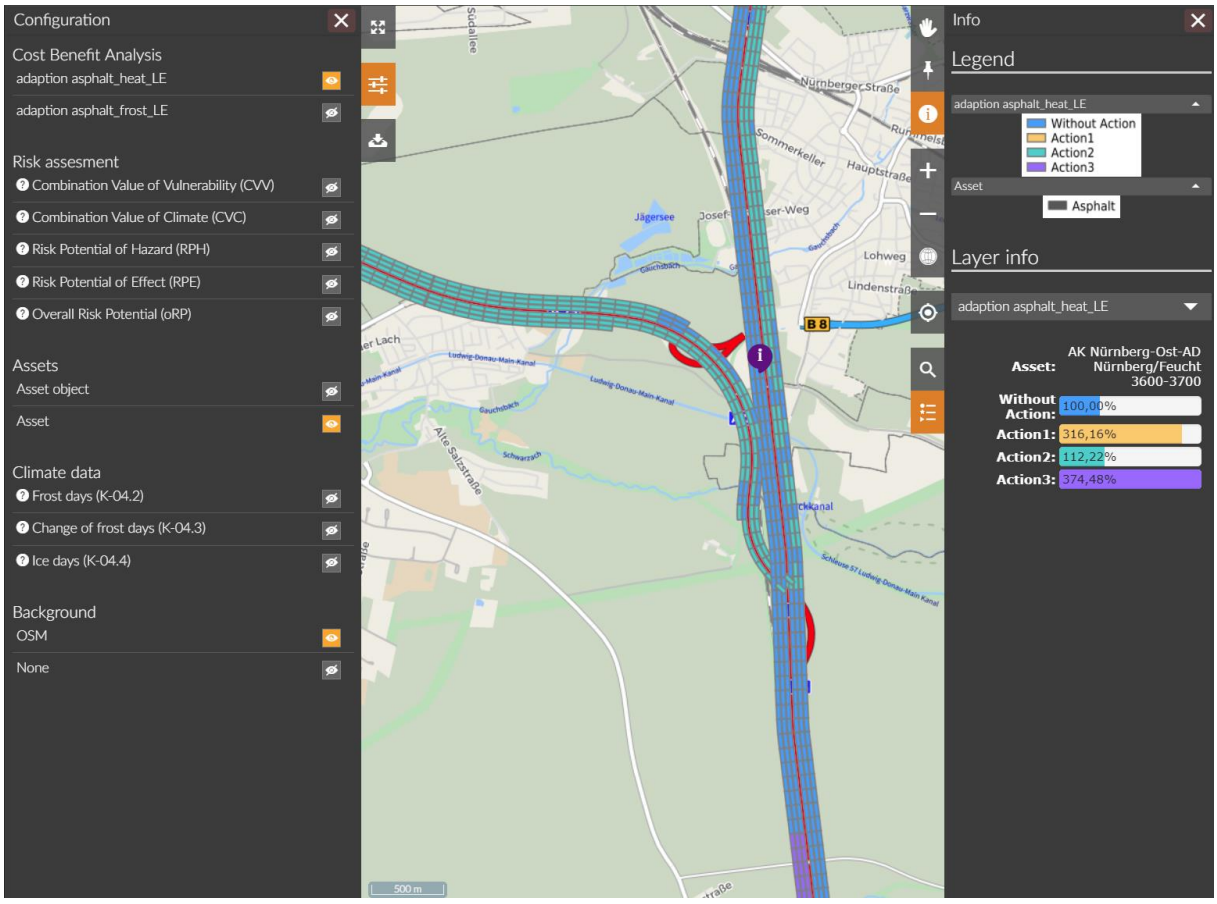

Figure 9: Browsing of proposed adaptation measures

Downloading of results

All the results produced by the web-based tool can be downloaded to a local computer, so the user is able to use the results for further analysis. The tool provides the results in commonly used formats like an Excel spreadsheet or SHAPE file.

Cost-Benefit Calculation

The adaptation action costs consist of two elements direct costs and indirect costs. The total cost over the analysis period is calculated based on the number of failures over the analysis period, the traffic flow, the delay time, number of accidents etc. Costs for the action “do nothing” scenario are calculated, together with costs for three adaptation actions. The user is able to set the calculation criteria as well as define unit prices, discount rates and other relevant criteria (see Figure 10) so that it reflects their own organisation’s requirements and experience.

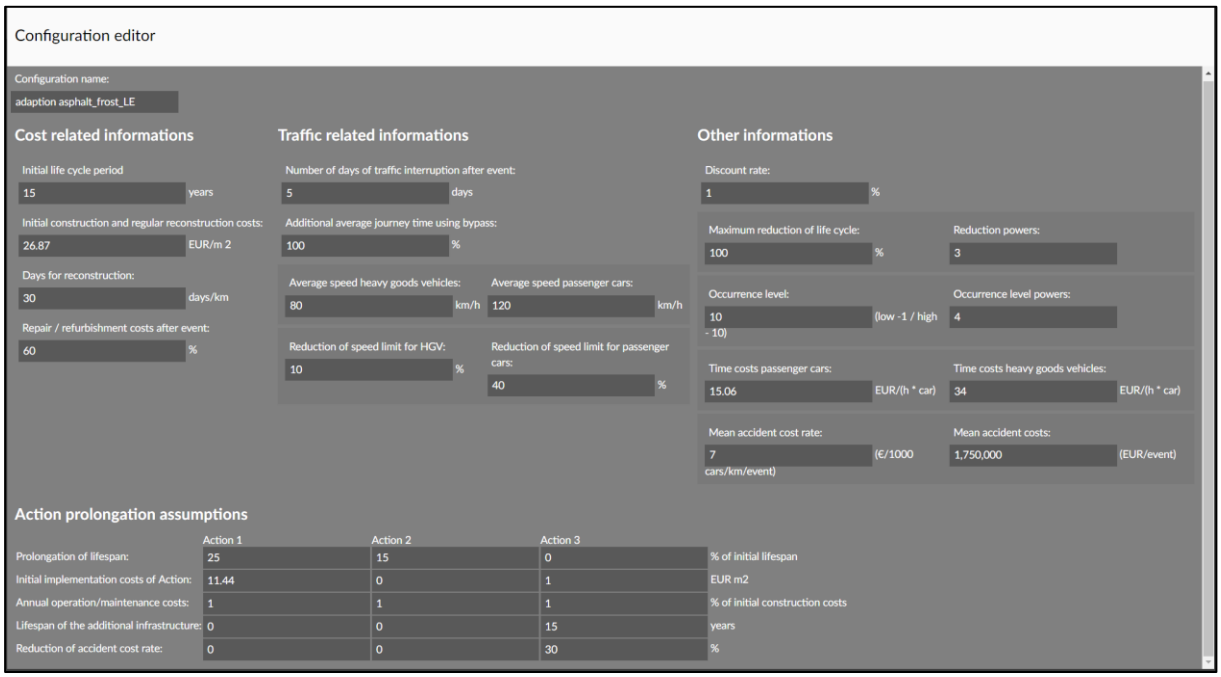

Figure 10: Settings for a Cost Benefit calculation

Browsing results of the Cost-Benefit Analysis calculation

The adaptation measures can be displayed on the map as an interactive thematic layer. The user can select an asset and the tool provides information such as the location, costs for possible adaptation actions and costs for the action “do nothing”.

The results from the Cost-Benefit Analysis calculation are downloadable as a spreadsheet.

2.2.2 *Procurement Collaboration Platform*

The Procurement Collaboration Platform provides NRAs with guidance and case studies related to embedding climate change in procurement and operational processes. The functional specification of this tool is based mainly on the stakeholder requirements identified at the DeTECToR workshop in Brussels. The major constraints related to the procurement tool expressed by the stakeholders were:

- The main goal of DeTECToR Procurement Collaboration Platform should be the enhancement of the collaboration between NRAs and sharing of experience and good practice between NRAs. This exchange is vital to progression in this area. The collaboration platform should enable NRAs access to a large knowledge database related to embedding climate change action into procurement processes.
- The tool should be focused on practical implementation and offer NRAs assistance in decision making processes. It may be necessary to consider the impact of procurement law and existing technical procedures on different procurement approaches.
- There is a large variation in the level to which climate change is embedded in NRA procurement processes. Some NRAs are quite advanced in their thinking, whereas others have not considered it at all. There will be different levels of ambition in address climate change therefore one approach will not be suitable for all NRAs.

The Procurement Collaboration Platform is a wiki-based tool to facilitate the exchange and collaboration of road administrations of different countries and to transfer knowledge. All users can add new topics or make changes in existing ones, upload images and insert external as well as internal links. However, it is not an open platform, but password-protected. All changes are traced and linked to the respective user. The main page contains a list of the content of the platform (see Figure 11).

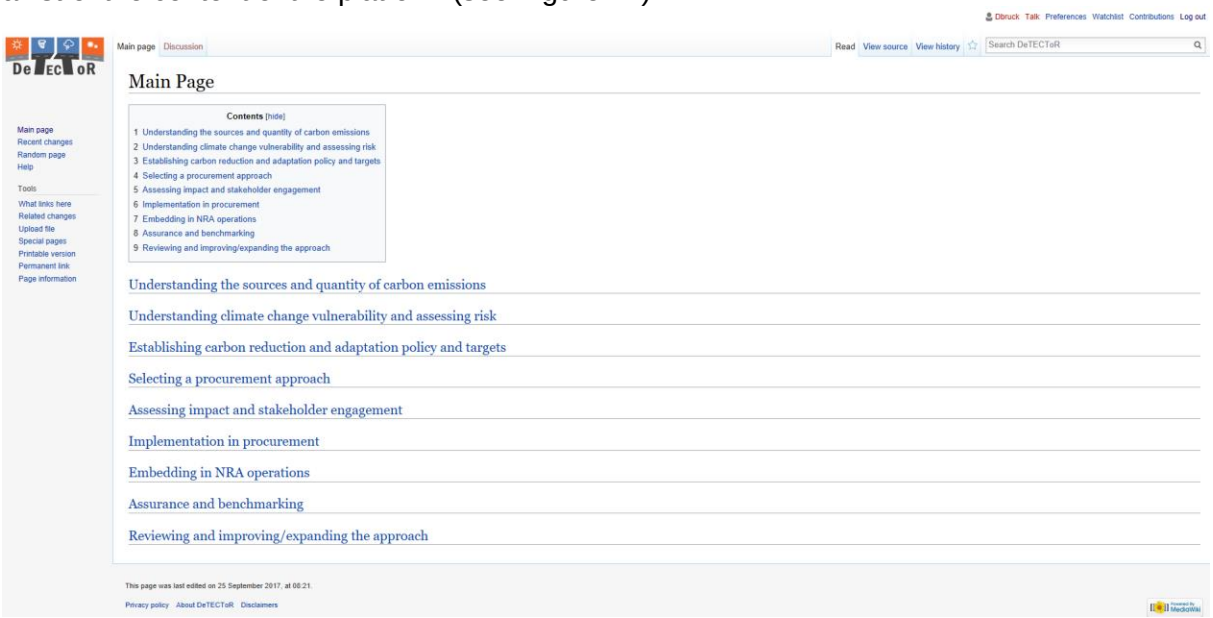

Figure 11 Main page of the procurement online platform

Essentially, the tool provides easy access to the required information. The user navigates through sections or can use a search function to obtain relevant information on different topics. This format provides flexibility and updatability so that the tool is useful for all NRAs, taking into account that levels of experience and ambition in this topic may differ greatly and are constantly changing.

The project has elaborated and implemented a Top Level Structure (TLS). The TLS was filled with initial content based on findings from the literature study and workshops with NRAs. Each section includes information on the different approaches that can be taken, recommendations on implementation and case studies from existing projects, literature and case studies developed in DeTECToR project illustrating the approach. It takes into account different types of procurement contracts, data availability and levels of ambition. Authorised users will be able to upload their own best practise case studies, indicating relevant categories such as which section it relates to.

The Procurement Collaboration Platform has been divided into nine sections, this Top Level Structure of guidance corresponding to areas of action for embedding climate change mitigation and adaptation into procurement and NRA operations:

1. **Understanding the sources and quantity of carbon emissions**
    - An introduction to the main sources of road carbon emissions and NRA influence on these
    - Descriptions of tools and methodologies that can be used by NRAs to identify and measure carbon emissions including findings from research projects such as CEREAL, LICCER and MIRAVEC (with links to summary sheets)

- A discussion on data sources (e.g. Environmental Product Declarations) and assurance
- Case studies: Examples of carbon tools being used in practice by NRAs and others such as Sweden's Klimatkalkyl and HE's carbon accounting tool
- Recommendations/key points for NRAs

2. Understanding climate change vulnerability and assessing risk

- An introduction to climate change impacts on roads and the need to assess risk
- Descriptions of tools and methodologies that can be used by NRAs to assess climate change risk including findings from research projects such as RIMAROCC and RIVA (links to summary sheets)
- Data sources for climate and asset data (e.g. CORDEX and NRA databases)
- Case studies: Examples of tools being used in practice by NRAs and others such as RIVA, HE's vulnerability index
- Recommendations/key points for NRAs

3. Establishing carbon reduction and adaptation policy and targets

- An introduction to international, European and national legislation, targets etc. and the impact of this on NRAs
- Types of NRA carbon reduction and adaptation policies and targets
- Discussion on what impact this has on operations e.g. in terms of carbon reduction and resilience, but also cost and quality
- Case studies: Examples of how NRAs have gone about developing different policies and targets e.g. Sweden's carbon targets, Highways England's adaptation framework
- Recommendations/key points for NRAs

4. Selecting a procurement approach

- An introduction to including carbon reduction and adaptation in procurement
- Description and comparison of different approaches such as setting project carbon targets, requiring suppliers to produce a carbon management or climate change adaptation plan, financial incentives for suppliers
- Potential barriers such as procurement laws, impact on SMEs, fear of increasing costs, organisational silos and culture
- Case studies: Examples of different approaches including the Swedish Klimatkalkyl, Dutch CO_2 ladder and GreenRoads
- Recommendations/key points for NRAs

5. Assessing impact and stakeholder engagement

- An introduction including why working with suppliers and other stakeholders is so important

- Discussion on different approaches of engaging stakeholders, workshops etc. and collaborative working
- Case studies: Examples of different approaches e.g. Sweden's impact study for their carbon tool
- Recommendations/key points for NRAs

6. Implementation in procurement

- Introduction to procurement types and stages of procurement
- Descriptions of approaches (including contract requirements, use of KPIs, schemes such as CEEQUAL, competition between suppliers, assurance) and reference to relevant projects such as SUNRA
- Inclusion in asset management
- Case studies: examples of implementation and results, e.g. was there an impact on cost includes Sweden and Dutch CO_2 ladder
- Recommendations/key points for NRAs

7. Embedding in NRA operations

- Introduction on embedding consideration of climate change mitigation and adaptation
- Inclusion in operations, asset management and economic appraisal
- Case studies: examples such as inclusion in standards and planning
- Recommendations/key points for NRAs

8. Assurance and benchmarking

- Introduction to the importance of assurance and the role of benchmarking
- Descriptions of approaches and reference to good practice guidance and standards
- Case studies: examples of implementation and results.
- Recommendations/key points for NRAs

9. Reviewing and improving/expanding the approach

- Introduction to need for review
- Descriptions of types of review
- Case studies: examples of how reviews and implications of carbon initiatives have been undertaking
- Recommendations/key points for NRAs

2.3 Development of the guidance documents

Each software tool has an accompanying guidance document consisting of two parts. The economic guidance document Part A provides information on including climate change in economic appraisal and covers topics such as the advantages and disadvantages of different types of economic appraisal, discount rates, appraisal periods, dealing with uncertainty and using climate projections. Part B provides information on the calculations and assumptions used in the risk assessment and CBA tool and guidance on its use including uploading data. Examples taken from the pilot study are used to illustrate how to use the tool and the format of the outputs produced.

In the procurement guidance document, Part A provides information on including climate change in procurement and operations and covers topics such as life cycle assessment tools, use of environmental product declarations and including carbon reduction targets in project specifications and contracts. The topics covered in the written guidance are reflected in the information uploaded into the procurement tool as initial content. Examples from the pilot studies (see Section 4.1) are included in the guidance document to illustrate different approaches. Part B of the document is a user manual for the collaboration platform. It includes examples taken from the pilot studies to illustrate how to upload and edit content. Part A of both the guidance documents are based on the literature review described in Section 2.1.1 and input from the pilot study NRAs.

2.4 Carrying out the pilot studies

The European road network is extremely diverse, comprising of different types of pavement, structures, geotechnics, drainage and communication equipment and passing through different combinations of climate, topography and geology. In order to ensure that the tools and guidance documents produced by DeTECToR are widely applicable to all of these, several pilot regions in different CEDR member countries were selected (see Table 2). The economic pilot studies were carried out in regions which are likely to face climate change impacts with different characteristics and emerging risk scenarios (e.g. alpine region, maritime region, main flatland areas). For the procurement pilot studies countries applying an innovative approach to including climate change mitigation and/or adaptation in procurement were selected in order to provide useful content for the online platform. The six pilot study countries are listed in Table 2.

Table 2. Overview of pilot regions for risk assessment or procurement

DeTECToR tool	Country	Participating NRA	Type of activity
Risk assessment and CBA tool	Austria	ASFINAG	Data collection
	Germany (Free State of Bavaria)	BASt, and Bavarian Ministry of housing, building and traffic	
	United Kingdom (south west Scotland)	Transport Scotland	
Procurement collaboration tool	Norway	Vegvesen	NRA interviews
	The Netherlands	Rijkswaterstaat	
	Sweden	Trafikverket	

As can be seen from Table 2, the risk assessment tool and the procurement collaboration tool differ in the type of work necessary to apply the tools. Since the risk assessment and CBA tool includes different asset types such as bridges, tunnels, road segments etc. collection of asset data is an integral part of the risk assessment tool, whereas the information required for the procurement tool was more qualitative and obtained from interviews with NRA staff.

Figure 12 shows the location of the pilot studies. The boxes for the three risk assessment and CBA tool pilot studies are the bounding boxes for the historic weather data and climate projection data sets. As the calculations needed rectangular grids which encompassed the whole pilot region and Austria and Bavaria are neighbouring there is some overlap.

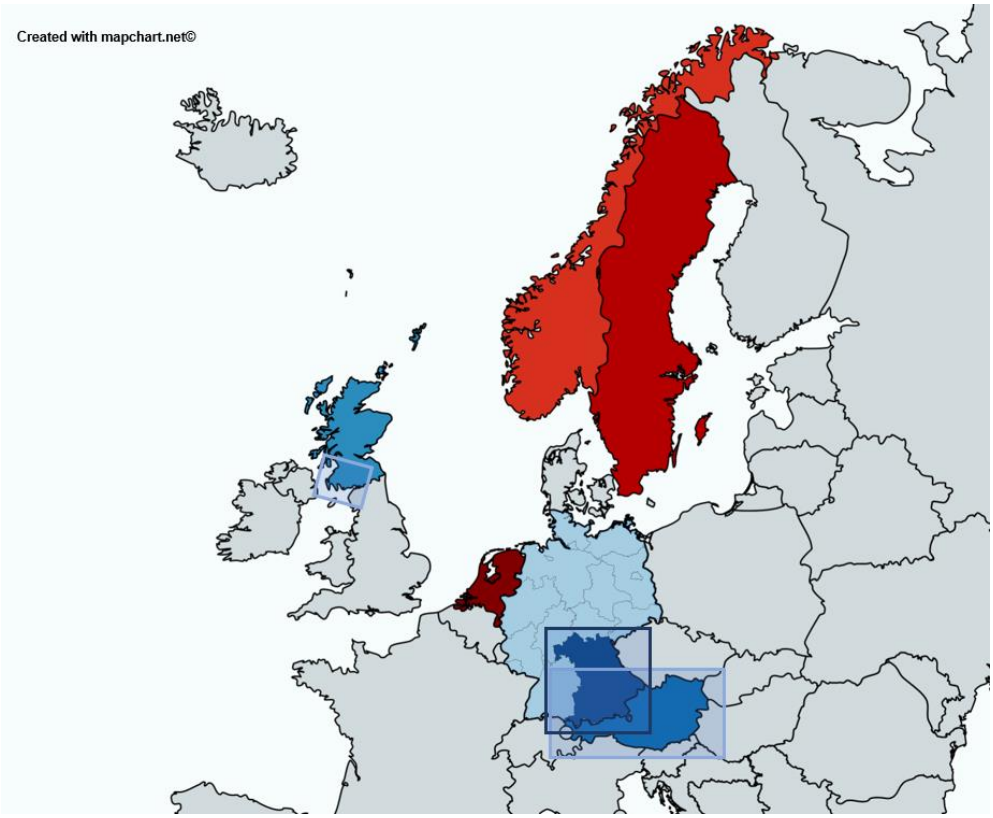

Figure 12. Location of the selected pilot studies: Blue denotes the risk assessment and CBA pilot studies and red the procurement pilot studies

2.4.1 *The risk assessment and CBA tool pilot studies*

2.4.1.1 Austrian pilot study

The Austrian primary road network features more than 2,200 km motorways and expressways maintained and operated by ASFINAG, the National Road Administration for highways. As can be seen from Figure 13 the Austrian pilot study consists of most of the existing motorways, except parts of the A10 (Tauern Autobahn) and S16 (Arlberg Schnellstraße) where data was missing.

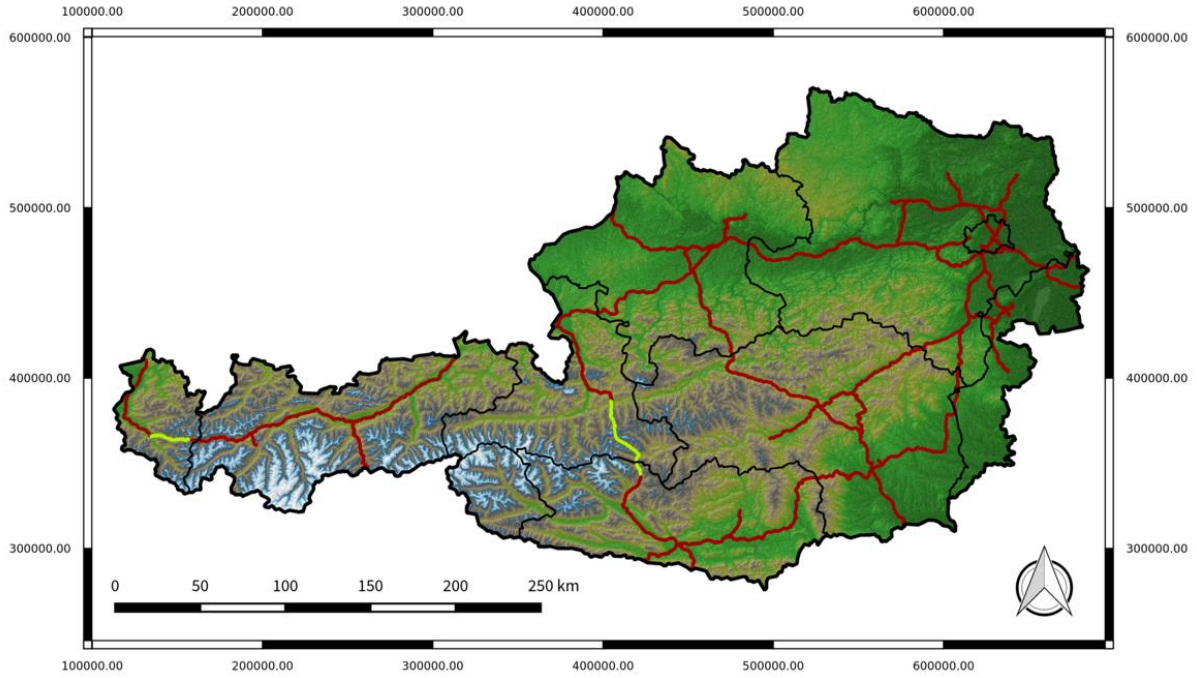

Figure 13. Overview of Austrian road network (red) participating in the pilot study

The following DPCs were selected for this pilot study:

- DPC-06a - Heat-related damages and restrictions on the asphalt road surface
- DPC-06b - Frost-related damages and restrictions on the asphalt road surface
- DPC-07a - Heat-related damages and restrictions on the concrete road surface
- DPC-07b - Frost-related damages and restrictions on the concrete road surface

2.4.1.2 German pilot study

The German motorway network comprises a total length of approximately 12,500 km. For the German pilot study, the area of the Federal State of Bavaria was selected for in-depth analysis of the effects of climate change on the road infrastructure (see Figure 14). The motorway Bavarian primary road network consists of almost 2,500 km of road with more than 3,500 bridges. Nearly 85 percent of the road surface consists of asphalt and 15 percent concrete pavement.

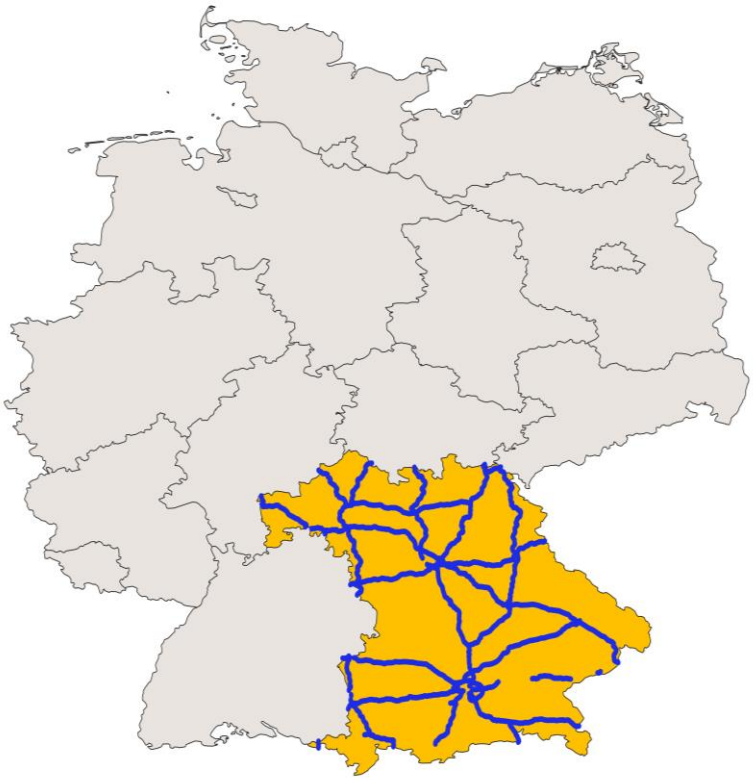

Figure 14. Overview of the Bavarian road network (blue) participating in the pilot study

The following DPCs were selected for the German pilot study:

- DPC-01a - Heat-related damages and restrictions at bridges
- DPC-01b - Frost-related damages and restrictions at bridges
- DPC-06a - Heat-related damages and restrictions on the asphalt road surface
- DPC-06b - Frost-related damages and restrictions on the asphalt road surface
- DPC-07a - Heat-related damages and restrictions on the concrete road surface
- DPC-07b - Frost-related damages and restrictions on the concrete road surface

2.4.1.3 Scottish pilot study

The Scottish trunk road network is 3,507 km in length encompassing busy motorways and less heavily trafficked rural A roads and traversing a diverse range of topography and climate. The network is managed and maintained by Transport Scotland an executive agency of the Scottish Government. It is divided into four main units, a separate unit for the Forth Bridge and three Design, Build, Finance and Operate units for the purposes of managing maintenance (see Figure 15).

The South West Unit (yellow) operated by Scotland TranServ was selected as a pilot region for the risk assessment and CBA tool as it suffers from a range of climate hazards which frequently cause damage and disruption including coastal flooding, landslides and storms with strong wind.

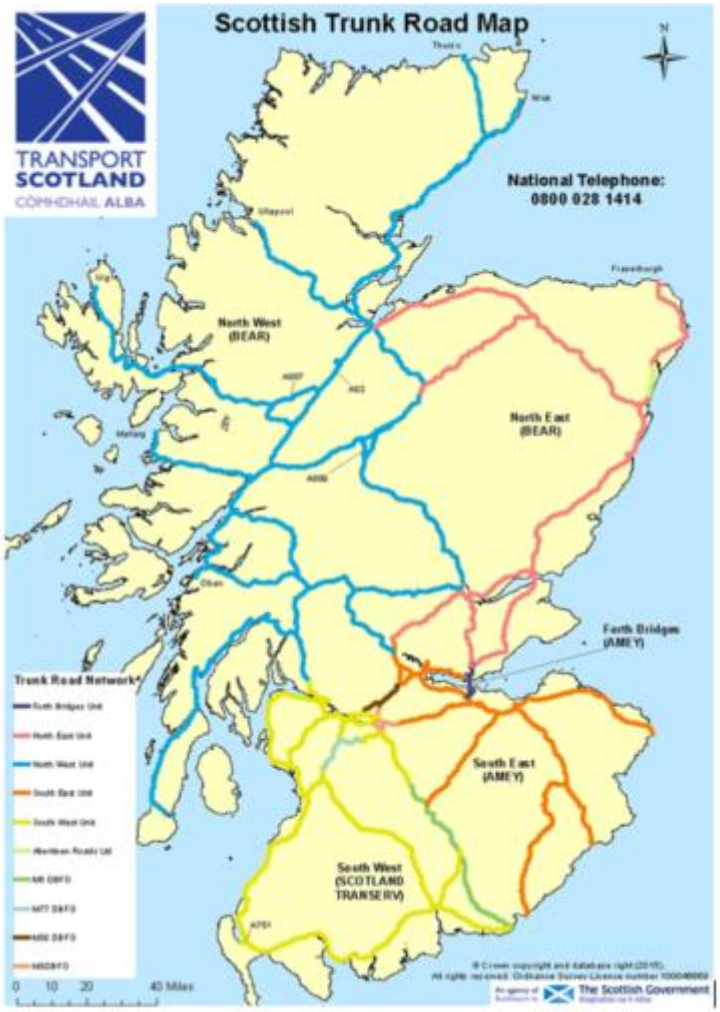

Figure 15. Map of the Scottish trunk road network

Asset data was collected for the 636km of road network which makes up the South West Unit (shown in yellow in the network map). There are no concrete roads within the pilot study regions. For the Scottish pilot study the DPCs to be included were initially:

- DPC-06b - Frost-related damages and restrictions on the asphalt road surface
- DPC-01e - Damage and restrictions at bridges due to storms
- DPC-12a - Damages and restrictions due to sea-level rise on asphalt

However, it was not possible to implement the new coastal flooding DPC within the pilot study due to time and budget restrictions.

2.4.1.4 Data preparation

The exact data requirements depend on which DPCs are being analysed. Asset and traffic data was provided by the pilot NRAs according to the region and DPCs selected for the case study. This included:

- AADT vehicles
- AADT heavy vehicles
- Material type (bridge)
- Static system of the bridge
- Overall bridge condition index

- Year of bridge construction
- Position (exposure)
- Longitudinal slope
- Cracks (note, Index)
- Surface layer type for asphalt pavement
- Age of surface layer
- Patches (percentage value)
- Thickness of asphalt or concrete layers
- Rut depth (value)
- Surface Condition Index for concrete pavement
- Patched spots (partial replacements with asphalt) for concrete pavement
- Surface area
- Section length
- Part of the TEN network
- Type of soil
- Urbanity
- Topography
- Number of lanes

The climate data was obtained from the European project called CORDEX. CORDEX is an unprecedented initiative to cover continent-wide areas concerning climate model data. This encompasses re-simulations of the current climate and climate projections with regional climate models. CORDEX relies on a unified grid that covers Europe and the contributing models are forced to produce their output on that grid. The resolution of the CORDEX grid is 10km. The following climate indicators were calculated:

- number of hot days per year
- number of summer days [d] per year
- number of [n] heat waves per year
- number of tropical nights per year
- maximum temperature within the period [Tmax in °C]
- maximum spread [K] TX and TN per year
- number of hot days with PR>20 mm (temperature drop)
- number of days with freeze thaw cycle [d] per year
- lowest temperature within period [Tmin in °C]
- number of frost days [d] per year
- change (%) number of frost days per year against 1971-2000
- number of Ice days [d] per year
- number of days [d] of the longest continuous frost period (TM < -5°C) per year
- number of days [d] with PR > 20 mm precipitation per year
- change [%] number of days with PR > 20 mm NS per year against 1971-2000
- sum precipitation [mm] within 5 days. Maximum within period.
- number of days [d] with PR > 10 mm precipitation per year
- sum [mm] PR precipitations hN per year
- change [%] Sum PR precipitations hN per year against 1971-2000
- number of potential snow days [d] (days with precipitation and daily mean temperature ≤ 2°C) per year
- number of [n] events per year where strong rainfalls occurs after long dry period [n]

All the data is stored in a geospatial database.

2.4.1.5 Configuration

Both functional modules (the Risk Assessment and Cost-Benefit modules) are fully configurable. The calculation algorithms are stored in configuration files. This enables the designated NRA Configuration Provider (see Section 2.2.1) to undertake adjustments in the calculations to tailor the tool to their network if desired. Configuration is stored in a form of structured plain text document (please refer to Figure 16).

The project provides the basic configuration for all three pilot studies. The risk assessment approach was based mainly on the RIVA project; however during the pilot studies the configurations were developed based on NRA feedback, and tailored to the type of network and focus of the individual pilot studies.

```
Node "Asphalt road surface" (asphalt_road_surface) {
    property: [
        1 "Cracks (IT-ZEB ZWRISS)" (cracks, .Any)
        1 "Tendency (IT-ZEB)" (tendency, .Any)
        1 "Rut depth (IT-ZEB MSPT)" (rut_depth, .Any)
        1 "Type of the layer (construction data)" (type_of_the_layer, .Any)
            1 "Layer thickness (construction data)" (layer thickness, .Any)
        1 "AADT-heavy vehicles (road traffic count)" (aadt heavy vehicles, .Integer)
            1 "Number of lanes (per lane)" (number_of_lanes, .Integer)
            1 "Age (construction data)" (age, .Any)
            1 "Condition (from SIB)" (condition, .Any)
            1 "Mends (IT-ZEB FLI)" (mends, .Any)
            1 "Surface layer thickness (construction data)" (surface layer thickness,
.Any)
            1 "Position (derived from flood risk maps)" (position, .String)
            1 "Type of Drainage (currently no data)" (type_of_drainage, .String)
            1 "Embankment (currently no data)" (embankment, .String)
            1 "Number of twisting area (currently no data)" (number_of_twisting_area,
.Any)
    ]
}

Node "06a - Asphalt road surface - heat-related damages and restrictions on the asphalt
road surface" (dpc 06a) {
    property: [
        1 "Value" (Value, .Double)
    ]
}
Rules For dpc_06_aadt_heavy_vehicles Through firstCalculatedGate("Value") [

    ```lua

            value = ${asphalt_road_surface}.aadt_heavy_vehicles

            if value < 4000 then
                    return 1
            elseif 4000 <= value and value < 9000 then
                    return 2
            elseif 9000 <= value and value < 12000 then
                    return 3
            elseif 12000 <= value then
                    return 4
            else
                    error ("Invalid key value")
            end

    ```
]
Rules For dpc_06_type_of_the_layer Through firstCalculatedGate("Value") [
    ```lua
            value = ${asphalt road surface}.type of the layer

            if (value == "PA" or value == "MA" or value == "GA" or value == "OPA") then
                    return 2
            elseif (value == "SMA" or value == "AC" or value == "AB") then
                    return 3
```
```

```
                else
                        error ("Invalid key value")
                end

    ```
]
```

Figure 16: Example of configuration script

2.4.1.6 Pre-calculation

Due to the amount of related data, the calculation of risk level and relevant adaptation action can take some time. From a user experience point of view, it was necessary to do the calculations only once, i.e. after importing the data. Additionally, the pre-calculation before the main analysis guarantees the consistency of the results.

2.4.2 *Procurement pilot studies*

Three countries that are applying an innovative approach to including climate change mitigation and/or adaptation in procurement were selected as pilot studies for the procurement tool in order to provide useful case studies. These were:

- Norway, Vegvesen
- The Netherlands, Rijkswaterstaat
- Sweden, Trafikverket

Sweden was chosen because of Trafiverket (the Swedish Transport Administration)'s novel approach to including carbon emission reductions into its procurement process using its bespoke tool Klimatkalkyl. Sweden also has experience with climate change adaptation actions (The Swedish Transport Administration's Strategy for Climate Change Adaptation, 2014). Trafikverket is responsible for the long-term planning of all transport modes and the construction, operation and maintenance of state road and railways.

Norway was chosen as a pilot study country for procurement because of its experience with embedding carbon emission reductions into the Norwegian procurement process as well as because of its experience with risk assessment and adaptation in the context of climate change. Vegvesen, the Norwegian Public Road Administration (NPRA), is responsible for managing and maintaining the national and county roads in Norway. The National Road Network has a length of approximately 10,500 km.

The Netherlands pilot study was based on interviews and information provided by Rijkswaterstaat (RWS). The Netherlands is a densely populated country with a temperate maritime climate and low lying land. Rijkswaterstaat (RWS), part of the Ministry of Infrastructure and Water Management, carries out the construction and management of the Dutch national road network and main waterways. It maintains over 3,100 km of roads together with tunnels, bridges and other road assets.

Several members of staff from the Swedish, Norwegian and Dutch NRAs were interviewed via teleconference by members of the DeTECToR team. Before carrying out the interviews a list of questions were prepared relating to the different top level sections in the online procurement tool. These questions were circulated to the interviewees before the interview. Different people were responsible for climate change adaptation and mitigation so several interviews per NRA were carried out. The interviewees also provide additional written information such as presentations, reports, strategy documents and guidance which were linked to in the platform (not all of these were in English).
```

In addition to the interviews the project coordinator attended a workshop on sustainable procurement hosted by the Swedish NRA in Stockholm in February 2018. This workshop took the form of the Dutch and Swedish road and rail administrations sharing their approaches to including sustainability and carbon reduction in procurement. Attendance of the workshop provided additional information on two of the three pilot study countries and contacts for the interviews.

3 Overview of the DeTECToR tools and guidance

An overview of the tools and guidance produced by the project are provided in this section. For more detailed information on how the tools were produced please refer to Interim Report 2, for instructions on how to use the tools please refer to the relevant guidance document.

3.1 Risk assessment and cost benefit tool and economic guidance

The risk assessment and cost benefit tool is a web-based GIS analysis tool. The tool enables NRAs to conduct a network wide risk assessment in the context of climate change and compare the costs associated with different climate change adaptation measures.

The tool consists of two modules; the risk assessment module which provides information on the level of risk for different time periods and emission scenarios; and the CBA module which compares the costs of different adaptation options and a "no adaptation" option.

The risk module uses the theoretical concept of the RIVA-methodology; a hierarchical-structured indicator model using a series of indicators to ascertain climate risk. The methodology, selected based on a literature review of risk assessment methodologies, builds on the approach developed in CEDR projects RIMAROCCA and ROADAPT. The risk potential is analysed as a function of cause (potential of hazards) and effect (potential of impacts). These are based on complex cause-effect chains (CEC), which were used in the RIVA-project for the systematic description of typically damage / restrictions caused by the climate. Furthermore, the CECs are the basis for the determination of so called damage(s)-patterns categories (DPC); the main unit of measurement of RIVA methodology

Within the CBA module direct costs and indirect costs are calculated over an appraisal period. Benefits are expressed as a reduction in costs. The variation in costs incurred within different climate scenarios can be explored and the module enables the comparison of impact of different climate change adaptation options/measures being employed. The optimal solution in terms of cost-benefit analysis is the one with the lowest sum of direct and indirect costs over the appraisal period. The calculation uses the risk potential of hazard calculated in the risk module as an indicator of the frequency of hazard occurrence and the cost information and criteria provided by the NRA.

It should be noted that the CBA module will provide indicative costs for the specified options selected by the user. A significant number of assumptions and estimations are made in the calculations, so the results cannot be taken as an accurate costing.

This tool was trialled on three pilot regions using selected damage pattern categories as part of the project (see Section **Error! Reference source not found.**). The data relating to the three pilot regions was uploaded into the tool and a series of analysis run. Figure 17 is a screenshot of the CBA module showing the results from the Free State of Bavaria.

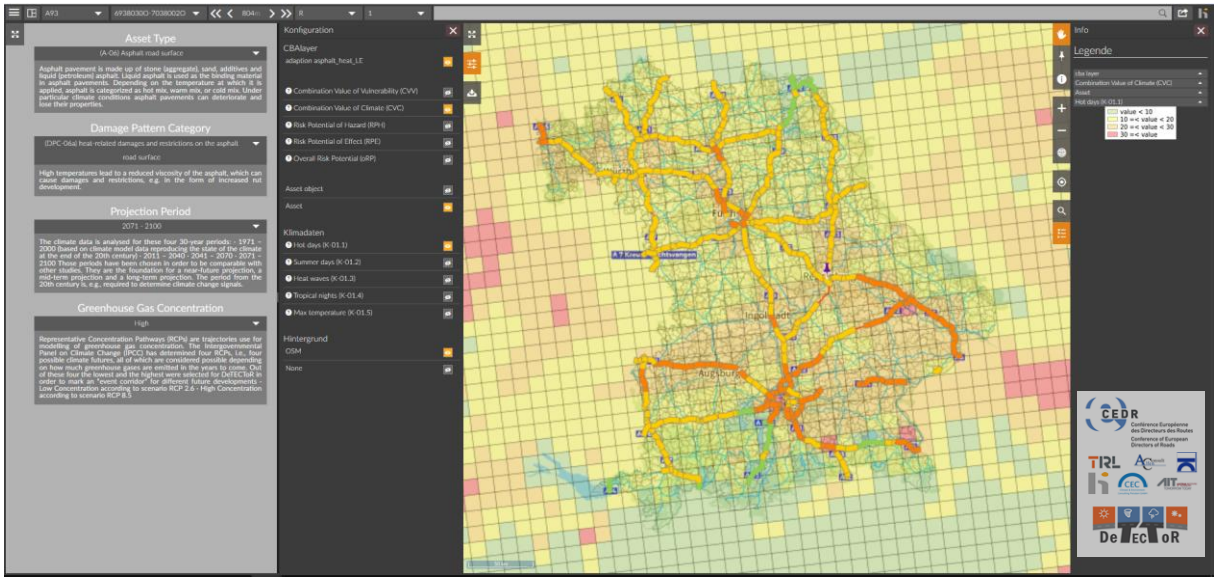

Figure 17: Screenshot of the DeTECToR risk assessment and CBA tool. CBA results from the Free State of Bavaria, one of three pilot regions are shown.

As can be seen in Figure 17, the tool user interface is divided in a number of areas. The central area is the GIS-based map where the results of the calculation are displayed graphically on a network map. On the left site the user can select the asset type, the damage pattern category, the climate projection period and the emission scenario underlying the climate projection. Also on the left hand site of the map, the user can select which layer is displayed in the map. The user can select different climate indicators (depending on the previously selection of asset and DPC), or different calculated values (CVV, CVC, RPH, RPE, oRP). The right site provides the user with more detailed information such as the exact calculated value of a selected section/point on the map (the colours on the network map depict a range over an assessment area).

Part B of the economic guidance document contains further information on the methodology and assumptions used in the tool calculations. It also provides a step-by-step guide to using the tool. The appendices of the guidance document include information on the adjustment of the indicators and their thresholds and the data sources used for the CBA input data. The tool's default values are adopted from the RIVA-project so relate to Germany. Using the information provided in the guidance document NRAs can redefine indicators or thresholds their values differ from the defaults or if a type of input data is not available.

3.2 Procurement collaboration platform and procurement guidance

The procurement collaboration platform was created to enable NRAs exchange procurement related information and experience and to educate NRAs who are less advanced in embedding climate change related requirements and processes into procurement. The platform provides guidance on how to conduct embedment of climate change into procurement based on state of the art literature review and real examples of implementation carried out by the three procurement pilot study countries - Sweden, Netherland, and Norway. The procurement tool was created to meet the following general objectives:

- Provide an avenue for sharing good practice among NRAs
- Provide information on relevant research projects and NRAs practices related to embedding climate change into procurement and operations

- To be collaborative: enabling NRAs to include their own information and share their experience with others
- To be a learning platform for those NRAs who are less mature in the subject
- To be an intuitive and user friendly tool

The procurement online platform is a wiki-based tool to encourage collaboration between road administrations in different countries and to facilitate knowledge transfer. All users (based on NRAs preferences regarding access) can add new topics or make changes in existing ones, upload images and insert external as well as internal links. However, it is not an open platform, but password-protected. All changes are traced and linked to the respective user. The main page contains a list of the content of the platform (see Figure 18).

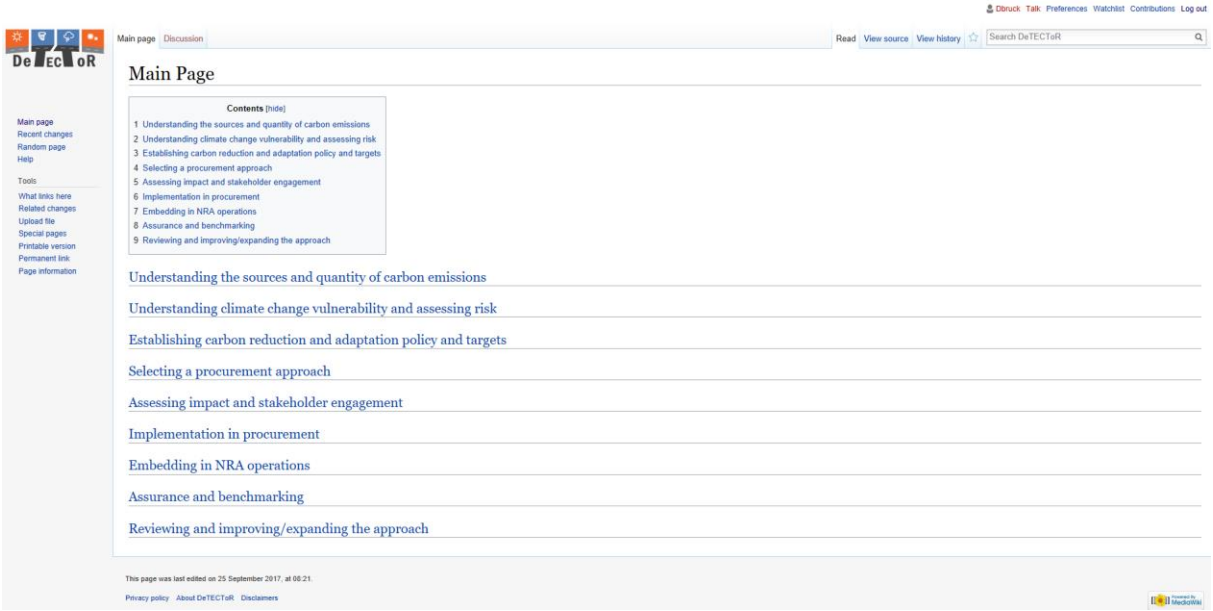

Figure 18. Main page of the procurement online platform

To edit an existing topic, the user first clicks on the topic of interest and thereafter on the "Edit" button on the right. To add new content to the platform, the user clicks on the button "Discussion" and simply starts writing into the box showing up (see Figure 19). The main topics (titles) in the top level structure will not be editable to keep the platform focused on the subject. If users decide to add new topics it would need to be done by the site administrator.

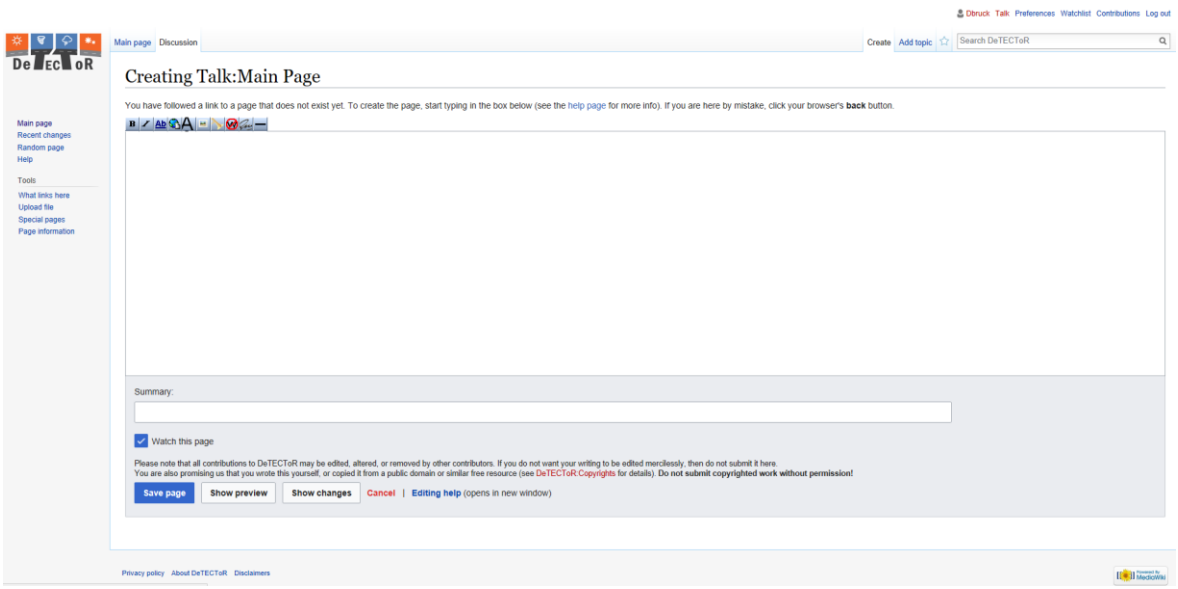

Figure 19. Adding new content to the procurement online platform

Procurement guidance is given in detail in the deliverable: *Final guidance on embedding climate change into operations and procurement*. However some high level points on procurement are summarised below.

Sharing good practice: A stronger mechanism is needed for sharing knowledge. Contracting authorities should make best use of the full range of public sector networks on climate change and procurement, including collaborative procurement opportunities. NRAs should seek and share good practice case studies. This should include examples of specifications and evaluations, and capture the full range of adaptation measures (i.e. not just design features, but end-user behaviour measures too).

Guidance and support: There is a need to develop a programme of support for NRAs on sustainable procurement. This is expected to include workshops, training, good practice examples and access to expert panels. It is important that climate change adaptation is fully integrated into this. Guidance needs to be made available about the different ways in which climate change adaptation can be embedded in the procurement process. This should include the importance of the specification and evaluation criteria, investment in skills to manage the process and recruitment of an expert evaluation panel. Guidance could also be explored on how to best distribute risk between the NRAs and contractors and how contracting authorities should reflect their risk acceptance in the procurement process.

Engage the contractors: NRAs should include climate change adaptation in the vision for the project from the outset. In many contracting authorities this means raising awareness and training people in service directorates that adaptation needs to be a core principle, rather than an “add-on” by the central procurement team at a later stage. NRAs then need to develop clear objectives (in consultation with the contractors market), benchmarks and indicators, and communicate this to stakeholders and potential bidders. Adaptation should be written into procurement documents and contracts.

Define and apply the vision: NRAs need to engage the market early and openly to develop a shared understanding with bidders. The market needs to know the authority is serious about adaptation by weighting the evaluation criteria such that it is a significant part of the project. NRAs need to be open to challenge and ready to enter dialogue about relative priorities (e.g. in striking a balance between carbon management and adaptation). Detailed

specifications can be overly prescriptive; instead the market should be allowed to innovate based on the contracting authority's defined outcomes.

Long term thinking: NRAs should consider the impacts of climate change on the design and operations over the estimated lifetime of the project (whole life cycle), taking account of potential future refurbishment and changes of use, not just the initial length of the contract.

4 Pilot study findings

4.1 The risk assessment and CBA tool

4.1.1 *Data collection and upload*

The relevant data-sets held by the NRAs (e.g. in their various asset management systems) were queried and the requested data provided to the DeTECToR team. The data sets received often had different formats, content and value ranges, so where necessary adjustment of the indicators or indicator thresholds were made in cooperation with the NRA. Data sets were often held by different groups within the NRA organisation and multiple discussions with different roles was required.

4.1.2 *Results*

The results of the analysis were in line with what was expected in terms of sense checking. For example the Risk Potential of Hazard of heat related damages and restrictions on the road infrastructure (e.g. bridges and road surfaces) for the projection period 2071 – 2100 increased compared to 2010 – 2040 and for high emissions compared to low emissions. Figure 20 shows the results of the CVC calculation for Bavaria for projection periods 2010 – 2040, low emissions and 2071 – 2100 high emissions in Bavaria. The change in the number of hot days (denoted by the coloured grids), one of the climate indicators feeding into the CVC, can be seen together with the subsequent increase in CVC. The comparison of the two maps shows sections of the road with a medium CVC becoming high CVC and those at low CVC moving to medium CVC. Figure 21 shows the RPH for the same scenario.

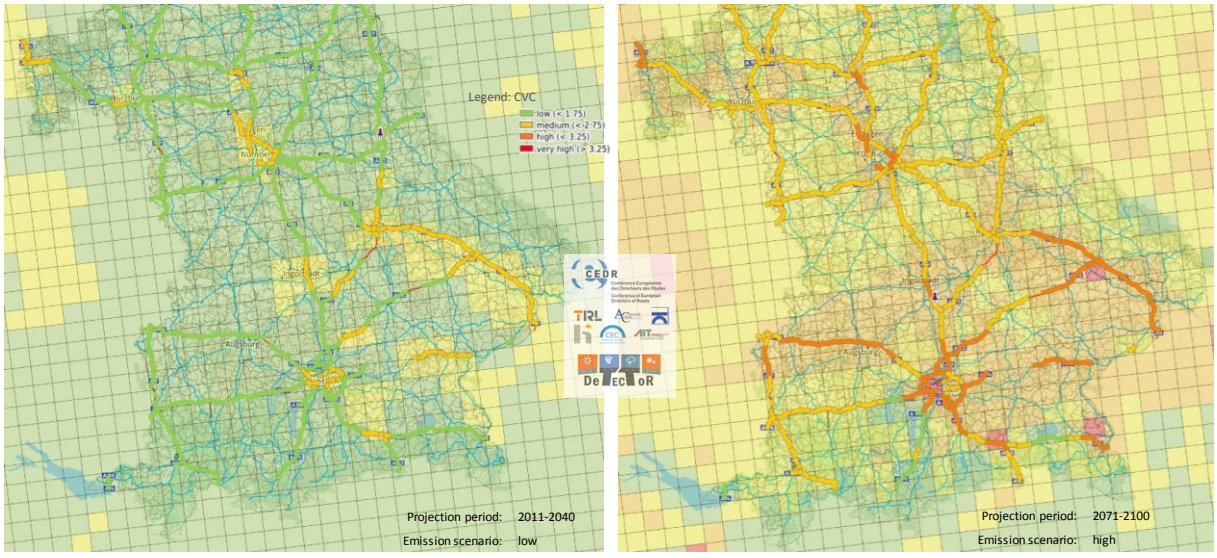

Figure 20: CVC-calculation result for the Free State of Bavaria (heat related damages and restrictions on asphalt road surfaces), number of hot days as underlying map

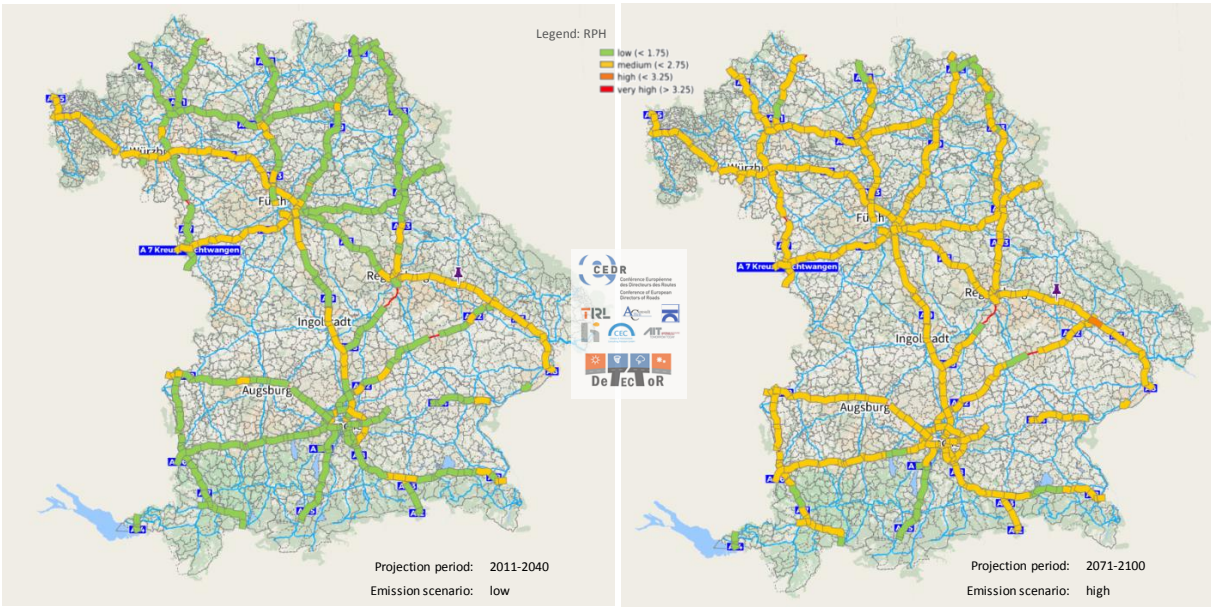

Figure 21: RPH-calculation result, map view network wide (heat related damages and restrictions on asphalt road surfaces), Free State of Bavaria

Generally, the used approach is able to identify sections in network with high Risk Potentials of Hazard in relation to the damage pattern category being considered. The comparative analysis of the results for the individual climate projection periods also allows an assessment of the influence and sensitivity of the (projected) climate change in the future. In addition, by considering the Risk Potential of Effect, the sections of the network on which there is a higher overall Risk Potential regarding the selected hazard can be identified.

4.2 The procurement collaboration platform

A summary of the findings from the three procurement pilot studies are provided here; more detail is available in the Appendices in Interim Report 2.

4.2.1 *Norway*

NPRA are embedding climate change adaptation in daily operations in various ways, but it is currently not explicitly included in their procurement processes (e.g. tender specifications and evaluation). However they have included it in design standards, planning (via EIA) and are carrying out a risk assessment of their network. At the start of each maintenance contract and annually the risk assessment is reviewed with the contractor, updated and any mitigation measures to be implemented are agreed.

Currently NPRA do not have any consistently implemented mechanisms to reduce carbon through procurement, however they are testing a new approach within selected projects as part of a research project (KraKK). They are targeting the largest sources of carbon during construction; materials such as concrete, asphalt and steel which have high amounts of embodied carbon and the emissions generated by fossil fuel powered construction plant. A bonus/ penalty system has been developed whereby the contractor receives financial incentives for using lower carbon materials/less materials and alternatively fuelled plant. NPRA sets project specific targets regarding the carbon associated with materials such as concrete and use of alternatively powered plant at the planning stage. If these targets are met or exceeded a bonus is received. The contractors need to provide EPDs for the low

carbon materials used and declare the volume of material used. The EPDs can be from manufacturers or self-generated using an EPD-generator approved by EPD-Norway. NPRA plan to employ a third party verification organisation to carry out random checks of contractor generated EPDs.

In 2015 the NPRA developed an excel-based LCA tool called VegLCA-tool. The tool is used at the end of the road planning process (design and contract phase) when the amounts of materials required have been estimated. The objective is to use VegLCA for the environmental optimisation of material choices, material quantities, transport distances, bridge and tunnel designs, construction equipment and technologies as well as emissions related to operation and maintenance. In the KraKK pilot study projects VegLCA is being used in the procurement process, making environmental impact budgeting part of the decision basis in the road administration procurement. However NPRA do not currently use VegLCA as base for awarding bonus/malus to contractors.

4.2.2 *Netherlands*

Driven by both national policies and targets and the ambitions of their senior management RWS have taken action to include both climate change mitigation and adaptation in their procurement processes and operations. In terms of including climate change mitigation they are quite advanced in their actions with established procedures and demonstrable results. They have engaged with their supply chain throughout and the suppliers have modified their procedures to address the new procurement requirements.

RWS include sustainability in the project goals from the start and establishes its ambitions for the project. It identifies measures to reach these goals which are included in the tender evaluation criteria. RWS uses a tool called the Sustainable Planning Circle to review 12 aspects of sustainability, such as water, accessibility, energy and carbon and identify potential actions to address these with the planned project. The Ambition Web is used to identify project requirements under the sustainability topic headings. Project sustainability requirements are a mixture of national standards (e.g. use of sustainably grown timber), organisational requirements (e.g. use of LED lighting) and project specific requirements.

RWS employ two tools to support their sustainable procurement approach an LCA tool called DuboCalc and the CO_2 performance ladder. DuboCalc is used to calculate the environmental impact of a construction design over its lifetime, assessing eleven environmental impacts including carbon. The output is a single value referred to as the Environmental Cost Indicator (MKI). A lower value indicates a design with a lower environmental impact. This enables designers to compare design and material options, but is also used by RWS in their procurement process. Tenderers are required to submit the MKI as part of their proposal and demonstrate how they would achieve this. This value is used in the tender evaluation process (part of the MEAT (Most Economically Advantageous Tender) criteria), and if their proposal is successful obtaining the promised MKI becomes a contract requirement. The Netherlands has a national database of EPDs which provides an easily accessible, consistent data source for carrying out LCA. This database is used by DubCalc for its calculations.

The CO_2 Performance Ladder (PL) is a concept developed by ProRail the Dutch rail infrastructure owner, but is now also used by RWS as part of its procurement process. There are five levels or rungs on the ladder, with 1 being the lowest and 5 the highest. Carrying out actions such as procuring green energy, more efficient uses of materials move an organisation up the ladder. Suppliers are awarded a 1% hypothetical reduction in the price of their proposal during the tender evaluation for each rung in the ladder providing a significant advantage over less sustainable competitors. The tool operates at an organisational level

working in tandem with the project level DuboCalc. When a supplier submits a tender a low MKI value contributes to a high quality score and a high PL level to a lower cost score. A more sustainable supplier is therefore more likely to be awarded the tender as the price/quality ratio will be higher and the hypothetical price lower. The MKI value is recalculated at delivery with the real data and independently verified. If the MKI meets the promised value, the supplier is paid the submitted price. If the MKI is exceeded a financial penalty is imposed and if the MKI is lower a bonus is awarded.

Including adaptation in procurement is not straight forward and therefore less advanced, but RWS is trying different approaches such as including it in the pre-qualification requirements and producing guidance on climate change for suppliers. RWS incorporate climate change adaptation in new build through modifying design standards to account for climate change and also as part of the EIA at the planning stage. It has also piloted the use of risk assessment (using ROADAPT) in a selected project at the planning phase. It is currently exploring how it can build on this to include adaptation in maintenance contracts.

4.2.3 *Sweden*

Trafiverket introduced carbon reduction targets in its procurement requirements for large new build infrastructure projects due to be completed from 2020 onwards in 2016. It developed a carbon calculation tool called Klimatkalkyl to provide a consistent methodology for measuring carbon emissions. The tool uses information provided by the user about the specific materials and design being used in the project together with default data to calculate a CO_{2eq} value for the project. Incorporated into the tool is a database containing emission factors for around 40 construction materials. If low carbon materials are used which are not contained within the database the emission factors need to be verified by third party EPD auditors. The tool is used at different stages in the project planning and procurement processes, firstly by the NRA to establish a baseline and set appropriate targets and then by the supplier to select a low carbon design for tender submission and establish the final carbon value.

Trafikverket issues functional specifications which allow the supplier the flexibility to develop an approach which meets the functional requirements and the carbon reduction target within a competitive budget. Trafikverket defines the carbon reduction target for the project as a percentage of the baseline and assigns the bonus available for exceeding this target. If a significant change to the scope of works is made during the project the baseline is updated, but the target is retained. At the end of the project the supplier has to submit a climate declaration stating the carbon value that was achieved. Bonuses are granted for exceeding the target, and penalties applied if the target is not met.

Requirements have also been put in place since 2018 on materials and fuels used in smaller projects and maintenance contracts that do not have climate calculations. This is a temporary solution until functional requirements based on climate calculations can be introduced for maintenance contracts. Trafikverket is currently piloting the expansion of the approach from the large projects to pavement contracts and maintenance projects. In parallel with this, Trafikverket has been working directly with the producers of widely used carbon-intensive materials to find a way to reduce carbon the embodied carbon.

Trafikverket's Strategy for Climate Change Adaptation published in 2014 sets out a number of areas it intends to focus on in order to adapt to climate change and maintain robust and reliable infrastructure. These include assigning responsibility for adaptation actions, undertaking research, incorporating consideration of climate change in planning and developing methods to decide which measures are cost-effective. There are no specific procurement requirements in relating to climate change adaptation. However design standards have been modified to include climate change impacts (e.g. drainage capacity).

4.2.4 *Conclusions and recommendations*

The three pilot study countries have all independently developed different methods of including climate change mitigation in procurement, however there are some similarities:

- Functional specifications – all three NRAs used functional specifications and incentivise carbon reduction actions rather than specifying the carbon reduction actions themselves. This enables the contractor to innovate and use their own ideas for reducing carbon.
- Targets - all three NRAs set numerical targets for suppliers and provided them with a tool to enable consistent measurement across suppliers in order to judge if the target is met.
- Financial incentives – all three NRAs provided financial incentives for meeting carbon targets.
- LCA and EPDs – all the NRAs used LCA type tools and EPDs as a data source for the tools.

The main differences were that the Netherlands focused on specific high carbon materials rather than all materials. They also include other environmental impacts, not just carbon in their assessment. The NRAs are at different stages of implementation with some systems having been established for several years and others at the pilot stage.

Key recommendations based on the pilot studies are**:**

- Start by requesting suppliers to provide carbon calculations for projects rather than introducing carbon reduction requirements right away.
- Strengthen the requirements (increase the percentage of carbon reduction required) over time in line with the national targets and internal targets. At the same time also increase the reduction needed to obtain a bonus.
- Get the industry on-board from the beginning and align with national goals and targets.
- It is important to carry out an impact assessment together with the industry and have initial interviews with suppliers before implementing the procurement changes.
- While setting up the targets it is necessary to keep in mind that they need to be realistically achievable within the budget.
- Outreach to entrepreneurs and consultants, organise conferences, seminars, etc to engage the industry in your carbon reduction plans.
- Set internal goals so everyone is aware of the approach being taken and the timeframe.

Inclusion of climate change adaptation in procurement process is less advanced, but the pilot study countries have taken different actions to incorporate it in their construction and maintenance activities. For example inclusion in the planning process (EIA), modifying standards and providing guidance for suppliers.

4.3 NRA feedback on the tools

4.3.1 *Risk assessment and CBA tool*

Feedback was obtained on the risk assessment and CBA tool at the CEDR climate change end of programme event in Utrecht, November 2018 when the tool was presented to an audience of NRAs and researchers. The draft tool was also distributed among the PEB members and the individual pilot study results discussed with the relevant NRAs.

There was a great deal of interest in this tool at the end of programme event as there is currently nothing similar available to NRAs. Several attendees would like to use the tool and see the need to take account of the impact of the climate change for the management of the road infrastructure. The majority of questions were on the asset data required. Some NRAs were concerned that they did not have sufficient data available, 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.

The pilot study NRAs highlighted the need for further DPCs, such as landslides or flooding after heavy rain events. The pilot studies trialled the tool using selected DPCs, for practical use, the tool should be extended by adding the DPCs most relevant to the user.

4.3.2 *Procurement collaboration platform*

Feedback of the procurement collaboration platform was obtained during the CEDR climate change end of programme event in Utrecht, November 2018 when the tool was presented to an audience of NRAs and researchers. The draft tool was also distributed among the PEB members and presented at a meeting organised by IBDiM with the Polish National Roadway Administration in December 2018.

In general when the concept and content of the tool was explained to potential users the feedback was very positive. A tool that encourages greater collaboration between NRAs was considered to be a good step forward in spreading good practice across CEDR members. It was felt that even the NRAs who are leading in this area could learn from the experiences of others, and that those less advanced would find it very 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.

An interesting comment was made by one of the workshop participants that perhaps it would be good to expand the benchmarking and assurance section to enable agencies to compare their performance with other NRAs in relation to the embedment of specific climate change related requirements in specifications. Perhaps this additional functionality can be added by CEDR following project completion. Workshop users also commented on the use and availability of EPDs. Sharing examples of EPDs from different countries for key materials via the platform may be useful.

It was noted that not all relevant information produced by the NRAs is available in English. Although it is helpful if national specific information is also produced in English so all users can benefit from them and understand them, it was agreed 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.

The ultimate usefulness of the tool depends on the participation of the CEDR members. The tool can be developed and evolve to share other types of information and experiences.

5 Conclusions and implementation

5.1 Project findings

In addition to producing practical tools and guidance, the DeTECToR project highlighted a number of different points relating to climate change and roads. The literature review found that although there are various examples of risk assessment methodologies including notably RIMAROCCA/ ROADAPT and RIVA, there are few examples of these actually being applied and used at a network level to inform asset management decisions. The survey findings appear to confirm this, with only 24 percent of respondents stating that they current use climate risk assessment tools. The survey also found that two thirds of respondents do not currently consider climate change in economic appraisal and it is clear from the literature review that including that quantifying the impact of weather hazards on road networks is challenging. There are multiple factors involved and data is not always available, especially for wider costs. It is important to identify which types of costs should be/can be included.

The DeTECToR risk assessment and cost-benefit tool is the first attempt (that the authors are aware of) to produce a decision-support software tool to aid NRAs in assessing risk and the economic cost-benefits of adapting to climate change. This necessitated numerous assumptions due to the inherent uncertainties around climate change impacts, lack of data and the limited project budget and timeframe. However, it does provide a large step-forward in understanding and addressing the issues. NRAs now have a framework with which to work, and a starting point for assessment which they can improve upon. The development of the tool also highlights the importance of data, in order to inform risk assessment and CBA. Collecting the right data, and robust analysis and management of data are an increasing important part of road asset management. Much of the asset data required for understanding climate change is already collected by many NRAs, but other types of data, often held by third parties, such as climate projections, geology, land-use, topography etc. are also necessary. This is something which has often been outside NRAs remit in the past, but is important when it comes to understanding the multiple factors affecting the vulnerability of their network to different climate hazards.

In terms of procurement the DeTECToR project has highlighted other types of challenges, and some potential solutions. Although most NRAs have carbon reduction, the survey found that only a third of respondents have requirements related to carbon reduction in project tender specifications. The project found that some NRAs are trialling and in some cases implementing novel approaches to including carbon reduction requirements in procurement. Other NRAs have only just started to consider including environmental concerns in procurement. There is a clear opportunity for greater knowledge transfer, and exchange in experience in this area. The online collaboration platform produced by DeTECToR could play a key role in this. Even NRAs more advanced in this area are focusing on different issues, such as high-carbon materials and fossil fuel powered construction vehicles therefore exchanging information and experiences of successes and failures could help NRAs at all levels of sustainable procurement maturity.

5.2 Recommendations for implementation and building on the project

5.2.1 *Procurement*

The procurement online platform includes some core information which enables NRAs to gain knowledge on the relevant topic. The inclusion of climate change in procurement and operations is wide and developing area. It is envisaged that the tool will be populated by the NRAs with more specific data and examples from each country so it can become a real collaborative tool. The NRAs can decide how much information they wish to include there and how openly they want to share amongst themselves (e.g. with different levels of password protected access for users). Future plans regarding the availability of the tool to the CEDR members are pending discussions with the PEB. Examples of what information could be included on the platform are demonstrated using the procurement pilot studies.

In terms of implementation it is recommended that CEDR members review the procurement information on the DeTECToR online platform and consider how approaches employed by other NRAs could be employed in their organisation. For additional detail NRAs should contact the relevant organisation to discuss how they implemented the approach and to seek their advice. If they decide they wish to investigate further carrying out impact studies, consulting with suppliers and gathering data to support the new approach would be useful next steps. If they precede carrying out pilot studies and implementing the approach slowly, e.g. only applying to major projects would be recommended.

5.2.2 *Risk assessment and CBA tool*

Road infrastructure planning and asset management require different analyses, information and decisions at different process stages. The DeTECToR risk assessment and CBA tool is intended support these process and provide useful information for the planning, maintenance and operation of the road infrastructure in the context of climate change. For example, the results can be used for the amendment of design and material guidelines and regulations or, in relation to a specific section of the network, to provide additional information e.g. selecting suitable construction or materials. In order to do so, the tool is used in two steps. First, vulnerable sections can be identified via the risk module. If the results suggest that most of the network or all those with certain characteristics are affected by a particular type of hazard modifications in standards may be required, whereas if only a few sections are affected, the tool supports the selection of suitable adaptation measures for these affected sections. The risk assessment module enables the road sections to be prioritised with regard to their risk potential. In a second step, the CBA module can be used to investigate various adaptation measures with regard to their effect to reduce the vulnerability of the asset and the cost implications of this.

The pilot studies have shown that the tool can be used for a network-wide and section-specific analysis of the impact of climate change on the infrastructure. Currently, however, the tool presents only the DPCs used in the pilot studies. As a first step in using the tool NRAs should identify which DPCs are their highest priority and ascertain if these are already defined in the tool. If not, they need to replicate the approach used to define suitable indicators. The data required for relevant existing and new DPCs needs to be reviewed and potential sources identified. Some types of data e.g. location of roads, traffic etc. will be used in a number of DPCs and will be readily available from asset management systems, whereas others will be more specialised and may require sourcing from third parties. The indicators and thresholds for these DPCs should be reviewed against the availability of data and if they need to be adjusted for the particular network. Someone within the NRA should be appointed

to be the Configuration Provider to co-ordinate this work and perform the initial set-up and data upload. This means primarily the creation and processing of the necessary database. The number of DPCs included and the indicators utilised can be expanded on as the business need arise and/or more data is collected sourced. The NRA should also decide how the use of the tool can be integrated into current asset management and planning processes, and if its use should be obligatory at certain decision-points or run regularly e.g. annually or following condition surveys.

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