**CEDR Transnational Road Research Programme**
**Call 2015: Climate Change: From desk to Road**

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

## Interim Report 2

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

## Interim Report 2

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# Glossary

| Term/Acronym | Definition |
|---|---|
| AADT | Average Annual Daily Traffic |
| Adaptive management | A long-established approach that uses monitoring, research, evaluation and iterative development to improve future management strategies. |
| 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. |
| 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 will be developed for both these areas. The risk assessment and cost-benefit tool produced will enable NRAs to identify the level of risk to different routes/assets from relevant weather hazards and understand how this is likely to vary over time due to climate change. It 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.

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. This report, Interim Report 2, summarises the development of the tools and guidance documents and describes how the pilot studies were carried out. The final report will summarise the whole project and its findings.

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 to asphalt pavement. This is based on the indicator method developed by the German RIVA project[1]. Climate, asset and effect indicators are defined for each DPC and are assigned a score 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 a wiki functionality. Information and good practice examples have been uploaded into the tool as part of the DeTECToR project, but the aim is for this to be added to by the CEDR members. This enables the NRAs to share

[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.

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 was 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 two year project covers topics A and B in the call's Description of Research Needs (DoRN):

A: Economic costs associated with integrating climate change into decision-making

B: Embedding climate change into practice and procurement

1. Implementing existing climate change research into practice
2. Embedding climate change into procurement processes

DeTECToR is also liaising with the Topic C project WATCH (Water Management for Road Authorities in the face of climate change).

## *1.1 Project objectives*

The overall objective of DeTECToR is to help National Road Administrations (NRAs) put into practice the latest climate change research and good practice. The project will produce decision support tools and guidance that will enable NRAs to better integrate climate change considerations in economic and procurement decision making.

Specifically it will produce:

- 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 will enable cost-benefit analysis of different adaptation options;
- A guidance document on embedding climate change research into economic decision making, which also provides guidelines and case studies on the use of the economic tool;
- A procurement 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 tool.

## *1.2 Project work packages*

The project objectives will be achieved through seven work packages as shown in Figure 1. The WPs will run across the two DoRN topics being addressed, with some sub-tasks addressing specific aspects of topic A (economics) or B (embedment in operations and procurement). In this way the interdependencies of the two topics can be addressed, whilst retaining sufficient focus on the individual topics when required. Project management and co-ordination will be carried out under WP1, and WP7 will focus on dissemination and implementation. There are five technical WPs:

- WP2 will gather all the information required to develop the tools and guidance. This includes reviewing literature, determining stakeholder requirements and mapping out the data requirements.
- WP3 consists of the development of the two decision-support tools, and will be carried out concurrently with WP4.
- WP4 will produce the two guidance documents to accompany the tools.
- WP5 will apply the tools and guidance in a number of pilot studies, carried out in conjunction with NRAs.
- WP6 will finalise the tools and guidance based on the feedback from the pilot studies.


Figure 1. Work package structure

## 1.3 Report scope

This interim report summarises the results of the activities carried out under WP3, 4 and 5, which were carried out between April 2018 and November 2018.

The objectives of WP3 were:

- To develop a cost benefit tool that will inform NRA decision-making in planning new roads and upgrading/maintaining existing ones

- To develop a procurement tool to aid embedment of climate change mitigation and adaptation in NRA operations and procurement processes

WP3 involved the development of the software tools including defining the technical methodology to implement risk assessment and cost-benefit analysis in a software tool, the functional and design of the tools and the actual coding to produce the software.

WP3 was divided into three major tasks as outlined below:

**Task 3.1 Development of a functional specification for both tools**

**Task 3.2 Development of a risk assessment and cost-benefit tool**

**Task 3.3 Development of a procurement tool**

The objectives of WP4 were:

- To produce guidance on the use of the cost-benefit tool developed and provide information on integrating climate change into economic appraisal and investment decision-making

- To produce guidance on the use the procurement tool developed and information on the incorporation of climate change mitigation and adaptation in operational and procurement processes

WP4 involved the development of the guidance documents accompanying the tools developed in WP3. Each document is divided into two sections: this first containing guidance and good practice and the second a handbook for using the tool.

WP4 was divided into the two tasks outlined below:

**Task 4.1 Development of guidance on economic appraisal and the DeTECToR cost-benefit tool**

**Task 4.2 Development of guidance on embedding climate change in procurement processes and operations and the collaboration platform**

The objectives of WP5 were:

- To select appropriate case study areas for trialling the tools.

- To collect the necessary data for implementing the tools in the case study areas.

- To trial the tools and capture feedback from stakeholders on their usefulness and ease of use.

WP5 was divided into the following tasks:

**Task 5.1 Selection of pilot study areas and data acquisition**

**Task 5.2 Implementation of pilot studies**

The remaining Task 6 is finalisation of the tools and guidance documents and involves evaluating the feedback received and incorporating this where possible.

This report consists of deliverables D5.1 Interim Report 2 and D5.2 Pilot studies (as described in the proposal). The main content of the report is D5.1; descriptions of the individual pilot studies (D5.2) are included as appendices.

Interim Report 2 is divided into the following sections:

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

**Section 2** describes the development of the risk assessment and CBA tool.

**Section 3** describes the development to the procurement tool.

**Section 4** describes the pilot studies.

**Section 5** gives summarises the progress to-date and describes the steps planned to finalise the tools and guidance.

**Appendices A - F** contain the pilot studies.

## *1.4 Activities since Interim Report 1*

The main technical activities carried out since Interim Report 1 relate to WP3, 4 and 5. Task 3 was led by HI, Task 4 by TRL and Task 5 by AIT. All partners were involved in all three tasks. The methods used in these activities are described below.

### 1.4.1 *Development of the functional specifications*

Based on the information gather in WP2 and the stakeholder feedback obtained in the workshop functional specifications were developed for each tool. Functional specifications set out the functions that the system and its components will perform, its appearance, and interactions with users. The aim of the document is primarily to provide sufficient information for the described approach to be signed off by representatives of the future users of the tool (i.e. the Programme Executive Board (PEB)). It also provides the consortium with a common understanding of the tool and the project software developers with a description of the required functions. The functional specifications were submitted to the PEB for feedback before commencing work on the tools.

### 1.4.2 *Development of the draft tools*

The decision support tools were developed and installed on the server of HELLER Ingenieurgesellschaft mbH. For the CBA tool there was significant liaison between the different consortium members in order to ascertain how the principles of climate change risk assessment and CBA could be developed in a software tool in a manner that was robust, practical (within the project timeframe, budget and data availability) and which produced a useable tool providing NRAs the information they need in a way that could be easily interpreted. The online collaboration tool used MediaWiki, the software powering the world-famous Wikipedia, and was straightforward in terms of software development to produce.

### 1.4.3 *Development of the draft guidance documents*

Each tool has an accompanying guidance document consisting of two parts. In the first document Part A provides information on including climate change in economic appraisal and Part B is a user manual providing a step by step guide to using the CBA tool. In the second document Part A provides information on including climate change in procurement and operations and Part B is a user manual for the collaboration platform. Part A of both the guidance documents was drafted based on the literature review carried out in WP2. The two user manuals were not able to be written until after the development of the tools was complete. Therefore the first draft of the guidance documents submitted to the PEB for feedback contained only Part A and an outline of Part B. The two Part Bs will be completed as part of WP6.

### 1.4.4 *Pilot studies*

Each tool was tested using information from three countries. For the risk assessment and CBA tool the pilot countries were Austria, Germany and Scotland and for the procurement tool, they were Norway, the Netherlands and Sweden. The consortium worked with the CBA pilot study NRAs to select a suitable part of their network and appropriate damage pattern categories (DPCs) for the pilot studies. DPCs (see **Error! Reference source not found.**) efer to a specific type of damage inflicted on the road infrastructure due to one or several climate events (see
Table 2). Associated with each DPC is an asset type (e.g. concrete road surface), a list of associated asset indicators which affect the vulnerability to a specific type of damage and related consequences concerning the road condition, layer thickness, traffic flow etc. The actions for the CBA tool pilot studies focused on collecting data for the selected damage pattern categories in relation to the case study regions. Climate indicators were produced based on CORDEX data and historic weather data provided by UBIMT. Climate projections for low and high concentrations of greenhouse gases and time periods 1971- 2000, 2011 - 2040 and 2071 – 2100 were used to provide a range of potential future scenarios. Asset data was obtained from the asset management systems of the relevant NRAs. The data was uploaded into the tool and adjustments made in relation to the different data availabilities and formats of the different countries.

For the procurement tool the pilot studies involved interviewing the three NRAs on their approach to sustainable procurement and uploading the information into the tool. The Top Level Structure (TLS) initially based on literature study was populated with information and data received from the case studies. The procurement case studies were carried out by TRL, Alfen Consult and IBDiM and the CBA pilot studies by TRL, Alfen Consult and AIT. HI uploaded the information into the CBA tool and CEC produced the climate indicators.

Table 1: Overview of relevant damage pattern categories (DPC) for the risk assessment pilot studies (not all indicators were used for all pilot studies as this is dependent on the DPCs being trialled and data availability)

| DPC | Description | Asset type | Climate indicator | Asset indicator |
|---|---|---|---|---|
| ***DPC-01*** | Heat-related damages and restrictions at bridges | Bridges | K-01.1<br>K-01.5<br>K-02.1<br>K-02.2 | • AADT-heavy vehicles<br>• Position (exposure)<br>• Material type (bridge)<br>• Static system<br>• Overall bridge condition index<br>• Year of construction |
| ***DPC-01b*** | Frost-related damages and restrictions at bridges | Bridges | K-02.1<br>K-04.1<br>K-04.2 | • AADT-heavy vehicles<br>• Position (exposure)<br>• Material type (bridge)<br>• Static system<br>• Overall bridge condition index<br>• Year of construction |
| ***DPC-01e*** | Damage and restrictions at bridges due to storms | Bridges | K-11.1<br>K-11.2<br>K-11.3<br>K-11.4 | • AADT-heavy vehicles<br>• Overall bridge condition index<br>• Clearance (height)<br>• Superstructure |
| ***DPC-06a*** | Heat-related damages and restrictions on the asphalt road surface | Asphalt road surface | K-01.1<br>K-01.2<br>K-01.3<br>K-01.4<br>K-01.5 | • AADT-heavy vehicles<br>• Position (exposure)<br>• Longitudinal slope<br>• Cracks (Note)<br>• Layer type<br>• Rut depth (Value)<br>• Thickness of asphalt layers |
| ***DPC-06b*** | Frost-related damages and restrictions on the asphalt road surface | Asphalt road surface | K-04.2<br>K-04.3<br>K-04.4 | • AADT-heavy vehicles<br>• Position (exposure)<br>• Cracks (Note)<br>• Layer type<br>• Age<br>• Patches (Value)<br>• Thickness of asphalt layers |
| ***DPC-07a*** | Heat-related damages and restrictions on the concrete road surface | Concrete road surface | K-01.1<br>K-01.2<br>K-01.3<br>K-01.4<br>K-01.5 | • AADT-heavy vehicles<br>• Longitudinal slope<br>• Position (exposure)<br>• Structural Condition Index<br>• patched spots (partial replacements with asphalt)<br>• Voids/spallings<br>• Thickness of concrete layer |
| ***DPC-07b*** | Frost-related damages and restrictions on the concrete road surface | Concrete road surface | K-03.1<br>K-04.2<br>K-04.3<br>K-04.4<br>K-04.5 | • AADT-heavy vehicles<br>• Longitudinal slope<br>• Position (exposure)<br>• Structural Condition Index<br>• Patches (partial replacements with asphalt) |

| | | | | |
|---|---|---|---|---|
| | | | | • Voids/spallings<br>• Thickness of concrete layer |
| ***DPC-12a*** | Damages and restrictions due to sea-level rise on asphalt | Asphalt road surface | K-11.1<br>K-11.2<br>K-11.3<br>K-11.4<br>K-12.1 | • Road elevation<br>• Proximity to coast<br>• Level of sea protection<br>• Fetch<br>• Bathymetry |

Table 2: Overview of relevant climate indicators for risk assessment pilot studies (the indicators produced for each pilot study region depends on the DPCs being trialled)

| ***Caption*** | **Description** | **Definition** | **Annotation** |
|---|---|---|---|
| ***K-01.1*** | Number of hot days per year | Tmax≥ 30°C | |
| ***K-01.2*** | Number of summer days [d] per year | Tmax ≥ 25°C | |
| ***K-01.3*** | Number of [n] heat waves per year | | at least 6 consecutive heat days (Tmax >= 30°C & modulo (6)) |
| ***K-01.4*** | Number of tropical nights per year | Tmin ≥ 20°C | Time interval: 00:00 - 24:00 (i.e. a 24 hr period during which the minimum temperature doesn't fall below 20°C) |
| ***K-01.5*** | Maximum temperature within a year [Tmax in °C] | | Mean Tmax per year |
| ***K-02.1*** | Maximum daily spread [K] TX and TN per year | | Daily temperature range from TX (minimum daily temperature) and TN (maximum daily temperature) |
| ***K-02.2*** | No. of summer days with RR >= x mm (temperature drop) | Tmax >= 30°C & RR >= x mm | Two different thresholds for daily precipitation (RR) (10, 20 mm) |
| ***K-03.1*** | No. of days with strong freeze-thaw cycle [d] per year | Tmax ≥ 2°C & Tmin ≤ -2°C | |
| ***K-04.1*** | Minimum daily temperature within a year [Tmin in °C] | | |
| ***K-04.2*** | No. of frost days [d] per year | Tmin < 0°C | |
| ***K-04.3*** | Change (%) number of frost days per year against 1971-2000 | | Derived indicator |
| ***K-04.4*** | No. of ice days [d] per year | TMax < 0°C | |
| ***K-04.5*** | No. of days [d] of the longest continuous frost period (TMax < 0°C) per year | | Number of consecutive ice day |
| ***K-11.1*** | Average wind speed over the 30 years of the period | | |

| | | | |
|---|---|---|---|
| ***K-11.2*** | Days per year in which a wind speed of 10 m/s were surpassed, averaged over the 30 years of the period | | |
| ***K11.3*** | Days per year in which a wind speed of 15 m/s were surpassed, averaged over the 30 years of the period | | |
| ***K11.4*** | Maximum wind speed as it occurred in each year of the 30 year period 1971-2000, averaged over the 30 years | | |
| ***K-12.1*** | Relative sea level rise | | CORDEX does not contain sea level rise, but the UK climate projections (UKCP09) do. It was not possible to produce indicators for the same DPC from different sources due to the different grids, therefore a uniform sea level rise was used for the Scottish pilot study. |

# 2 Development of the risk assessment and CBA tool

Section 2 provides an overview of the development of the risk assessment and CBA tool. The DeTECToR-Analysis 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.

## *2.1 Risk module*

Following the theoretical concept of the RIVA-methodology, all indicators are associated either to the sphere of causes or the sphere of impacts. Within these spheres, the indicators are broken down by dimensions of content (characteristics/attributes of the infrastructure and the climate). The dimensions “events of climate” and “vulnerability of elements” were dedicated to the sphere of cause / hazard. The dimensions “characteristics of effects” and “criticality” were classified into the sphere of effect / impact as depicted in Figure 2.

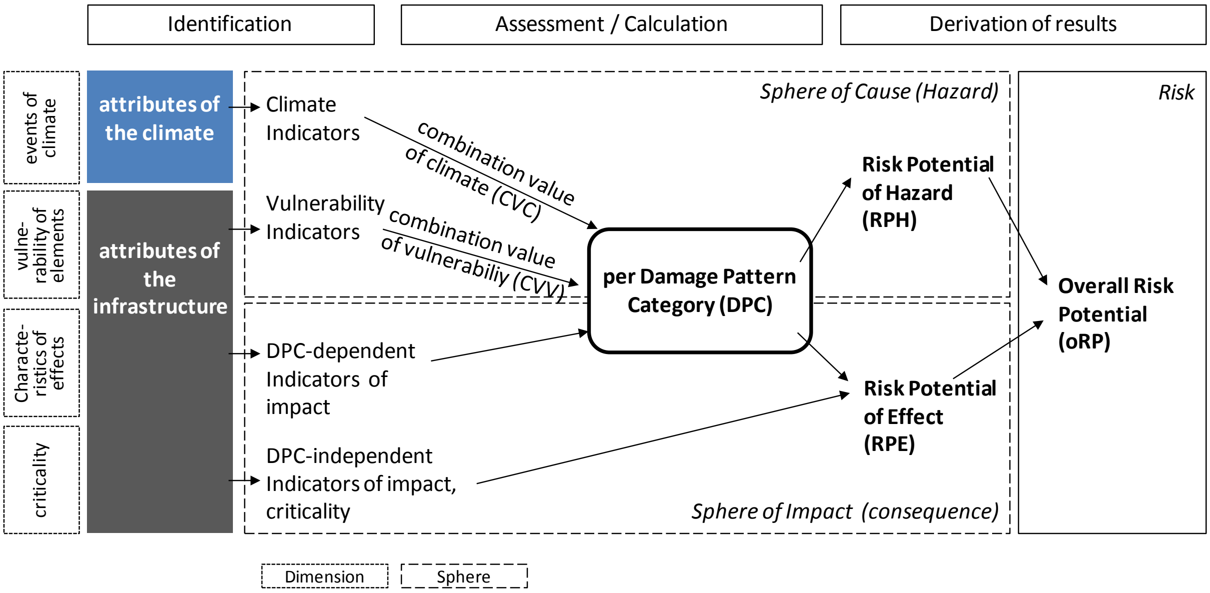



Figure 2. Calculation of risk

Potential risks may only be realised if an asset is vulnerable to a particular climate-related event. Therefore the dimension "vulnerability" includes all indicators for the vulnerability of the infrastructure (traffic-load, position / track alignment and structural or constructional attributes).

The dimension "characteristics of effects" includes all indicators of infrastructure attributes which determine the basic technical effects. These include costs of the refurbishment, maintenance and operation as well as the costs of accident and the extent of traffic interruptions.

The dimension "criticality" includes all indicators of the importance of the road sections for the traffic which affects the economic scale of the traffic impacts.

On these premises, the calculation of the risks is based on a multi-step approach for each single damage pattern category and for each section or single elements. The damage pattern category (DPC) is the central unit of the RIVA risk assessment approach. A damage pattern category is defined for each element (e.g. bridge, tunnel, surface) by similar damage patterns caused by an event of climate.

The RIVA-methodology is based on a hierarchical indicator model using several indicators to ascertain climate risk. Therefore, the "*Manual - Country specific adjustment of indicator´s thresholds*" contained in part B of the guidance document describes the indicators related to vulnerability and climate. For each of these indicators, thresholds for the value range 1 to 4 were be defined within the RIVA project for the use of the RIVA-pilot-tool for the Germany motorway network. Therefore, the thresholds have to be verified for the use in other countries and, if necessary, have to be adjusted to reflect differences in materials, design, collection of data etc. The objective of the manual is to guide this process. Doing so, the assumptions of the determination/definition of the thresholds will be described as the basis for the adjustment.

The implemented risk assessment module follows the principle of the RIVA risk assessment methodology. The module allows analysis of the risks for infrastructure due to climate change. For the pilot projects, there are four categories that can be configured: Asset Type, Damage Pattern Category, Projection Period and Greenhouse Gas Concentration (see Figure 3). Firstly, the user can choose between the asset types; bridge, asphalt road surface and concrete road surface. Secondly, the impacts on the selected asset type are distinguished into heat-related and frost-related damages and restrictions. Thirdly, the time period for which the climate data shall be analysed has to be defined. There are four 30-year periods given. The first one comprises the period from 1971 to 2000 reproducing the state of the climate at the end of the 20th century using historic weather data to determine climate change signals. The other three time periods were chosen to be comparable with other studies and to enable near-future (2011-2040), mid-term (2041-2070) and long-term (2071-2100) climate projections based on models. Finally, the greenhouse gas concentration can be selected. Representative Concentration Pathways (RPCs) are used to model either a high or a low concentration of greenhouse gas.

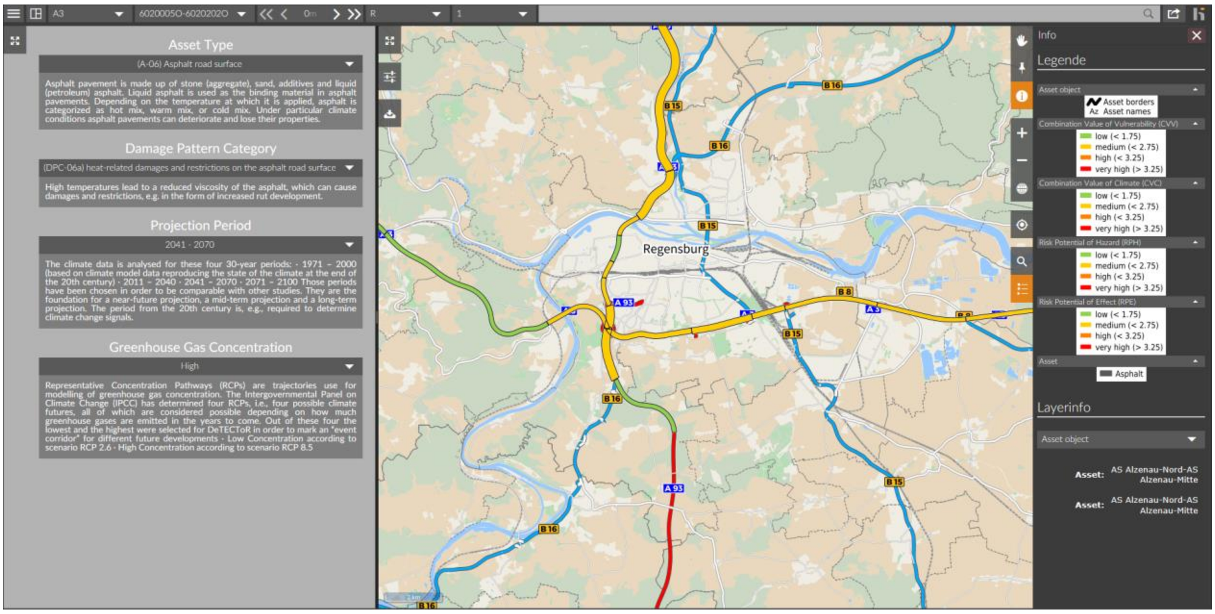



Figure 3 Risk Module: Example for heat-related damages on asphalt roads in Bavaria from 2041 to 2070 with a high concentration of greenhouse gas

With the configuration buttons on the left, the displayed data can be further configured in terms of different map layers, a CBA layer, various climate data and the background (see Figure 4). The map in Figure 3 shows the data with the selected map layers: Asset Object, Combination Value of Vulnerability (CVV), Combination Value of Climate (CVC), Risk Potential of Hazard (RPH), Risk Potential of Effect (RPE) and Asset.

The tool first calculates the Combination Value of Vulnerability (CVV), i.e. the condition of the asset objects, and the Combination Value of Climate (CVC). The CVV merges all information of the dimension vulnerability for the selected damage pattern category in the considered asset object. The CVC merges all the information of the dimension climate for the selected damage pattern category in the selected projection period and using selected emission scenario in the considered asset object. It is used for the derivation of the hazard potential. After that, the Risk Potential of Hazard (RPH) and the Risk Potential of Effect (RPE) are calculated. The RPH merges the CVV and the CVC for the selected damage pattern category in the considered asset object. The RPE is calculated by considering several relevant indicators and its weighting for selected damage pattern category in the considered asset object. This indicator is independent of the selected projection period and emission scenario. Finally, the Overall Risk Potential (oRP) is calculated. To show the calculation results, the user needs to first click on the information button on the right and thereafter on the road section or object of interest. Figure 4 shows the calculated overall risk potential for the selected road section.

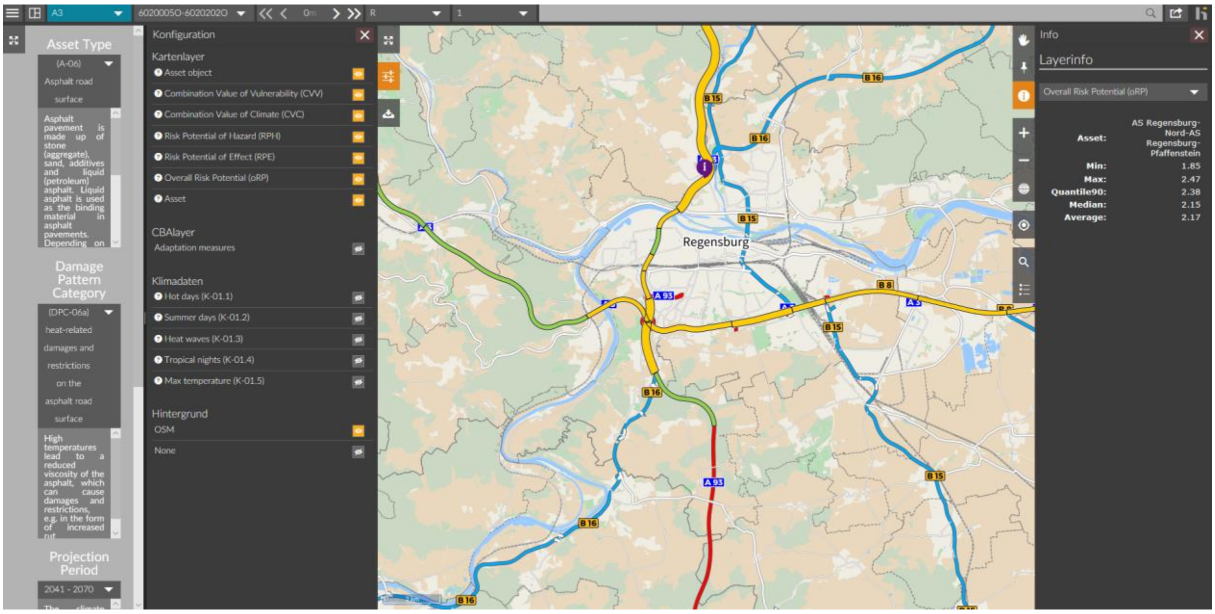



Figure 4 Risk Module: oRP for a selected road section in the City of Regensburg

The displayed data can be exported either as a text file or as a shapefile by clicking on the download button on the left.

## 2.2 CBA module

Within the cost-benefit analysis direct costs and indirect costs will be calculated. The benefits will be expressed as indirect costs and their differences between the different options/measurements compared in the CBA-module. Direct costs are the costs incurred by the NRA such as (re)construction costs, repair costs and the initial costs of implementing the adaptation actions and additional operation/maintenance costs of adaptation action. The indirect costs are those costs associated with increased journey times, accidents, and congestion during and after a climate event (see also the 5 stages of the temporal sequence of socio-economic evaluation of a "network problem" described in ROADAPT Guidelines Part D – socioeconomic impact assessment). 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 is based on the risk potential of hazard calculated in the risk module and the cost information and criteria provided by the NRA.

It should be noted that the DeTECToR-Analysis tool 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. The section "*Country specific cost data provision*" in the tool manual (Part B of the CBA guidance document) will give recommendations how to define these assumptions and estimations.

The CBA-module reflects the lifecycle of the asset/elements. Depending on the lifespan of an asset/element several lifecycle periods can occur during the analysis period. Therefore, costs are calculated on an annual basis and assume a development of lifecycle depending on changing vulnerability indicators (used for the calculation of Risk Potential of Hazard (RPH)). Hence, the RPH-value increases during a life cycle as the condition deteriorates and the asset becomes more vulnerable to climate change impacts and decreases when a routine renewal of the asset is performed.

The RPH-value affects the cost calculation in two ways. Firstly, the initial lifespan (provided by the NRA) is reduced depending on the RPH value to account for the impact of climate. In principle, it is assumed that climate events have a negative effect on the lifespan of an asset/element. The extent of lifespan reduction is an exponential function of RPH-value. This is used for the calculation of the reduced lifespan and for the depreciation of reconstruction costs, as well as of the calculation of the indirect costs during reconstruction sites at the end of a lifecycle. Secondly, the RPH value is used to estimate the annual occurrence that a climate event leads to damages or interruptions. The Level of Occurrence used is a function of the RPH-value. The Level of Occurrence influences both repair/restoration costs after a climate event (direct costs) and indirect costs such as monetarised costs of additional journey times as a result of the event.

The annual discounted direct and indirect costs are added up separately (net present value). The total sum of the discounted direct and indirect costs is being presented to the user for each of the three climate projection periods. Furthermore, results are shown for RPH-value related quartile areas[3] of the investigated section of the network in order to give the NRA the possibility to choose – if appropriate – different adaptation measure depending on the vulnerability, the hazard potential (RPH) and the climate projection period (near and/or far future). The results will be presented to the user in an appropriate way as relative value to the no adaptation variant.

The tool manual gives an overview of the assumption / estimations needed for the calculation within the CBA-module. Some of these assumption / estimations were determined by the DeTECToR research team due to the lack of further information. Other assumptions were based on available sources or based on the expertise of the DeTECToR research team. During the pilot study phase these assumption / estimations were discussed with the NRAs.

As previously described, the optimal option is defined by the lowest sum of direct and indirect costs, therefore, the discounted sum of direct costs and indirect costs are summarised for both the adaptation measures and Do-Nothing option. Furthermore, the summarised amount is calculated per quartile area and per climate projection period. These sums are used for the preparation of the results, which are presented to users as percentage variation relating to the Do-Nothing variant. The following diagram shows an example presentation of the results for a section of the network.

[3] Quartiles provide additional statistical data on the aggregated section values to help users understand the distribution of values. The first quartile is the middle number between the smallest and median, the second quartile is the median and the third quartile is the middle value between the median and highest value. This divides the data into four sets.

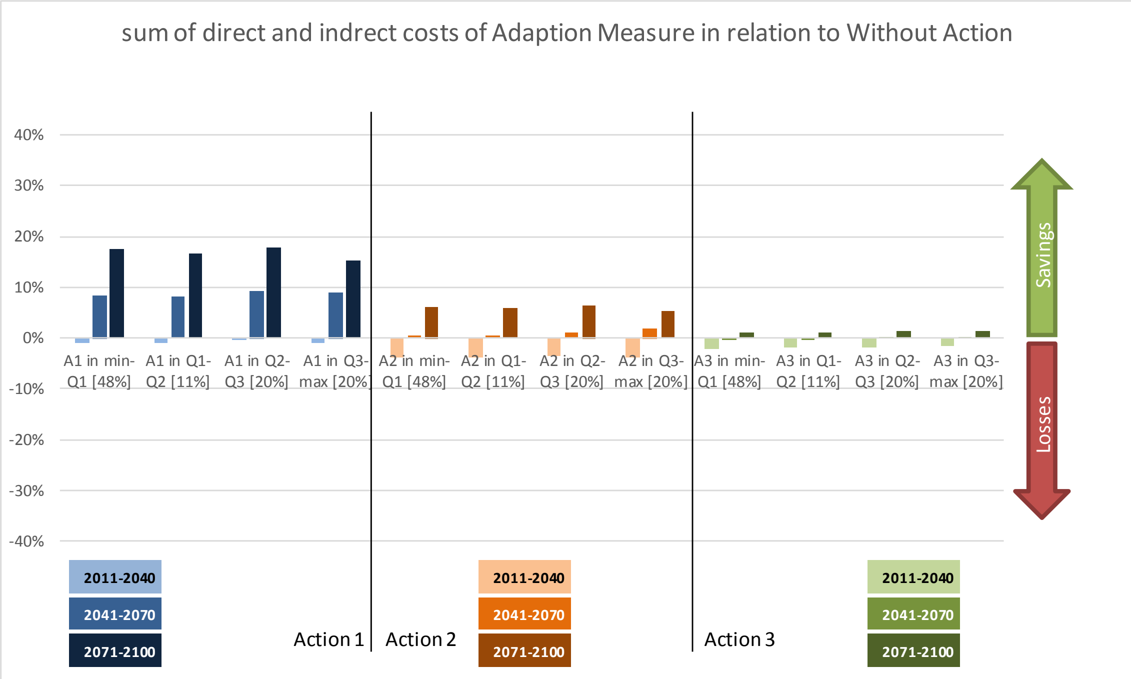



Figure 5: example result presentation – sum of direct and indirect costs

The diagram above shows the example results for the comparison of three (different theoretical) adaptation measures as percentage in relation to the Do-Nothing variant. This is the difference of the combined direct and indirect costs of the respective adaptation measures and the Do-Nothing option. For each adaptation measure the diagram presents the results for each quartile area; and for each of these the results (the columns) in the diagram represent the three climate projection periods (for the low emission scenario). It can easily be seen from the diagram, that the adaptation action 1 will be the best option in comparison to the Do-Nothing variant as well as to the other adaptation actions. Furthermore, the diagram indicates an increasing advantage over time (climate projection periods) of the actions in comparison to the Do-Nothing option.

Figure 6 shows the breakdown of direct and indirect costs and the development over the time.

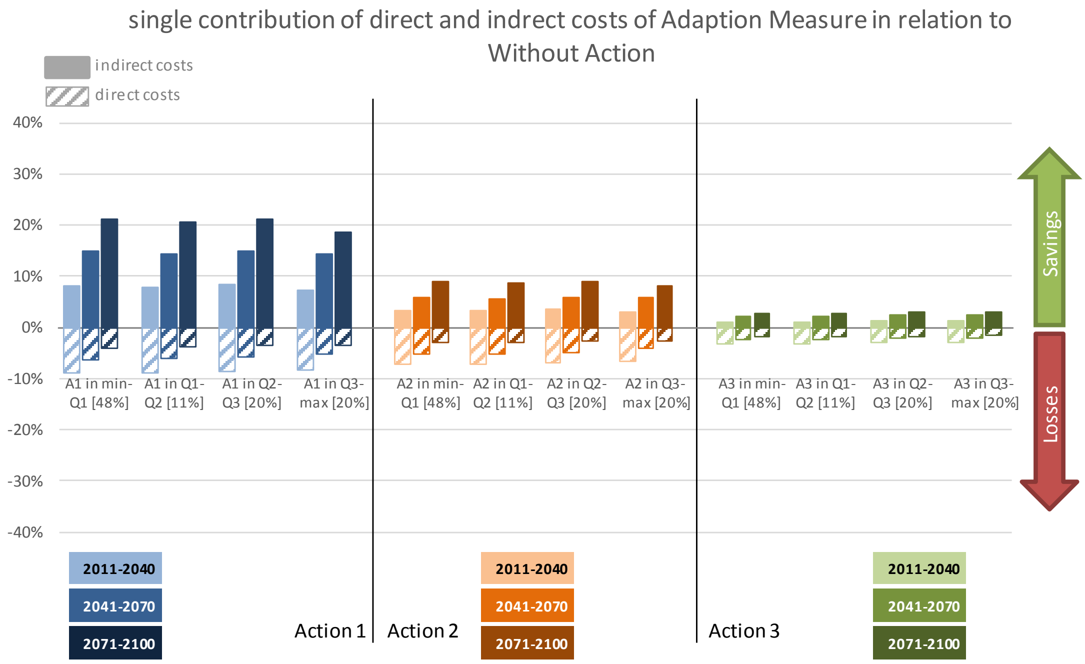



Figure 6: example result presentation – single contribution of direct and indirect costs

The Cost Benefit Analysis (CBA) module allows the user to add new configurations, to edit or delete existing configurations and to start calculations. To add a new configuration, the user clicks on the button "New" and fills in all the information demanded, such as cost and traffic-related information, in the configuration editor. The tool will propose three actions to compare to the null-option (see Figure 7).

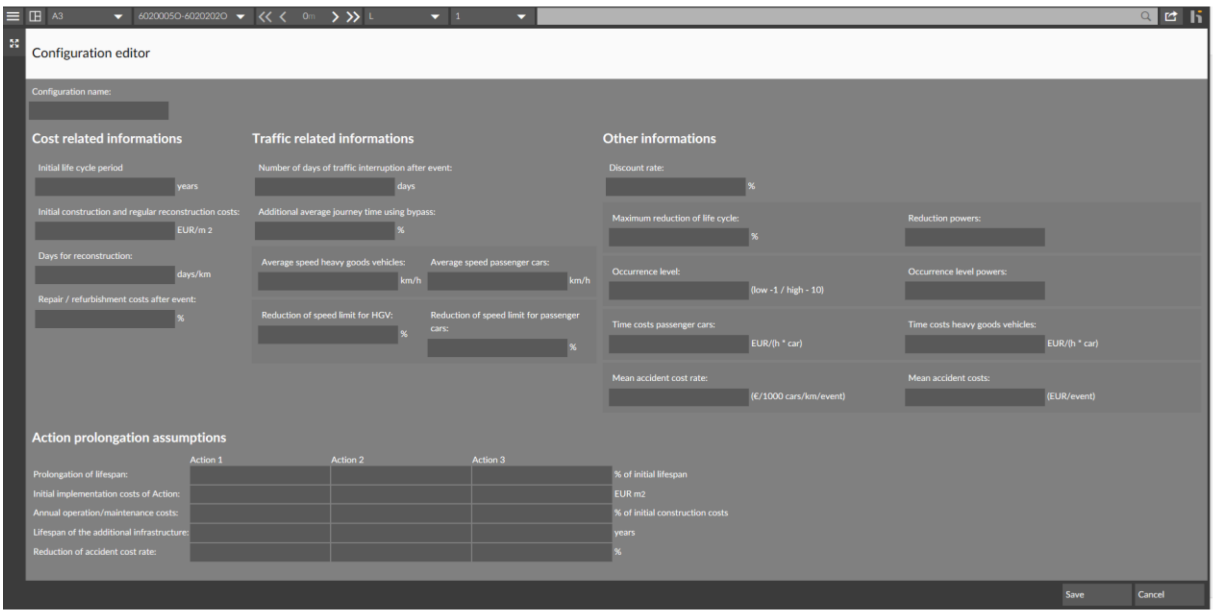



Figure 7 Configuration editor of the CBA module

After adding or editing a configuration, the user can commence the corresponding calculation by clicking on the “Start calculation” button. The system will ask for an asset type, a damage pattern category as well as for an e-mail address to inform the user when the calculation is finished. The results of the calculation can be shown on the map of the Risk Module by clicking on the configuration button on the left and selecting the CBA layer. After that, the detailed results and adaptation measures will be shown by first clicking on the information button on the right and thereafter on the road section or object of interest (see Figure 8).

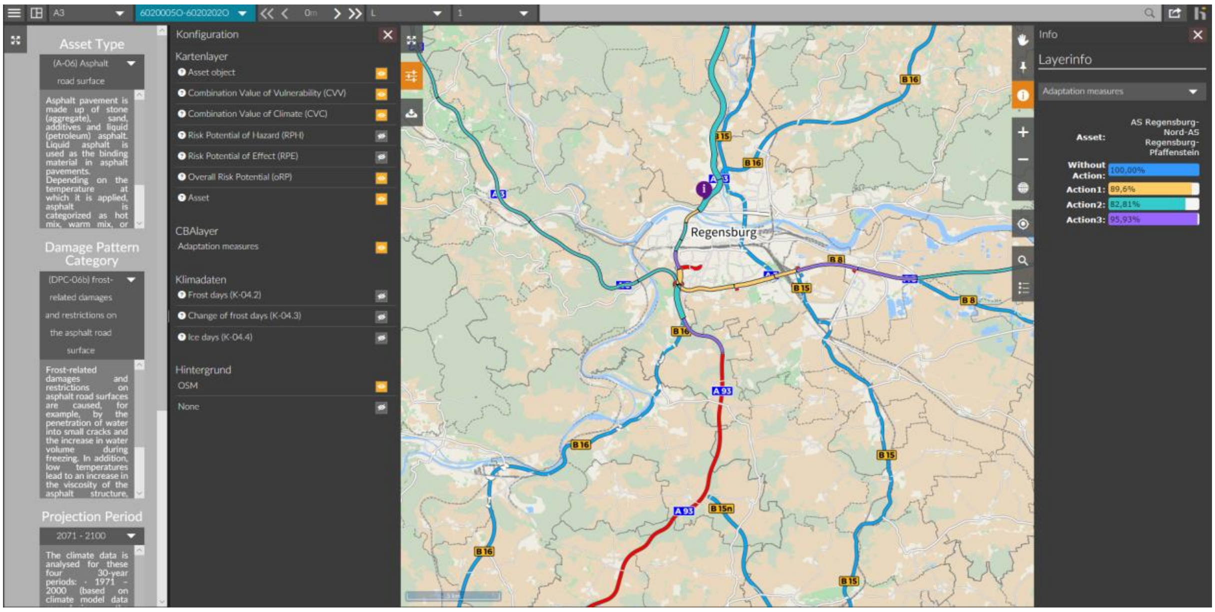



Figure 8 Results of the CBA calculation displayed in the Risk Module

Each of the three actions proposed is compared to the null-option, i.e. the scenario in which no actions are carried out. The null-option represents 100% of the costs possibly needed at the end of the selected time period. The costs of the proposed actions are stated in relation to the costs of the null-option. For example, the results in Figure 8 suggest that action 2 would only cause 82.81% of costs compared to the null-option and would therefore be the best of the proposed actions.

# 3 Development of the procurement online platform

Section 3 describes the content of the procurement tool.

## *3.1 Development of the platform*

The procurement tool was created to meet the following objectives:

1. Provide an avenue for sharing good practice among NRAs
2. Provide information on relevant research projects and NRAs practices related to embedding climate change into procurement and operations
3. To be collaborative: enabling NRAs to include their own information and share their experience with others
4. To be a learning platform for those NRAs who are less mature in the subject
5. To be an intuitive and user friendly tool

The procurement online platform is a wiki-based tool to facilitate the exchange and collaboration of road administrations of different countries and to transfer knowledge. 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 9).

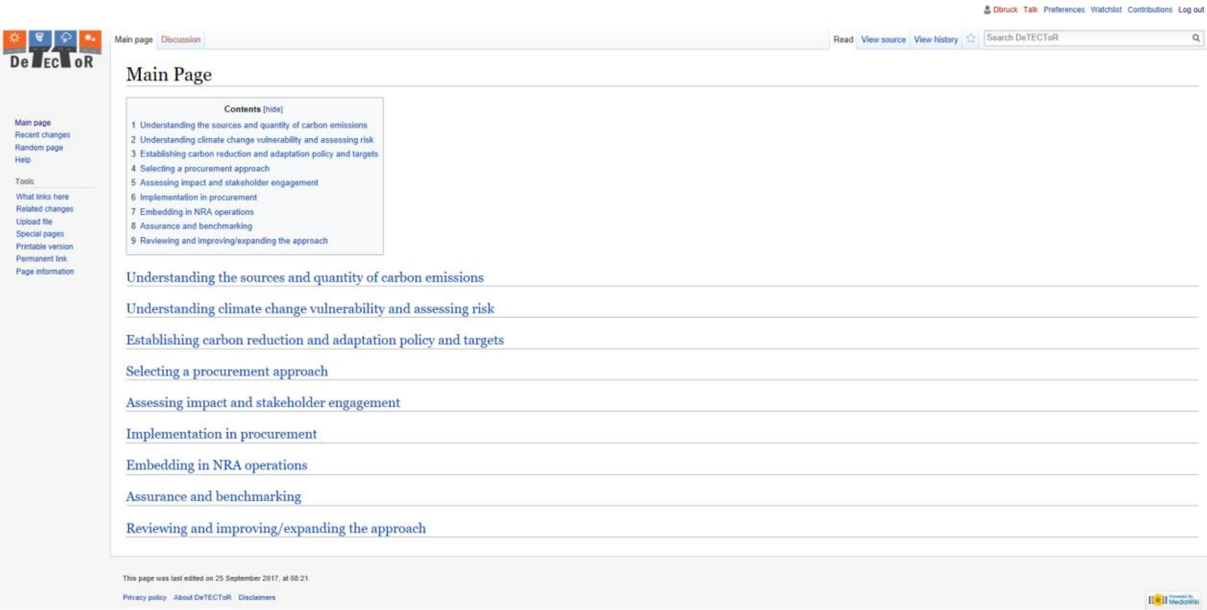



Figure 9 Main page of the procurement online platform

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 10). 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.

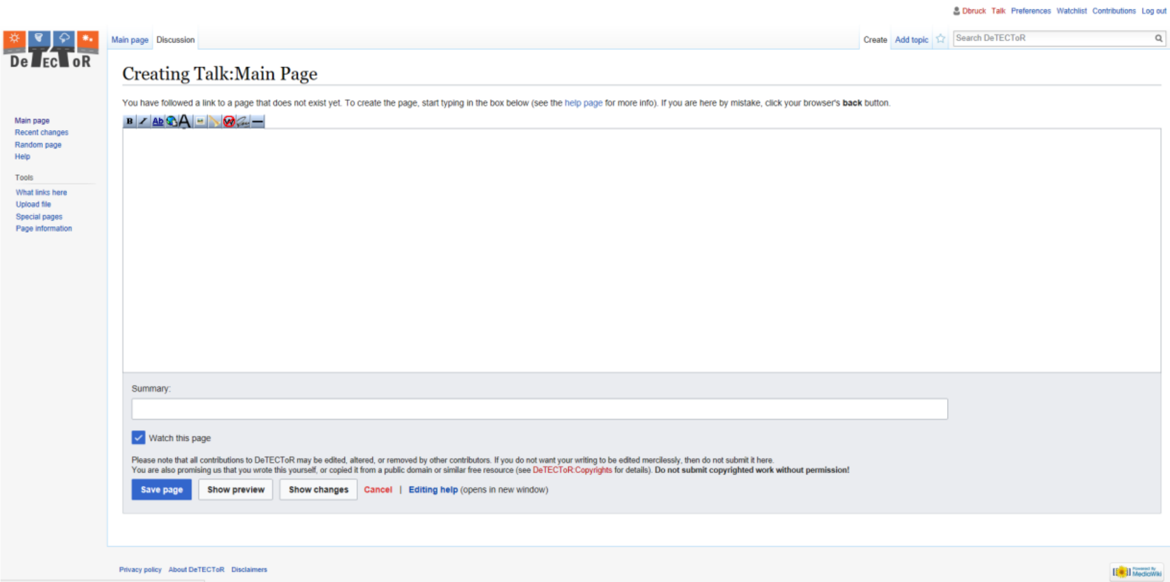



Figure 10 Adding new content to the procurement online platform

## 3.2 Development of the content

The content of the procurement tool was developed by establishing the Top Level Structure based on the steps or topic areas required for embedding climate change in procurement and operations. The top level structure, which was agreed with the PEB, consists of the following sections:

1. Understanding the sources and quantity of carbon emissions
2. Understanding climate change vulnerability and assessing risk
3. Establishing carbon reduction and adaptation policy and targets
4. Selecting a procurement approach
5. Assessing impact and stakeholder engagement
6. Implementation in procurement
7. Embedding in NRA operations
8. Assurance and benchmarking
9. Reviewing and improving/expanding the approach

Each of the topics was then filled out with the relevant information collected during various the project activities such as the literature study of existing projects, stakeholder survey and pilot studies with the NRAs (Sweden, Netherlands, and Norway). Once clicking on each tab (1-9) the user is taken to another page (within the tool) where detailed information is provided. The user is free to view and search the existing content, but can also upload their own text, images, graphs and relevant data directly to the page. This is performed using the edit and download button as presented in Figure 11 below.

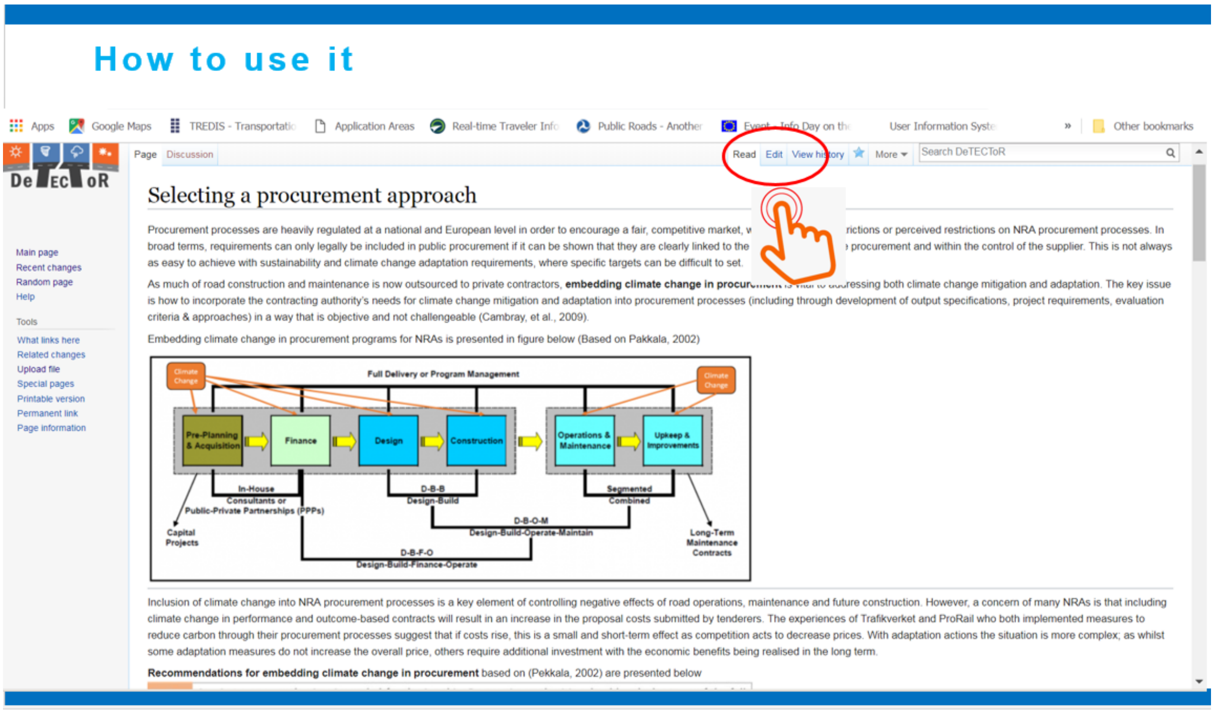



Figure 11 Editing content in procurement tool

The selection and modification of different types of material is described below with relevant screen shots from the tool to provide an overview of the tool functionality.

Understanding the Sources and quantities of carbon emissions addresses the topics depicted in Figure 12:

- $CO_2$ sources
- Findings from research projects
- Description of currently used tools
- Examples of Environmental Product Declaration (EPDs)

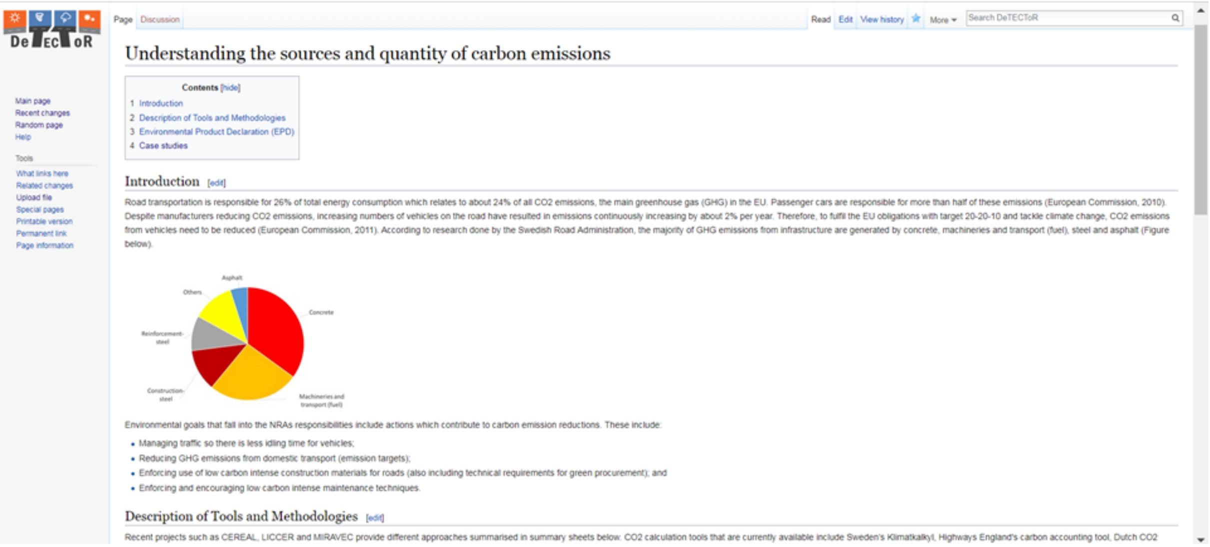



Figure 12 Sources and quantities of carbon emissions tab content

Understanding climate change vulnerability and assessing risk addresses as depicted in figure 13:

- Climate change impacts on roads and why risk needs to be assessed
- Description of current risk assessment tools based on research and practice

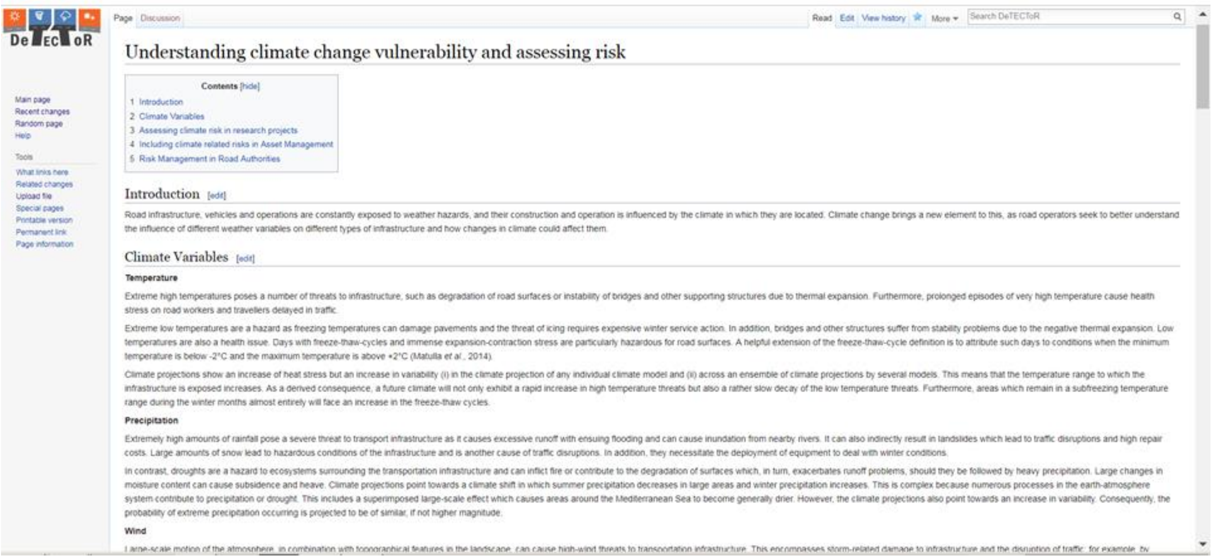



Figure 13 Understanding climate change vulnerability and assessing risk addresses tab content

Establishing carbon reduction and adaptation policy and targets addresses the following (Figure 14):

- Introduction to $CO_2$ reduction targets
- Relevant case studies and summary sheets of existing projects

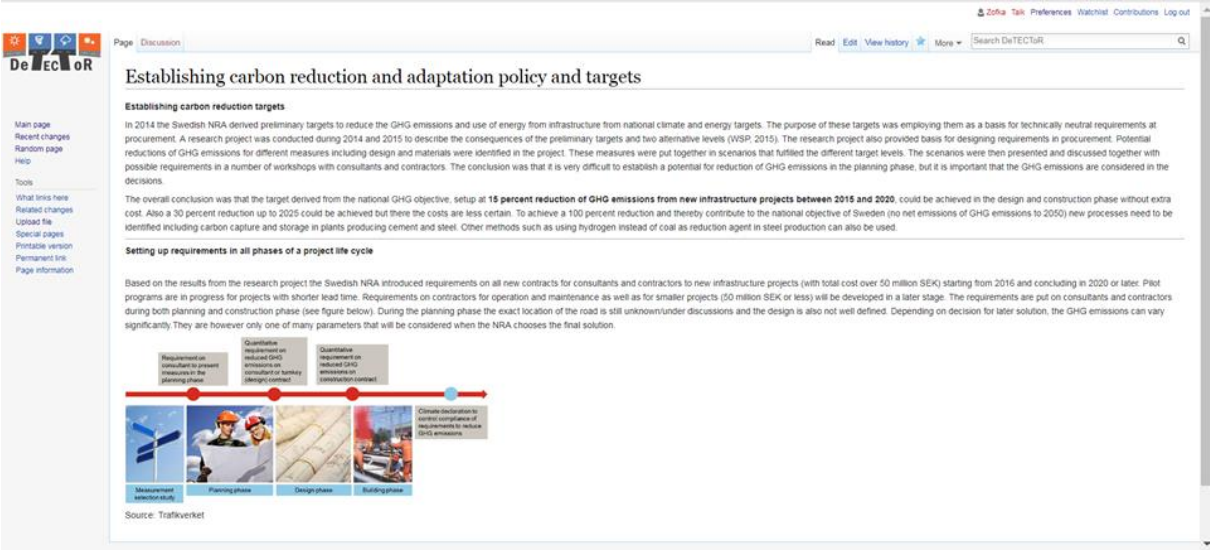



Figure 14 Establishing carbon reduction and adaptation policy and targets tab content

Selecting a procurement approach addresses the following (Figure 15):

- Procurement types, types of contracts
- Different approaches
- Barriers
- Outcome based contracts for maintenance including examples of various KPIs

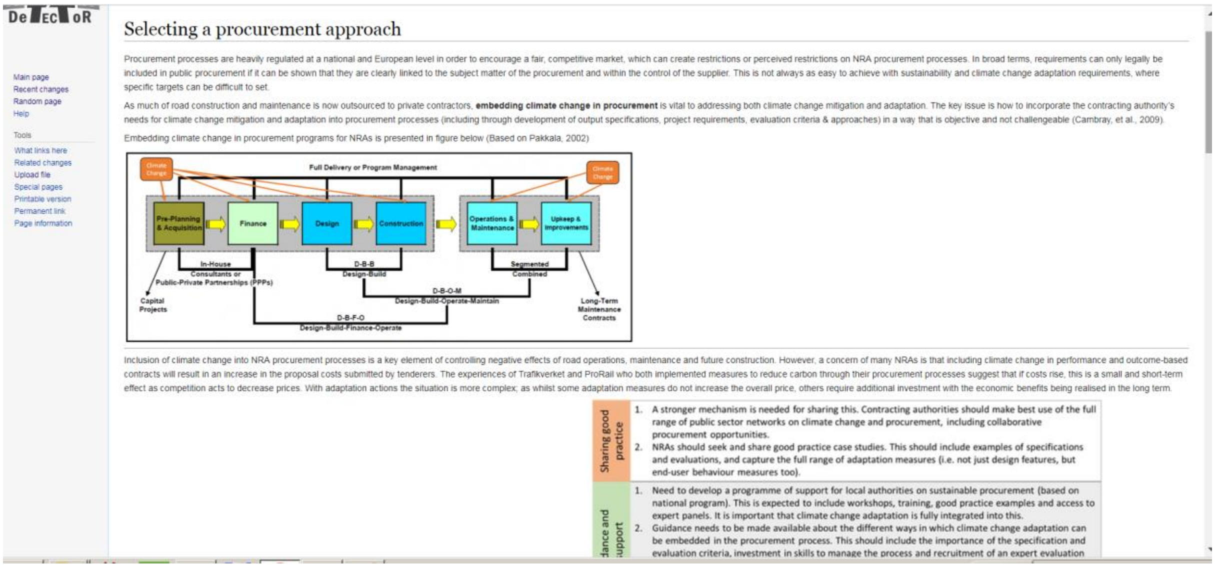



Figure 15 Selecting a procurement approach tab content

Assessing impact and stakeholder engagement includes the following topics (Figure 16):

- Methods of stakeholder engagement: workshops, information, seminars, collaboration and innovation days, etc.
- Recommendations for NRAs

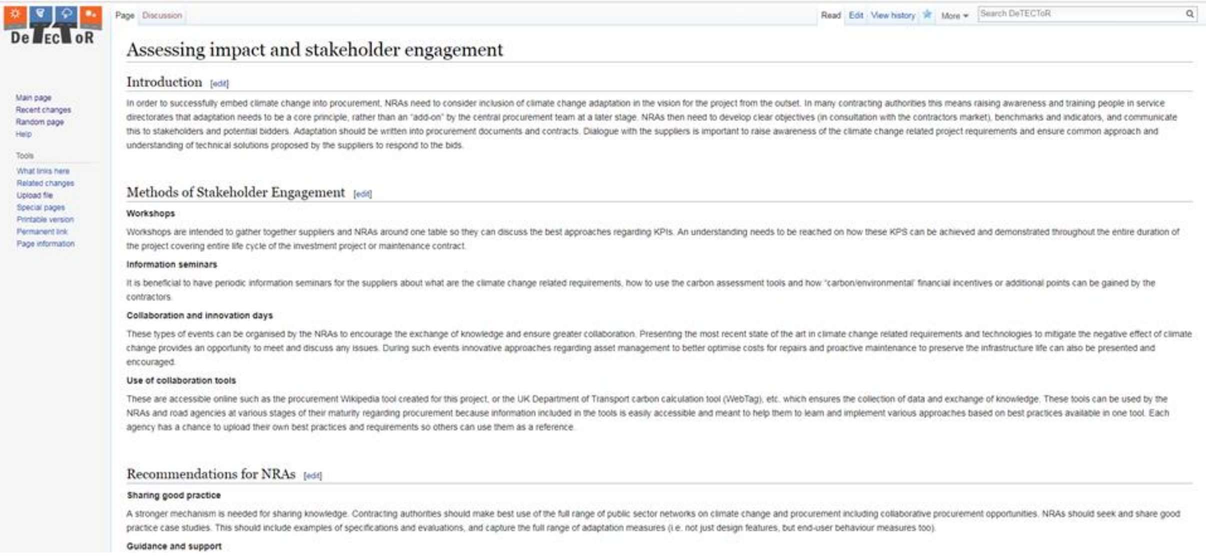



Figure 16 Assessing impact and stakeholder engagement tab content

# 4 Pilot studies

In Section 4 the pilot studies for the two tools are summarised. Further details on the individual pilot studies are provided in Appendices A-F. This Interim Report describes how the pilot studies were carried out, the final report will provide the results of the pilot studies.

## *4.1 Overview of 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 3). To ensure a widespread scope of application and to lessen the administrative burden for participating NRAs, it was decided that an NRA should test either the risk assessment and CBA tool (RACBAT) or the procurement collaboration tool (PCT). The studies were also 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 case studies for the online platform. After discussion with the NRAs involved the countries listed in Table 3 were proposed for the pilot studies and these were agreed to by the PEB.

Table 3: Overview of pilot regions for risk assessment or procurement

| DeTECToR tool | Country | Participating NRA | DeTECToR partner | Type of activity |
|---|---|---|---|---|
| **Risk assessment and CBA tool (RACBAT)** | Austria | ASFINAG | AIT | Data collection |
| | Germany | BASt | ALFEN Consult | |
| | United Kingdom | Transport Scotland | TRL | |
| **Procurement collaboration tool (PCT)** | Norway | Vegvesen | ALFEN Consult | NRA interviews |
| | The Netherlands | RWS | TRL | |
| | Sweden | Trafikverket | IBDiM | |

As can be seen from Table 3, the risk assessment tool and the procurement collaboration tool differ in the type of work necessary to apply the tools. Since RACBAT 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 via NRA interviews.

Figure 17 depicts the location of the pilot studies for the tools.

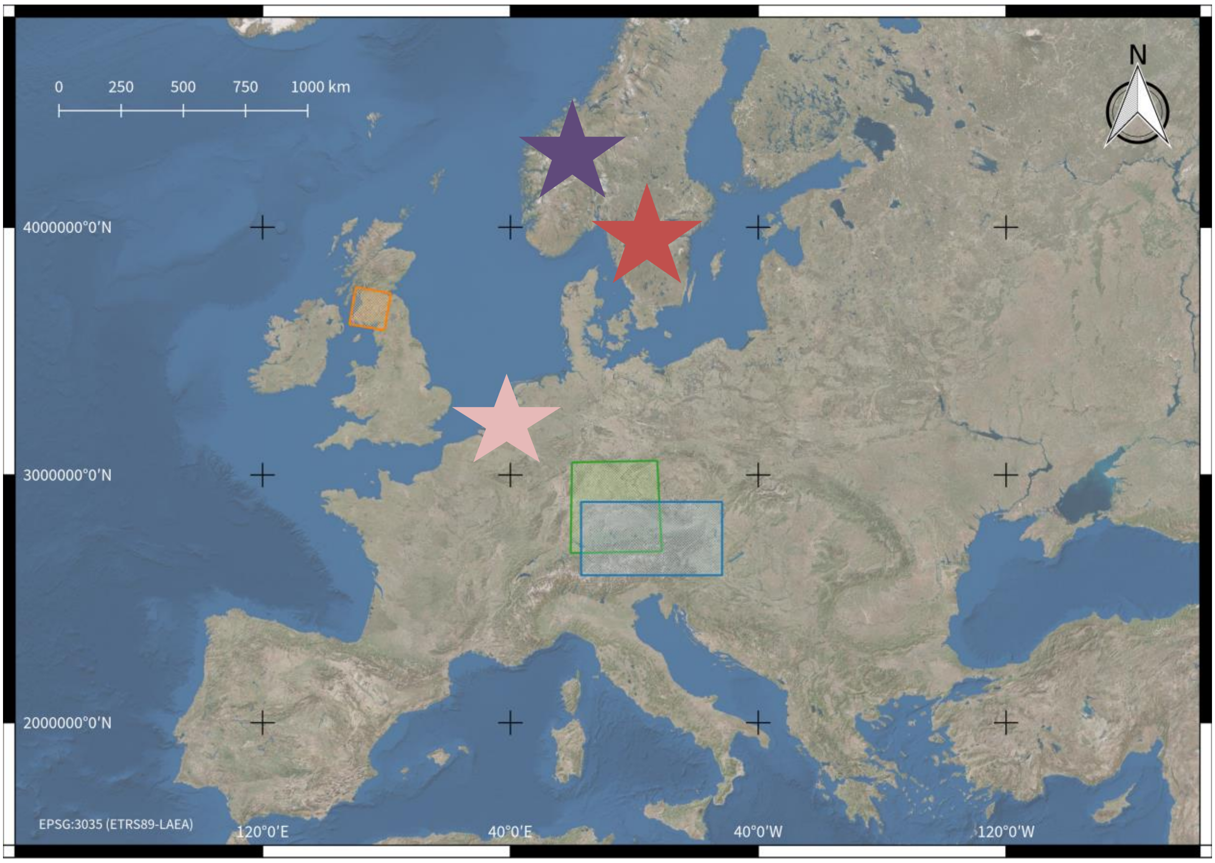



Figure 17: Location of the selected pilot studies: South West Scotland (orange box), Bavaria (green box), Austria (blue box), the Netherlands (pink star), Norway (purple star) and Sweden (red star). The boxes for the three CBA pilot studies are the bounding boxes for the historic weather data collection. As the calculations needed rectangular grids which encompassed the whole pilot region and Austria and Bavaria are neighbouring there is some overlap.

## 4.2 Obtaining asset data

Periodic monitoring of road surface conditions is an important factor to ensure that the road network remains in an acceptable state and maintenance costs are kept economically viable. Therefore all the pilot study NRAs carry out various forms of surveys to collect asset data which they store and analyses in asset management systems. For example for Austria asset data was obtained from the RoadSTAR system, a mobile high-performance laboratory developed to measure all parameters relevant to road safety (e.g. skid resistance, transverse and longitudinal evenness, texture, gradient, crossfall, curve radii). RoadSTAR allows the most important surface properties and road geometry data to be measured under normal traffic conditions at a measuring speed of 60 km/h. The RoadSTAR system is equipped with satellite navigation (dGPS) and digital video recording systems capable of referencing measurement data and pavement characteristics with an absolute horizontal accuracy of up to 3cm. The raw data was collected at a spatial resolution of 1m for each traffic lane and both driving directions. It was averaged across all lanes and subsequently aggregated to segments of 100m length.

## 4.3 Obtaining climate and weather data

Historic, i.e., measurement-based as well as modelled climate data was collected for the three case study areas. UBIMET provided the historic climate data based on measured data collected from weather stations between 1971 and 2000 and transformed into 1 km grid squares. Data relating to the modelled current climate and the projected future climate was sourced from the European domain of the CORDEX data set. CORDEX data is produced in 12 km grid squares. Climate model projection data for low and high concentrations of greenhouse gas emissions (RCP, i.e., Representative Concentration Pathways 2.6 and 8.5) were downloaded. The periods comprised 30 years each: 1971 to 2000 as the reference period and 2011 to 2040, 2041 to 2070 and 2071 to 2100 as the projection periods. After downloading the gridded data sets were cropped to the pilot study regions. Using those data, the DeTECToR climate indicators for the pilot study DPCs (see Table 2) were computed for each square, time period and GHG concentration. They can be viewed in the DeTECToR tool.

*Note: In order to determine climate signals, i.e., differences of climate states between current conditions and future periods, the present climate information needs to be taken from simulations of the current conditions, not from measurements. This way, a minimisation of model-specific bias is ensured.*

## 4.4 Procurement interviews

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 could be 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.

# 5 Conclusions and next tasks

The risk assessment and cost-benefit analysis tool and procurement online collaboration tool were successfully produced by the DeTECToR consortium. The development of the software platform for the procurement tool was relatively straightforward, but producing the CBA tool was complex as there was no precedent for this type of tool. Assumptions needed to be made either due to the innate uncertainties related to future climate change and how the infrastructure will react, but also due to lack of data and the limited resources and time available for the project. The pilot studies were extremely helpful in raising some of the data issues and the differences between countries. These aspects of the pilot studies will be explored further in the final report.

The procurement online platform has been developed and includes some core information which enables NRAs gain knowledge on the relevant topic. It is envisaged that the information in 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.

Draft guidance documents have been produced for procurement and economic appraisal. Part A for both is relatively complete and has been submitted to the PEB for feedback. Part B (the tool manuals) will be finalised as part of WP6. The final actions are to complete the CBA pilot studies, finalise the guidance documents and write the final report.

# 6 Acknowledgement

The research presented in this report was carried out as part of the CEDR Transnational Road Research Programme Call 2015. The funding for the research was provided by the national road administrations of Germany, Netherlands, Ireland, Norway, Sweden and Austria.

# Annex A: Germany pilot study

Annex A provides a description of the pilot study carried out in Germany for the risk assessment and cost-benefit analysis tool.

## Case study description

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 (*see Figure 18*).

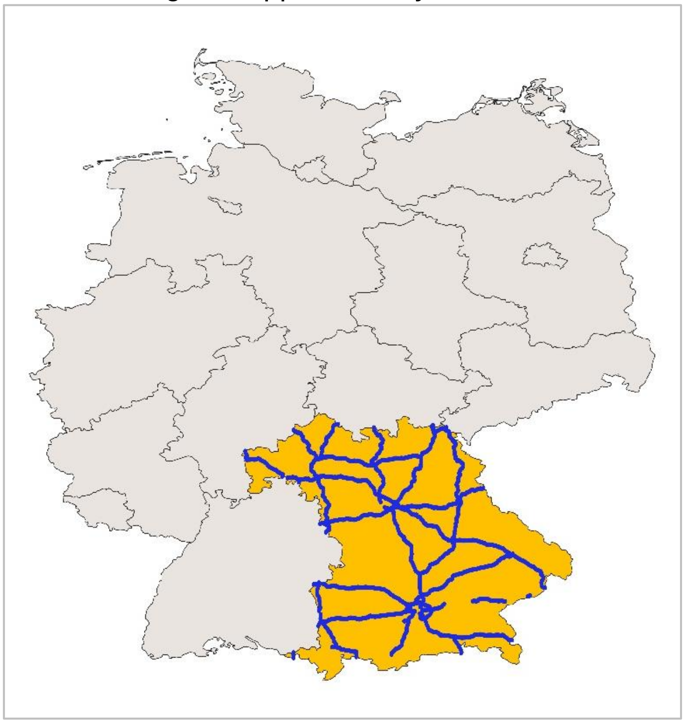


Figure 18: Overview of the Bavarian road network (blue) participating in the pilot study

Federal state of Bavaria

- Population: 12.5 Mio. people
- Area: 71.000 km2
- Motorway road network: 2,500 km (2010)

Description of the Bavarian trunk road network (Autobahn):

- length of almost 2,500 km;
- thereof
  - 85% asphalt pavements surface
  - 15% concrete pavement surfaces
- almost 3,600 bridges.

In addition to the Alpine region in the south, flat regions can also be analysed in the Federal state of Bavaria. By selecting this pilot region, different climatic regions can thus be analysed.

The following DPCs were selected for the 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

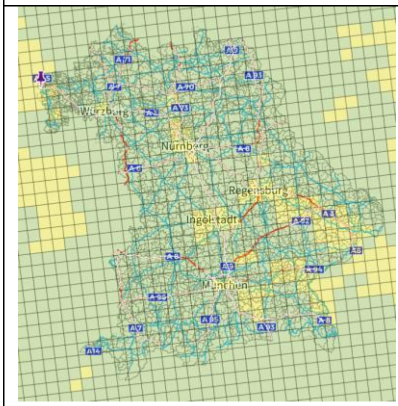
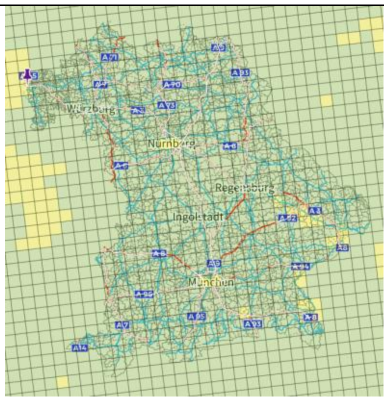
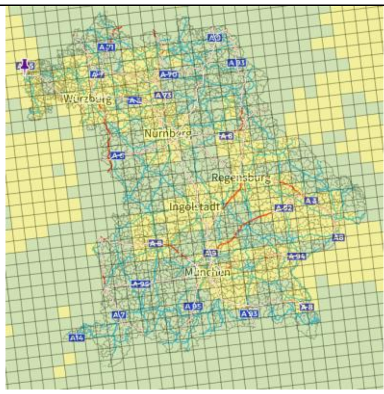
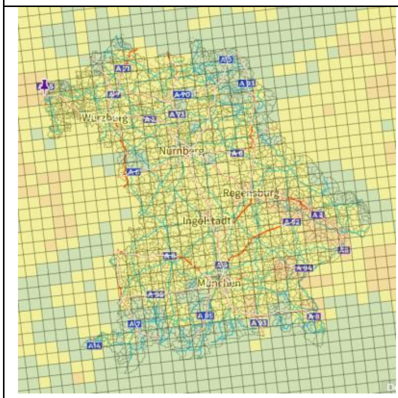
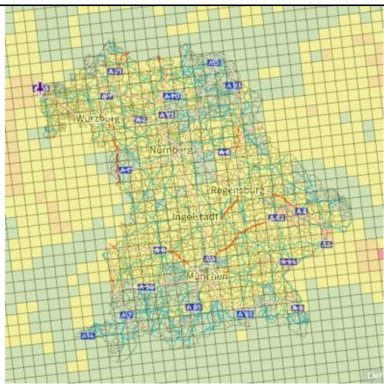
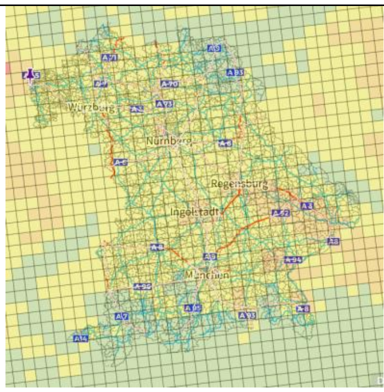
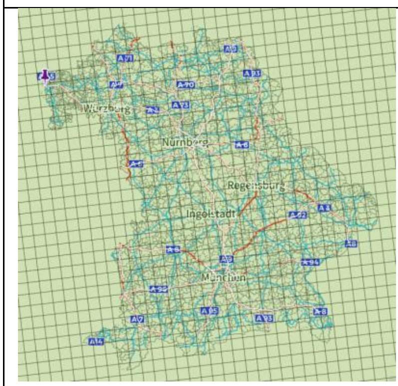
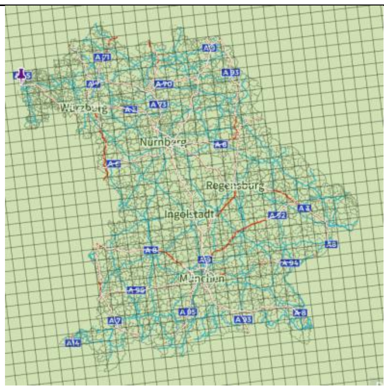
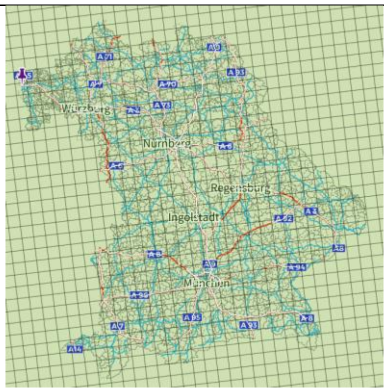
## Data acquisition

Different data and data sources were used to evaluate the indicators for the DPCs listed above. The following overview shows the asset indicators used for the different DPC evaluated for the German pilot study. These indicators were used for determination of Combination Value of Vulnerability.

Table 4. German pilot study asset indicators

<table>
<tr><th>Caption</th><th>Description</th><th>Asset type</th><th>Asset indicators</th></tr>
<tr><td>DPC-01a</td><td>Heat-related damages and restrictions at bridges</td><td>Bridge</td><td rowspan="2">• AADT-heavy vehicles<br>• Position (exposure)<br>• Material class<br>• Statical system<br>• Condition<br>• Year of construction</td></tr>
<tr><td>DPC-01b</td><td>Frost-related damages and restrictions at bridges</td><td>Bridge</td></tr>
<tr><td>DPC-06a</td><td>Heat-related damages and restrictions on the asphalt road surface</td><td>Asphalt road surface</td><td>• AADT-heavy vehicles<br>• Position (exposure)<br>• Tendency<br>• Cracks<br>• Layer type<br>• Rut depth<br>• Layer thickness</td></tr>
<tr><td>DPC-06b</td><td>Frost-related damages and restrictions on the asphalt road surface</td><td>Asphalt road surface</td><td>• AADT-heavy vehicles<br>• Position (exposure)<br>• Cracks<br>• Layer type<br>• Age<br>• Mends<br>• Layer thickness</td></tr>
<tr><td>DPC-07a</td><td>Heat-related damages and restrictions on the concrete road surface</td><td>Concrete road surface</td><td rowspan="2">• AADT-heavy vehicles<br>• Tendency<br>• Position (Exposure)<br>• Condition<br>• Mends<br>• Spalling<br>• Layer thickness</td></tr>
<tr><td>DPC-07b</td><td>Frost-related damages and restrictions on the concrete road surface</td><td>Concrete road surface</td></tr>
</table>

The climate projections used for the derivation of the Combination Value of Climate (CVC) were provided by CORDEX. Figure 19 shows the climate indicators for DPC-06a - Heat-related damages and restrictions on the asphalt road surface for three different future time periods at low GHG concentration.

| Number of hot days | | |
|---|---|---|
| 2011-2040 | 2041-2070 | 2071-2100 |
|  |  |  |
| Number of summer days | | |
| 2011-2040 | 2041-2070 | 2071-2100 |
|  |  |  |
| Heat waves | | |
| 2011-2040 | 2041-2070 | 2071-2100 |
|  |  |  |

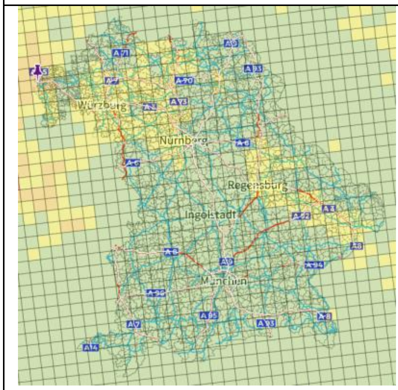
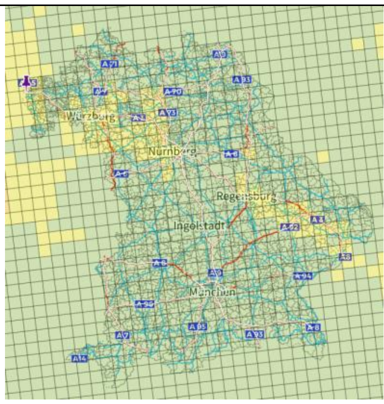
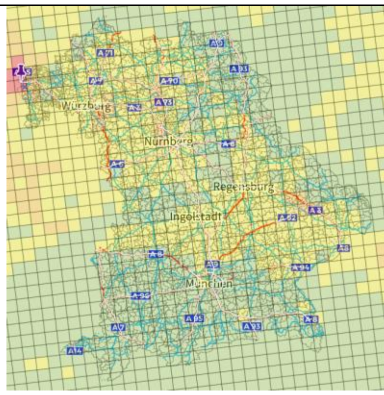
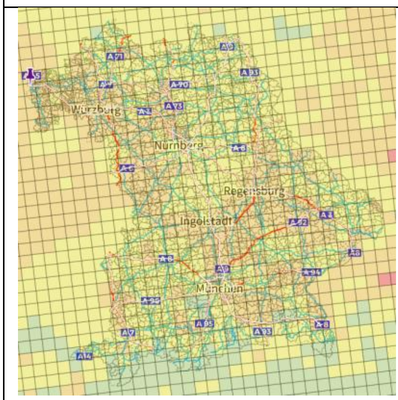
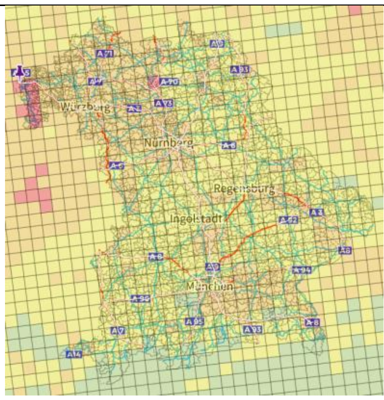
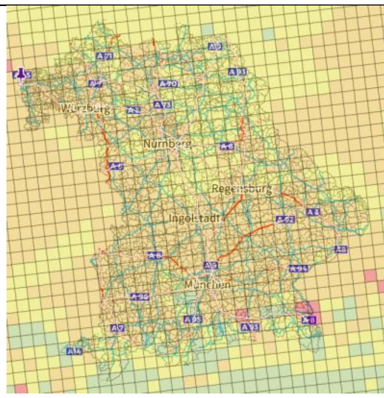
| | | |
|---|---|---|
| Tropical nights | | |
| 2011-2040 | 2041-2070 | 2071-2100 |
|  |  |  |
| Maximum temperature | | |
| 2011-2040 | 2041-2070 | 2071-2100 |
|  |  |  |
| | | |

Figure 19. Climate indicators for DPC-06a - Heat-related damages and restrictions on the asphalt road surface

# Annex B: Austria pilot study

Annex B provides a description of the pilot study carried out in Austria for the risk assessment and cost-benefit analysis tool.

## Case study description

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 20 the Austrian pilot study consists of most of the existing motorways, except parts of the A10 (Tauern Autobahn) and S16 (Arlberg Schnellstraße) where data is missing.

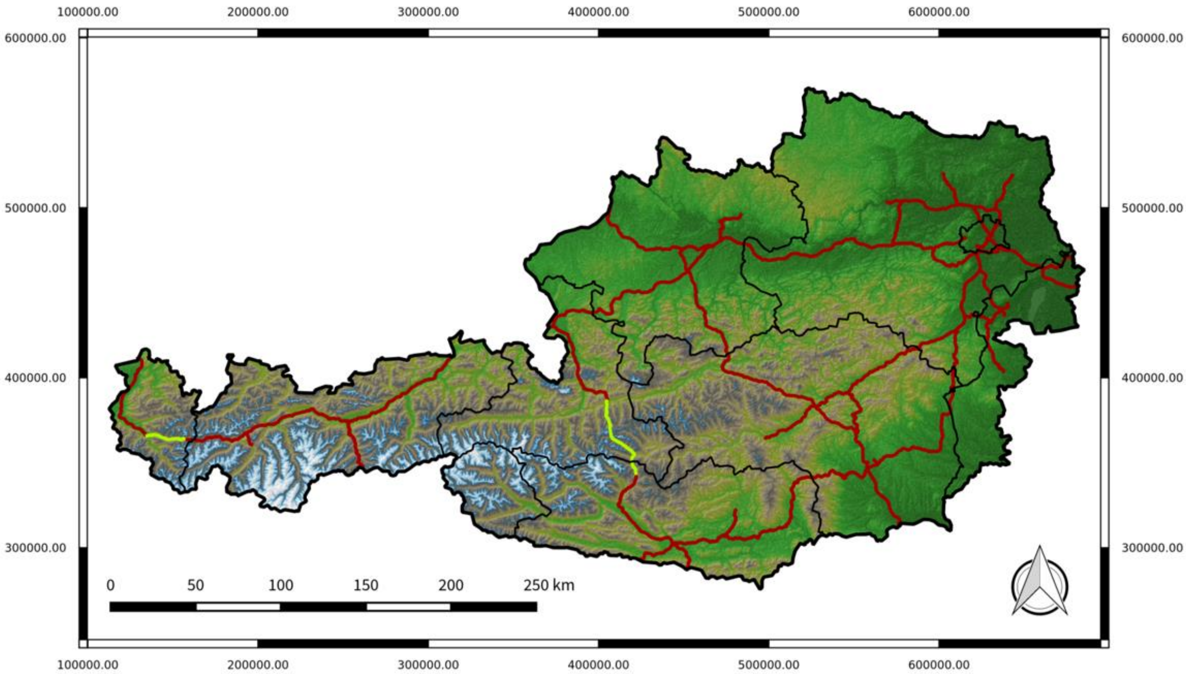



Figure 20: Overview of Austrian road network (red) participating in the pilot study

## Data acquisition

Within the Austrian pilot study, data from different sources had to be prepared, adjusted and pre-processed to obtain a merged, single data set. AIT is the operator of a high-performance measurement truck (RoadSTAR system) which was used to measure all relevant parameters for pavement management and road safety, i.e. skid resistance, transverse and longitudinal evenness, curve radii, gradient, crossfall, water film thickness (see Table 5). As a first step, a merged data set with a resolution of 1 m was created for the whole motorway network, which was aggregated to 100m segments. Several statistics (median, standard deviations, quantiles etc.) were calculated for each section to obtain characteristic values.

The following DPCs were selected for the 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

Table 5: Data set description for Austrian pilot study

| Variable name | Scale | Description |
|---|---|---|
| ***AADT*** | [-] | Annual averaged daily traffic (veh/24h); median value in period 2013–2016 |
| ***Bendiness*** | [gon/m] | Bendiness of road defined as the mean absolute change of heading angles [Gon/m] |
| ***Crossfall*** | [%] | Horizontal slope of road |
| ***Heavy Good Vehicles (HGV)*** | [-] | Annual averaged daily HGV traffic (veh/24h); median value in period 2013–2016 |
| ***Skid resistance*** | [-] | Frictional force between the measuring tyre and the wet road surface. The parameter obtained is designated as friction coefficient µ. Water film thickness between 0.5mm and 2mm and measuring speeds between 40 km/h and 120 km/h can be present. |
| ***Cracks*** | [-] | Reclassified from crack percentage as defined in RVS 13.01.16 (Assessment of Surface Defects and Cracks on Asphalt and Concrete Roads) |
| ***Gradient*** | [%] | Longitudinal slope. |
| ***Rut depth (transverse evenness)*** | [mm] | Measuring unit: fan-shaped arrangement of 23 laser sensors mounted on the front bumper. The measuring beam records the distance between the sensor and the pavement surface in order to determine the rut depth, profile depth and rut spacing. |
| ***Patches*** | [%] | According to RVS 13.01.11 (Pavement Distress Catalogue for flexible and rigid Pavements) surface damages comprise of four damage patterns (ravelling, grain break-out, mends, binder spill). |
| ***Voids/spalling*** | [%] | According to RVS 13.01.11 (Pavement Distress Catalogue for flexible and rigid Pavements), asphalt spalling consists of voids and potholes. No specific information on patches alone can be derived from this information. |
| ***Lanes*** | [-] | Number of lanes (categorical; levels 2, 3, 4) |

# Annex C: Scotland pilot study

Annex C provides a description of the pilot study carried out in Scotland for the risk assessment and cost-benefit analysis tool.

## Case study description

The Scottish trunk road network is 3,507km 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 21).

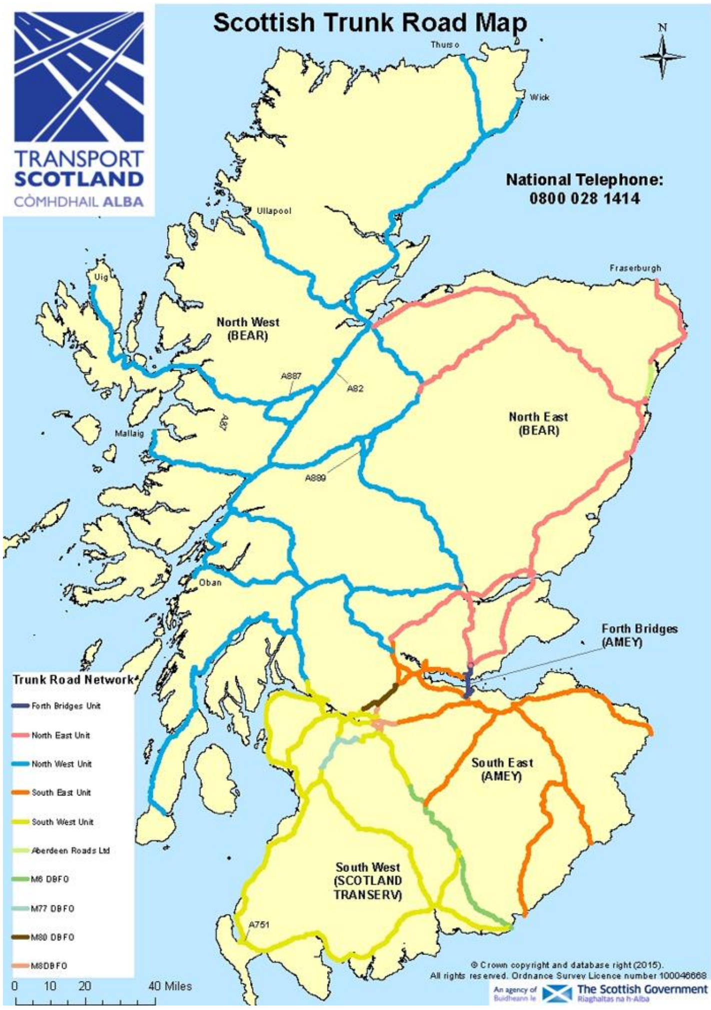



Figure 21. Map of the Scottish trunk road network

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.

## Data acquisition

Asset data was collected for the 636km of road network which makes up the South West Unit (shown in yellow in the network map). The tool was set up with three basic asset types for the pilot studies (asphalt roads, concrete roads and bridges). Transport Scotland does not have any concrete roads, so two asset types were used for this pilot study. The data requirements also depend on which DPCs are being analysed, for the Scottish pilot study this was frost related damages on asphalt road surfaces, wind related damages and restrictions on bridges and coastal flooding damages and restrictions on asphalt road surfaces.

Data had to be obtained from different databases held within separate parts of the Transport Scotland, for example bridge and pavement data is held in separate databases managed by different teams. This involved liaising with a number of different individuals within the NRA. Much of the required asset data came from SCANNER (Surface Condition Assessment of the National Network of Roads), the traffic speed vehicle survey routinely carried out to collect data on different types of pavement defects. The data (normally collected per 10 metres) is uploaded into an asset management system and used to generate condition indicators for indicating areas for further investigation, prioritising maintenance or reporting to government.

The original RIVA methodology the tool was based on was designed for the German road network so there were some differences which required adjustment to the tool, for example the use of different types of road surfacing or differences in data availability. The indicators, thresholds and weightings were adjusted to reflect these differences.

The asset data types collected from Transport Scotland are listed in Table 6. Also collected was locational and classification data such as road and section names, identification codes, and basic characteristics such as number of lanes, road type and asset type. Some environmental data such as geology and fetch was obtained from other freely available published sources. Most asset data is recorded by section.

Table 6. Data variables collected from Transport Scotland

| Variable name | Unit of measurement | Description |
|---|---|---|
| ***AADT*** | | Total average annual daily traffic flow (latest available) |
| ***Date of construction*** | | When the asset was constructed – enables age of asset to be calculated. |
| ***Direction*** | | Direction of road (e.g. east, south west etc.) |
| ***Elevation*** | metres | Road elevation as measured by SCANNER |
| ***Environment*** | | Options are rural, urban, suburban, layby, roundabout, slip road |
| ***Commercial traffic*** | | Average annual daily traffic flow of commercial vehicles |
| ***Crossfall*** | % | Transverse slope |
| ***Clearance*** | Metres | Used as a proxy for height of bridge |
| ***Cracking*** | % | Each 10 metres length is divided in 200mm squares. The number of squares with a crack is divided by the total number of squares to give a proportion of cracked squares. |
| ***Gradient*** | % | Longitudinal slope. |
| ***Date of last resurfacing*** | | Date of last resurfacing |
| ***Rut depth*** | mm | Calculated from transverse profile measured using |
| ***Surface type*** | | Type of surfacing material e.g. hot rolled asphalt, thin surface course |
| ***Speed limit*** | mph | Normal legal maximum speed for the road section |
| ***Thickness (bitumen)*** | mm | Depth of asphalt layer |
| ***TEN- T*** | | If the road is part of the TEN-T network. True or False. |
| ***Windscreen*** | | Yes or no |

# Annex D: Sweden pilot study

Annex D provides a summary of the case study information gathered for procurement online collaboration platform from the Swedish NRA. It forms the basis for the information uploaded into the tool.

## 1. Case study description

Sweden was chosen as a pilot study country for procurement because of Trafiverket (the Swedish Transport Administration)'s experience with embedding carbon emission reductions into its procurement process. Sweden has also 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.

## 2. Climate change policies and targets

### *2.1 Carbon reduction policies and targets*

#### *2.1.1 National*

From 1 January 2018 Sweden has a new Climate Act. The Climate Act establishes that the Government's climate policy must be based on the climate goals and specifies how work is to be carried out. The Climate Act states that the Government must present a climate report every year in its Budget Bill and draw up a climate policy action plan every fourth year to describe how the climate goals are to be achieved. The goals are that Sweden shall have no net emissions of greenhouse gases in 2045, 75 percent lower emissions of GHG in 2040 and 63 percent lower in 2030 compared to 1990. A prior goal is to reduce emissions by 40 percent by 2020 compared to 1990. There is also a sector goal that the transport sector (domestic transport excluding aviation) shall have 70 percent lower emissions of GHG in 2030 compared to 2010.

The Swedish government together with the construction industry produced a roadmap setting out the steps to achieving carbon neutral infrastructure by 2045. The initiative was led by the industry; it involved 30 to 40 different organisations with Skanska leading the roadmap's development. Trafikverket together with other key stakeholders participated in its development. The roadmap was published in April 2018 and is available (in Swedish only) at http://fossilfritt-sverige.se/wp-content/uploads/2018/01/ffs_bygg_anlaggningssektorn.pdf

#### *2.1.2 Organisational*

There are targets specific to the transport sector to support these ambitions, including some specific to transport infrastructure as this accounts for 5-10 percent of the road and rail GHG emissions. The Swedish Transport Administration, based on the national targets, has decided to set a long term goal to have climate neutral infrastructure by 2045, with interim targets of a 30 percent reduction in GHG by 2025 and 15 percent by 2020 compared to 2015 values. A goal for 2030 will be set in the beginning of 2019.

## 2.2 Climate change adaptation policies and targets

### 2.2.1 National

In March 2018 Sweden's first national climate change adaptation strategy was published and a law was passed that public administrations need to produce action plans, set targets and carry out risk assessments in relation to climate change adaptation.

### 2.2.2 Organisational

Trafikverket's Strategy for Climate Change Adaptation (link to PDF) 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. Following this an action plan (link to pdf) was developed to identify the actions required to implement the Strategy. In 2018/19 the Swedish government have provided Trafiverket a budget to fund climate change adaptation actions focusing on risk reduction.

# 3. Sources of GHG in road transport

Major contributors to GHG emissions in road transport in Sweden include:

- Traffic – approx. 80%
  - Direct emissions
  - In direct emissions from fuel (extraction, production and transport)
- Vehicles approx. 10-15%
  - Manufacturing (incl. materials)
  - Maintenance
  - Scrapping
- Infrastructure approx. 5-10%
  - Construction
  - Land use change
  - Operation and maintenance

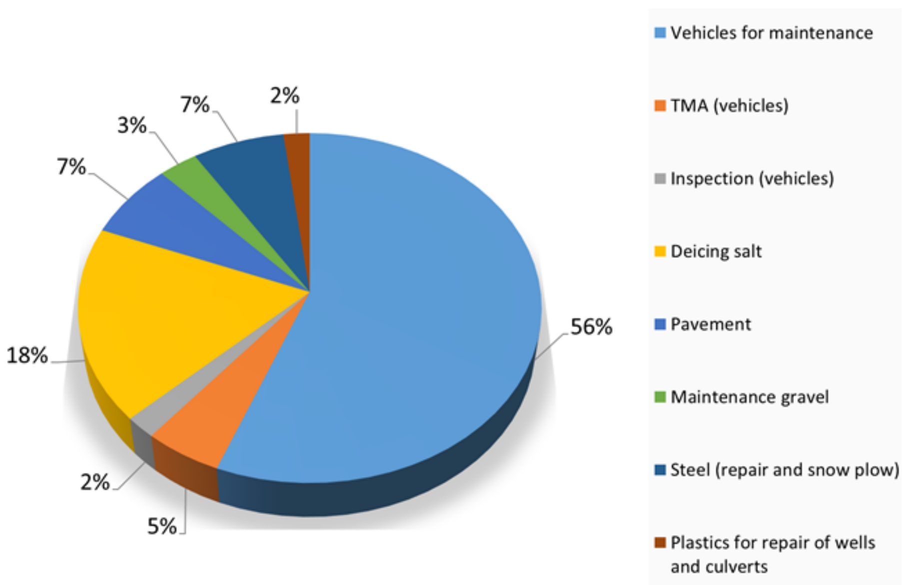



Figure 1. Sources of GHG in road maintenance, *Klimatkalkyl baskontrakt väg, WSP*

Major contributors of GHG emissions in road maintenance are:

- Fuel
- De-icing salt
- Pavement
- Repair of railing and use of snowplough (steel)

Sources GHG emissions from infrastructure projects (both road and rail) include:

- Concrete/Cement
- Machineries and trucks (fuel)
- Reinforcement steel
- Construction steel
- Asphalt

Road maintenance contributes 0.11 million tonnes of $CO_{2eq}$ per year.

# 4. Procurement approach

## 4.1 Mitigation

Trafikverket has introduced procurement requirements designed to reduce carbon emissions from its infrastructure projects. At the start it decided its approach had to follow six basic rules:

- Take a long-term perspective
- Be technical neutral
- Include monitoring
- Provide incentives for doing more
- Impose a penalty for not fulfilling requirements
- Include an assessment of the impact

The approach developed involves measuring the carbon emissions associated with an infrastructure project over its lifecycle, setting carbon reduction targets and providing suppliers with financial incentives to meet these targets. Functional specifications are utilised which provide tenderers with the freedom to suggest innovative materials and designs which reduce carbon, but still achieve the required functionality. There was a wide-spread consultation process involving contractors, material manufacturers and consultants before the procurement requirements were introduced and an impact study was carried out to assess the likely impact of introducing the new requirements (see Section 6).

### *4.1.1 Tools*

**Klimatkalkyl**

Trafikverket developed an LCA tool called ***Klimatkalkyl*** (Climate Calculator) to provide a consistent way for its staff and suppliers to estimate the GHG emissions and energy use associated with a project over its construction, operation and maintenance. 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. The user selects the type of component/material, and provides the quantities and transport distances; information already recorded for costing purposes.

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. As the project progresses additional detail can be added providing a more accurate estimation. The tool was initially developed in Excel, but is now available online. It is reviewed and updated annually including adding data from new EPDs (verified by a third party).

Klimatkalkyl*:*

- enables efficient and consistent approaches to calculate GHG emissions and energy use for infrastructure using a life cycle perspective (aligning with ISO 14040:2006 and EN 15804)
- builds on existing data (e.g. collected for costing) and is simple to use.
- Klimatkalkyl version 1.0 was developed in 2013, after which further development has taken place.
- from 2015 climate calculations are a mandatory requirement for new investment projects with a budget over > 50 MSEK that are due to be completed by 2020 (Guideline TDOK 2015: 0007)
    - it is used for decision making, improvement work and reporting
    - from early planning to climate declaration of completed road
- Since February 2016 (version 5.0) it has been expanded to enable the calculation of the carbon associated with the maintenance of existing roads.

Screenshots from the Klimatkalkyl user interface show the data input categories and output of results (Figures 2 and 3).

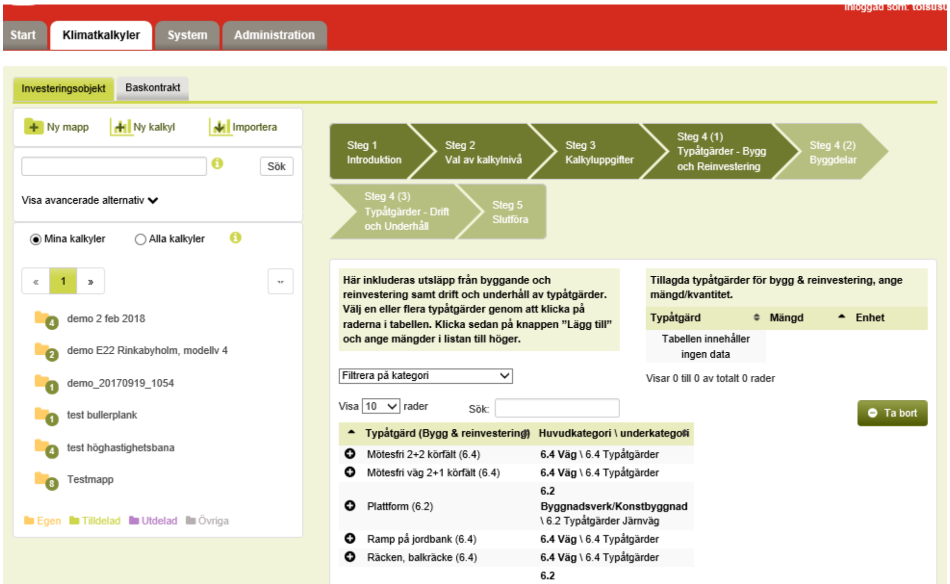



Figure 2. Klimatkalkyl user interface

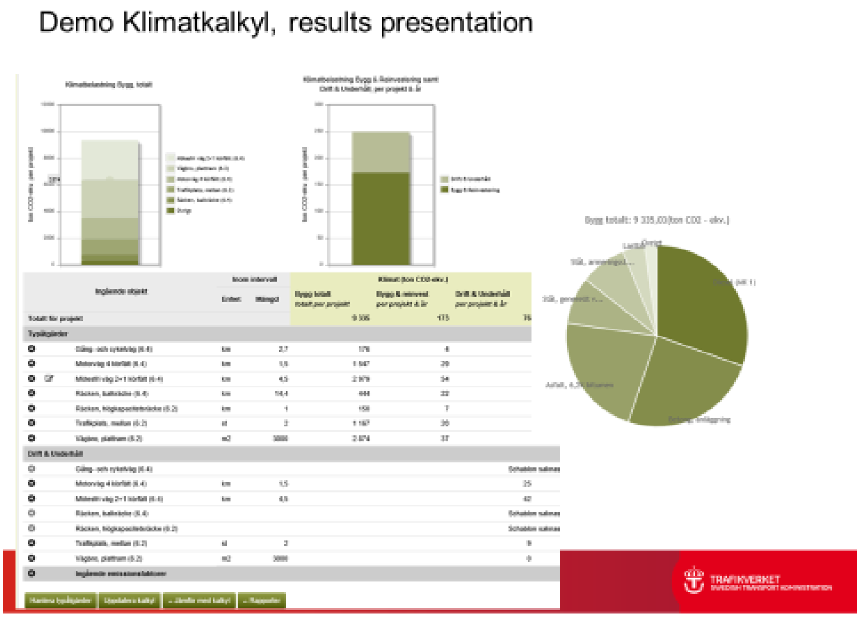



Figure 3. Klimatkalkyl results page

The Traffic Authority's guideline TDOK 2015: 0007 (Climate Calculation - Energy Conservation and Climate Impact in a Life Cycle Perspective) (link) provides information on when and how the tool should be used. The tool is available online (in Swedish) - http://webapp.trafikverket.se/klimatkalkyl/

**Geokalkyl**

Trafikverket also use a GIS tool called Geokalkyl in the early planning phase of a project to evaluate road and railway routes and overall design concepts. Information on the proposed route and design standard together with maps of elevation, terrain, land use and soil are used to assess the proposed route and design. The tool enables the identification of the points where some form of crossing is required and compares the installation of a bridge or tunnel. It also lets the user compare geotechnical approaches such as cut and fill options, stabilisation techniques etc. In addition to estimating the construction cost of each option it also produces an estimation of the energy consumed and GHG emissions. This enables the user to make an informed decision based on both cost and environmental concerns.

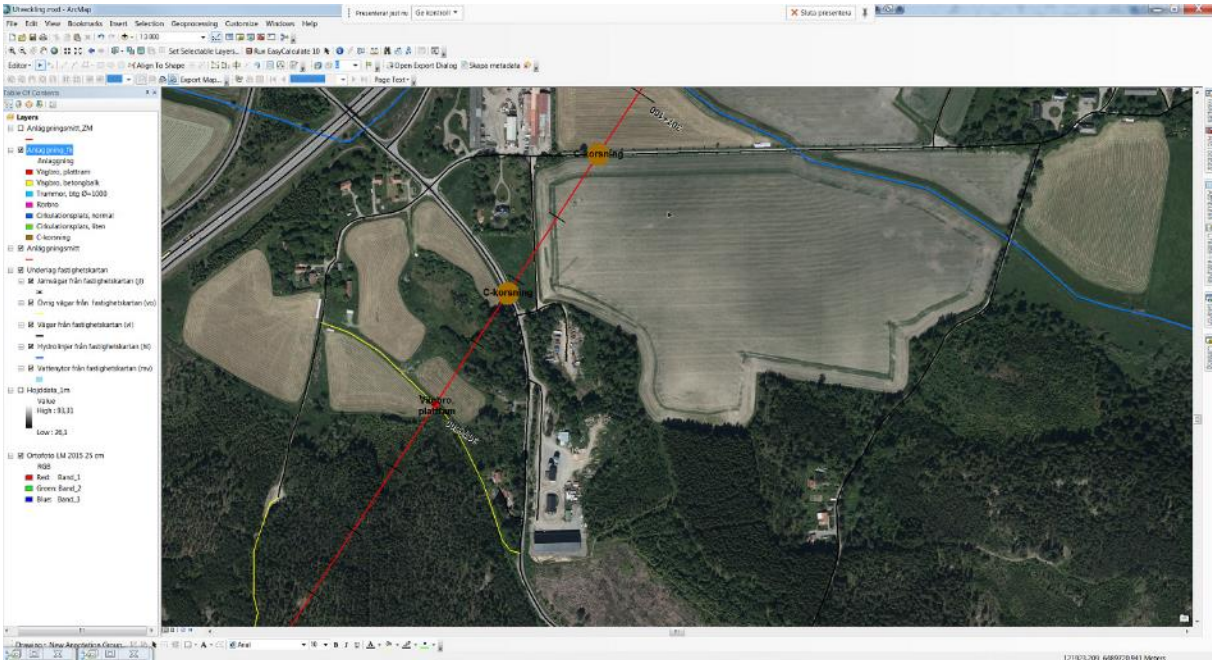


Figure 22. Screenshot of Geokalkyl

More information on Geokalkyl can be found here (in Swedish only) - http://www.swedgeo.se/geokalkyl

**EKA tool**

Trafikverket has developed an LCA tool called EKA which calculates the embodied carbon of asphalt. It includes the production of the mix from its constituent materials, transport and laying on site. The input data is from Eurobitume and as far as possible real data collected by plant suppliers, aggregate producers etc. The tool enables the user to calculate the $CO_{2eq}$ saved by using recycled aggregate, reclaimed asphalt, cold/warm asphalt, local materials etc. so that the lowest carbon material that fulfils the project requirements can be selected.

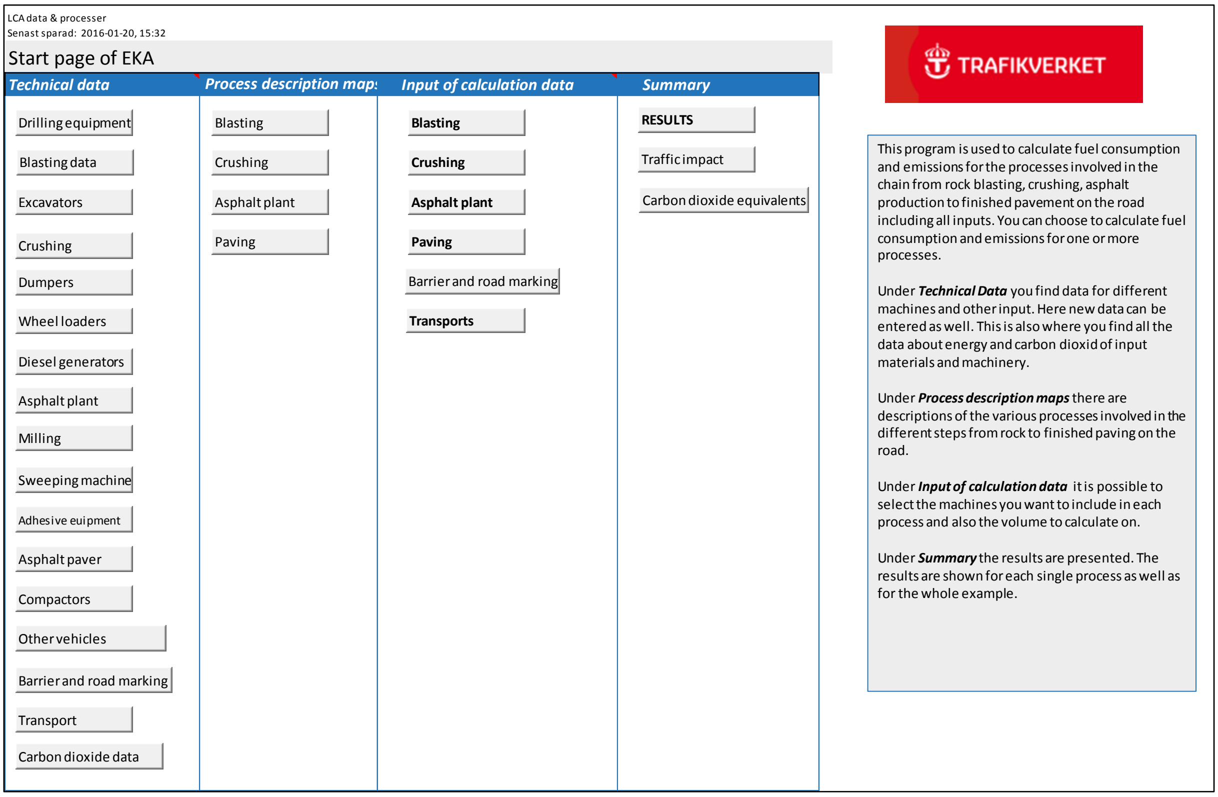



Figure 23. Screenshot of EKA tool

More information can be found here - http://www.h-a-d.hr/pubfile.php?id=1007

### 4.2 Adaptation

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).

## 5. Implementation in procurement

In April 2015 the Swedish Transport Administration made it mandatory to use Klimatkalkyl to calculate the GHG emissions and energy for all new infrastructure projects with a total budget over 50 million SEK (5.4 million €) which will be completed after 2020. Since February 2016 the tool has been used to set procurement requirements in projects that meet these criteria.

From March 2018 there are also requirements on materials and fuels in smaller projects (below 50 million SEK) and maintenance projects regardless of size. In these the requirements are directly on the climate performance of the materials and fuels since climate calculations not are done on these. In 2019 also requirements on pavement contracts and on summer and winter maintenance will be introduced.

As part of the early project planning process Trafikverket establishes a baseline carbon value for each relevant project using the Klimatkalkyl tool. It uses the tool to compare different options, for example comparing the GHG emissions associated with different routes, or tunnels with bridges. Once a route is selected the assessment enables the identification of the main contributors of GHG and an internal workshop is held to identify potential measures to reduce GHG measures and set a realistic carbon reduction target for suppliers. Trafikverket defines the carbon reduction target for the project as a percentage of the baseline and assigns the bonus available for exceeding this target (currently this is a maximum of 10% of the project value). If a significant change to the scope of works is made during the project the baseline is updated, but the target is retained.

Although the targets will vary depending on the project, on average the target reductions are:

- 15% for contracts ending 2020 - 2029
- 30% for contracts ending 2030 or later

Based on Trafikverket's experience up to a 50 percent reduction in carbon over the project lifecycle can be achieved without increasing project costs. Often cost reduction and reduction of carbon go hand in hand. Even larger reductions (than 50 percent) can be achieved with only minor increase in cost. This is mainly because material type and quantity have a large impact on carbon emissions, whereas the main component of economic cost is labour. Therefore even if using lower carbon materials increases material costs by a few percent there is little impact on the overall project budget. Clients need to ask for low carbon materials and then suppliers will provide them.

The NRA provides functional specifications, together with the baseline assessment and reduction targets. Suppliers submit tenders including measures to reduce GHG emissions and their estimate of the carbon savings this will produce calculated using Klimatkalkyl. In their tenders the suppliers do not need to show their calculations how to reduce the emissions. They only guarantee that they will achieve the target. The tenders are not evaluated for their sustainability, instead a systems of bonuses and penalties are employed to provide a financial incentive for reducing carbon. During the contract Trafikverket discuss the proposed measures with the contractor so that both parties are sure that they will be achieved. At the end of the project a climate declaration is submitted by the supplier providing the carbon value based on the actual materials and quantities used. 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 EPDs stored in the tool are available for download for suppliers (in Swedish only). Trafikverket obtains input from the industry regarding the EPDs and updates the tool accordingly. Development of the EPDs is a transparent process as sources are available (where it comes from and who developed it).

Once the climate declaration and any supported EPDs are submitted Trafikverket applies its bonus and penalty system:

- A bonus is paid if the supplier achieved a reduction of GHG emissions greater than the target set. The bonus given normally corresponds to about 1% of the contract value for a reduction of 10% more than the requirement. There are plans to give bonuses up to 100 % reduction for projects due to complete 2030 or later. They consider that these bonuses will not need to be more than 2 percent of the contract value for 100% reduction.
- If the requirements are not achieved, the contractor will not receive the carbon bonus or other bonuses e.g. for delivering on time.
- The amount of bonus or penalty applied is based on how far above or below the target the carbon value is.

In parallel with the new procurement requirements Trafikverket has been working with suppliers on reducing the carbon associated with commonly used carbon intensive materials such as asphalt and steel. They have been reviewing their procurement requirements on selected materials such as steel, concrete and cement.

Advise to other NRAs:

- Start by requesting suppliers to provide carbon calculations for projects rather than introducing carbon reduction requirements right away.
- Strengthen the requirements (i.e. increase carbon reduction) gradually over time in line with national and internal targets. At the same time increase the level of reduction needed to achieve 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.

## 6. Assessment of impact and stakeholder engagement

Trafikverket has carried out various forms of stakeholder consultation as part of the introduction of the new procurement requirements. Before applying the new procurement approach it consulted widely with suppliers and carried out an assessment of the potential impact of introducing the new requirements. In general suppliers were supportive of the proposals and the impact assessment suggested there should be little impact on project cost with reduction targets up to 30%.

In autumn 2018, after the requirements had been in place for two years Trafikverket commissioned a research project to carry out a review of the new procurement approach and map out its approach beyond 2029. During this research project the consultant interviewed entrepreneurs, consultants and suppliers about their experiences with the new procurement requirements. They were asked if the targets were appropriate, how easy the tool was to use and how further carbon reduction could be achieved. One of the biggest challenges is establishing an appropriate baseline level and reduction target, and the suppliers sometimes challenged the baseline assessment. The consultants have selected three projects to review in more detail. The project is due to be completed in December 2018.

As the procurement approach has been employed on projects completed in 2020 or later it is too soon to be able to evaluate the overall impact. However, Trafikverket consider the approach to have been successful and are expanding it to include lower value projects and maintenance projects in addition to new build. Based on Trafikverket's experience up to 50 percent reduction in carbon can be achieved without seeing any increase of the overall cost of the project. In most case suppliers are far exceeding the targets set. Some suppliers are very knowledge about carbon reduction actions, others are less so and would prefer to have a greater steer from the NRA. Trafikverket held a conference for 70 - 80 of their suppliers and asked them whether they would prefer to be provided with specific carbon reduction actions and KPIs rather than set a high level target. The response from the majority of suppliers (70-80%) was that they prefer the NRA to produce functional requirements and set high level targets enabling them to suggest carbon reduction actions that meet these. It wasn't necessarily the small organisations which struggled with carbon reduction; often small suppliers can be very innovative. Trafikverket hope that the new requirements will encourage those who are less knowledgeable about carbon reduction to upskill their staff so they can obtain the bonuses.

In order to encourage climate neutral infrastructure it is necessary to have government support and actions such as subsidies or incentives for companies producing lower carbon building materials such as concrete. Research programmes on low carbon materials are also important. In Sweden these actions are supported by the Energy Agency which funds research that can help meet the national $CO_2$ reduction targets.

## 7. Other carbon reduction actions

In addition to the inclusion of carbon reduction targets in the larger projects and the specific requirements on materials and fuels in smaller projects and maintenance regardless size Trafikverket also has requirements on railway materials that the administration buy directly for use of the contractors. For example they worked with the producers of concrete railway sleepers and achieved high $CO_2$ reductions without increasing cost (see figure 4 below). By decreasing the dimensions of the sleepers, which were for the most part unnecessarily large for the load, both carbon emissions and cost was decreased. Trafiverket has found that achieving climate neutral infrastructure doesn't necessarily mean an increase of total project cost, and sometimes reducing carbon can also save money.

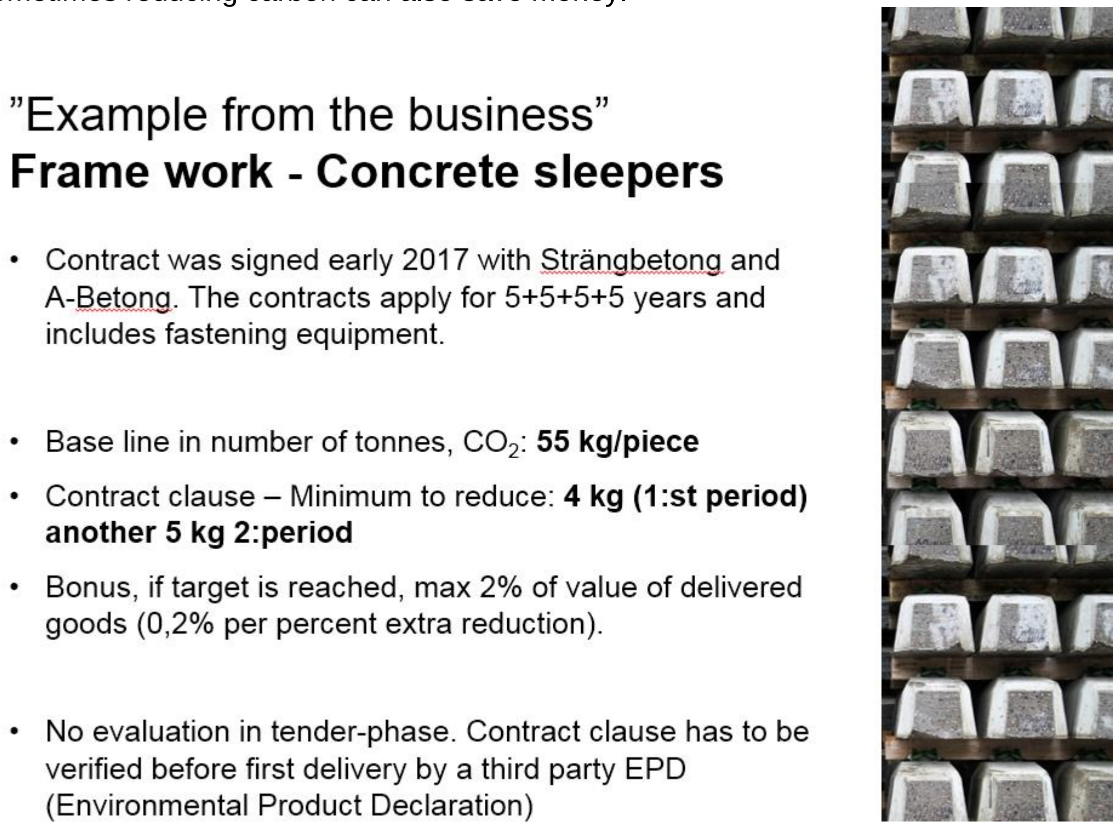



Figure 4. Concrete sleepers example

They are also planning on introducing requirements for zero emission plant to be used during construction, e.g. electric battery powered diggers.

## 8. Summary

Since 2016 Trafikverket has included carbon reduction targets in all its procurement requirements for large new build infrastructure projects due to be completed from 2020 onwards. It developed a carbon calculation tool called Klimatkalkyl to establish a baseline carbon footprint and provide a consistent methodology for measuring carbon emissions. This tool was designed to be simple to use and includes default emission factors for the most commonly used construction materials and components in order to reduce the data requirements. The tool is used at different stages of the project lifecycle; initially by the NRA to establish the baseline and appropriate carbon reduction targets and then by the supplier. Trafikverket issues functional specifications and allows the supplier the flexibility to develop an approach which meets the functional requirements and the carbon reduction target within a competitive budget. 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 put in place during 2018 on materials and fuels used in smaller projects and maintenance contracts that currently do not have climate calculations as an interim measure. Trafikverket is currently piloting the expansion of the approach used in 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.

# Annex E: Norway pilot study

Annex E provides a summary of the case study information gathered for procurement online collaboration platform from the Norwegian NRA. It forms the basis for the information uploaded into the tool. This case study was based on interviews and information provided by NPRA in summer/autumn 2018.

## 1. Case study description

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. 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.

## 2. Climate change policies and targets

**National**

The National Transport Plan (NTP) is a 10-year-plan (2014-2023) that is revised every fourth year, under the direction of the Ministry of Transport and Communications. The overall objective of the current NTP is: “A transport system that is safe, enhances value creation and contributes to a low-carbon society.” One of the main goals of the NTP is a reduction of greenhouse gas emissions and environmental impacts by the transport sector, to help meet national targets and Norway's international obligations. Preliminary studies for the last three NTPs included climate change and the transport sector´s need for adaptation. There are no explicit investments in adaptation to climate change, although changes in design rules and investment in maintenance will affect cost.

In June 2017 the Norwegian Parliament adopted a Climate Act which sets a target to reduce national GHG emissions by 40% by 2030 and by 80-95% by 2050 compared to 1990 values. The act also requires annual reporting of GHG emissions.

The Official Norwegian Report “Adapting to climate change” proposes that adaptation efforts can be strengthened by including knowledge on the effects of climate change in the highway standards (planning, capacity design and building) and specifications, and using these standards and specifications. Furthermore, that in order to do so, it is not enough to use only historical weather data as basis and climate change needs to be taken into account.

**Organisational**

***Adaptation***

NPRA have two research and development programmes relevant to climate change. The programme “Klima og transport” (climate and transport) initiated in 2007 focuses on climate change impact and risk assessment as well as on the derivation of adaptation measures in order to improve design, construction and maintenance of the road network in order to adapt to climate changes. The final report was published in 2013 and the findings are now being implemented. The NPRA’s project “Climate and Transport” represents a significant adaptation initiative for Norway.

In the NPRA project “Climate and Transport”, design manuals have been reviewed to ensure that the climate change is taken into account. The committee recognised that climate change adaptation in form of increased maintenance requirements and changed requirements for new parts of the infrastructure results in higher costs.

Both the current NTP 2010-2019 and the NPRA's Action Programme defined several goals for climate change adaptation: (i) prioritisation of maintenance, (ii) improvement of existing roads rather than building new roads, (iii) development of alternative contract types to reduce operation and maintenance costs.

With the R&D-programme "Climate and Transport" four main groups of adaptation measures were defined:

- <u>Planning, design and construction of new roads</u>
  The effects of climate change should be considered as an integrated part of the planning and development of a road project. For example, the road should be placed in areas less prone to landslide and flood hazard, or where this hazard is easier to handle.
- <u>Operation, maintenance and management of existing road network</u>
  Adaptation measures should preferably be carried out as part of scheduled maintenance. It is planned to include Climate Change in the risk assessment.
- <u>Preparedness and contingency plans (stepwise preparedness)</u>
  different level of preparedness were defined for the case of a climate event occurs (i) Yellow: possible threat under special conditions and elevated preparedness; (ii) Orange: threatening weather situation, could cause damage in some places and requires a high level of preparedness; (iii) Red: threatening weather situation in several places, requires an emergency level of preparedness. As part of the preparedness strategy the web portal www.xgeo.no. is an expert tool used for preparedness, monitoring and forecasting of floods, landslides and avalanches; with maps and time base compiled data from stations and models with events and field observations.
  An improved template for an emergency plan for natural hazard has been formulated and is being implemented in operation contracts. The plan includes more elaborate use of weather data and map-based information concerning the specific road stretch. Contractors can receive information concerning flood and landslides: history, statistics, repair carried out, special problems etc.
- <u>Improving the knowledge base for adapting to climate change</u>
  Support climate research and implementation of new knowledge. Interpretation of climate research for practical use is a precondition for adaptation. Improved monitoring of weather events. Improving maps and GIS databases. Good interface solutions, functional databanks for landslide data, better documentation of events in every-day operations.

Landslides and flooding have been identified as the main issues for Norway in the context of climate change.

***Mitigation***

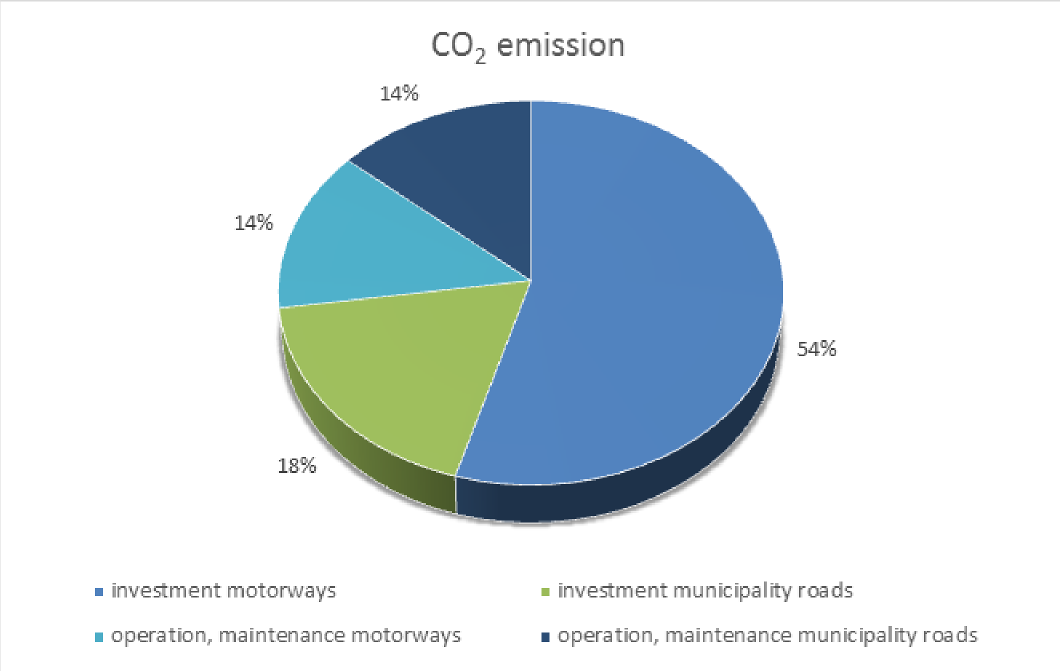
The other main project is named KraKK – "Krav til Klimakutt I Konkurransegrunnlag" (climate change requirements in public procurement) and focuses on possibilities to implement carbon emission-reductions requirements in the public procurement of construction, services/operational and maintenance tasks. The main task of the KraKK-project is to answer the question: How to implement carbon-reduction goals in the public procurement process. Krakk will deliver specific suggestions for contracts, process codes, manuals and courses.

The goal of the NPRA (defined in the Krakk-programme) is to reduce the carbon footprint in 2030 in relation to 1990 by:

- Operations and maintenance 50%
- Investments 40%.

## 3. Understanding the sources and quantity of carbon emissions

Approximately 2.2 million tonnes per year of $CO_2$ comes direct from the public road infrastructure. This is not including the production and operation of cars nor the production and extraction of fuel and oil. Investments in new road construction dominate the entire infrastructure's carbon footprint.




## 4. Understanding climate change vulnerability and assessing risk

The following graphs show the projected dramatic development of the annual temperature and precipitation in Norway until 2100. Along with these projections, landslides and flooding have been identified as the main challenges for Norway in the context of climate change.

Interactive maps for temperature and precipitation predictions are available on [www.klimatilpasning.no](www.klimatilpasning.no)

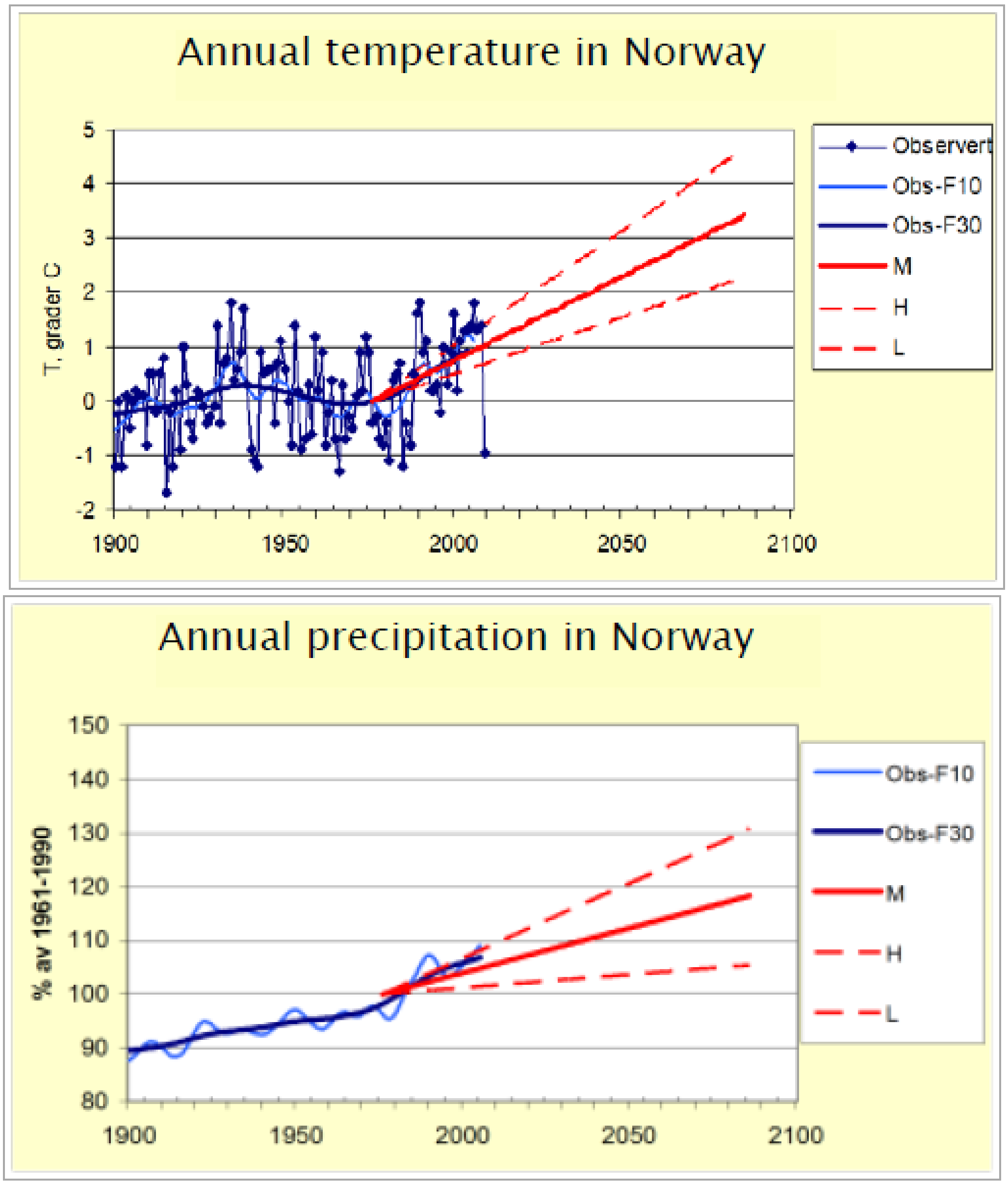



Figure 24. Norwegian climate projections (from the [Climate in Norway report](Climate in Norway report))

The Official Norwegian Report “Adapting to climate change” contains for all public sectors a short description of the challenges in the context of climate change. The Norwegian land transport infrastructure is already being affected by more frequent floods, landslides and avalanches. The report’s committee formulates the following climate change events as major events for the land transport infrastructure: (i) greater precipitation volumes (which leads to landslides, floods); (ii) increasing precipitation in the winter period (volumes and more wet snow leads to increasing problems of falling trees and blocking roads); (iii) increasing frost-thaw-cycle events; (iv) sea level rising in combination with storms (erosion and overflow). However the committee have seen also positive affects for example less snow in other parts of the country.

NPRA carries out a risk assessment on its network for multiple hazards which includes climate change. This is performed at the start of each term maintenance contract and as part of the EIA for new construction.

The NPRA have developed a tool for the risk assessment called VegROS. It uses a semi-qualitative indicator method and includes a set of spreadsheets, algorithms, and guidance rules on how to assess vulnerability of assets including climate change. Version 1 was released in 2014, version 3 is due to be launched in 2019. The assessment is carried out by a local team using their knowledge of the network together with relevant maps and data. It includes climate data up to 2050. For each section of road the threat (probability and consequence), value and adaptive capacity are scored and then combined using the equation below to give an overall risk score from 1-3. Risk is categorised into low (yellow), medium (orange) and high (red) and mapped onto the network.

| Level of threat | | Value /importance of the road | | Adaptive capacity | | Risk | |
|---|---|---|---|---|---|---|---|
| Low | + | Low | + | Low | = | Low | Measures can be implemented |
| Medium | | Medium | | Medium | | Medium | Measures can be implemented |
| High | | High | | High | | High | Measures must be implemented |

0.5 x threat + 0.2 x road value + 0.3 x adaptive capacity = risk score

# 5. Procurement approach

**Mitigation**

Since 2001 the Norwegian Public Procurement Act requires all levels of public authorities (state, counties, local), to consider its impact on the environment and resources when making any purchase. Currently NPRA do not have any official implemented mechanisms to reduce carbon through procurement, however they are testing a new approach within selected projects as part of the KraKK project. NPRA (University of Agder) have found that on construction sites almost two thirds of the carbon footprint comes from the materials and around a third from the plant vehicles and transportation from fossil fuel. The main material contributors are concrete and cement manufacturing, including reinforcement steel, and asphalt. Therefore their approach on materials focuses on a bonus/malus system connected to high carbon materials and introduction of zero-emission (electric/battery/hydrogen) machinery.

***VegLCA tool***

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 purpose of VegLCA is the environmental optimisation regarding material choices, material quantities, transport distances, bridge and tunnel designs, construction equipment and technologies as well as regarding operation and maintenance. The following pictures show the input interface and result sheet of the VegLCA-tool. Default values for emission factors are included in the tool, but new values can be added.

## HOVEDPROSESS 08: BRUER OG KAIER

| | | Bruer totalt | | Bru 1 | | Bru 2 | |
|---|---|---|---|---|---|---|---|
| | Lengde: | 510 | m | 240 | m | 270 | m |
| | Stedskode: | | | Blekken | | Hamre | |
| | | Mengde | Enhet | Mengde | Enhet | Mengde | Enhet |
| + | 81: LØSMASSER | | | | | | |
| + | 82: BERG | | | | | | |
| + | 83: KONSTRUKSJONER I GRUNNEN | | | | | | |
| + | 84: BETONG | | | | | | |
| 84.1 | Stillas, provisoriske avstivinger og overbygg | - | RS | | RS | | RS |
| 84.2 | Forskaling | - | m2 | | m2 | | m2 |
| 84.3 | Armering | - | tonn | | tonn | | tonn |
| 84.31 | Armering kamstål B 500 NC | - | tonn | | tonn | | tonn |
| 84.32 | Slakkarmering, spesialkvaliteter | - | tonn | | tonn | | tonn |
| 84.322 | Bi-stål | - | tonn | | tonn | | tonn |
| 84.323 | Armering av Kamstål, rustfritt | - | tonn | | tonn | | tonn |
| 84.324 | Armering påført korrosjonsbeskyttelse | - | tonn | | tonn | | tonn |
| 84.325 | Fiberarmering | - | kg | | kg | | kg |
| 84.326 | Ikke-metallisk armering | - | kg | | kg | | kg |
| 84.33 | Sveisede armeringsnett og armeringsenheter | - | tonn | | tonn | | tonn |
| 84.37 | Spennarmering | - | mMN | | mMN | | mMN |
| 84.4 | Valg: Betongtype — Betongstøp | - | m3 | | m3 | | m3 |
| 84.41 | Valg: Betongtype — Betongstøp over vann, normalvektsbetong | - | m3 | | m3 | | m3 |
| 84.413 | Valg: Betongtype — Betong SV-40 | - | m3 | | m3 | | m3 |
| 84.4131 | Betongstøp, B35, CEM II — Betong B35 SV-40 | - | m3 | | m3 | | m3 |
| 84.4132 | Valg: Sementtype — Betong B45 SV-40 | - | m3 | | m3 | | m3 |
| 84.4133 | Betongstøp, B35, CEM I — Betong B55 SV-40 | - | m3 | | m3 | | m3 |
| 84.4134 | Betongstøp, B35, CEM II / Betongstøp, B35, CEM III — Betong B65 SV-40 | - | m3 | | m3 | | m3 |
| 84.414 | Valg: Betongtype — Betong SV-30 | - | m3 | | m3 | | m3 |

### Resultater for E6 Egge - Sletta, totalt for 60 års analyseperiode

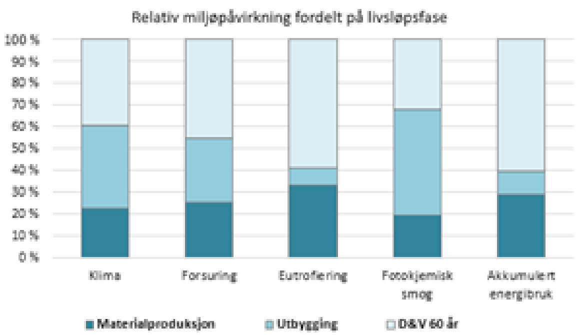
**Prosjekt- og analysebeskrivelse**

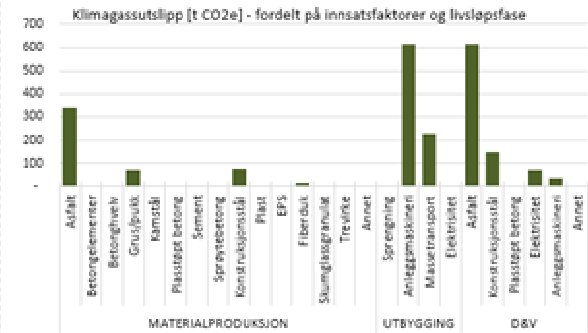
| | | | |
|---|---|---|---|
| Navn på den som har utført analysen | J. Hammervold | | |
| Dato for analyse | 02.11.2016 | | |
| Analyseperiode | 60 | år | |
| Utslippskoeffisienter brukt i analysen | Norske gjennomsnittsdata | | |
| Utbyggingsprosjekt | E6 Egge - Sletta | | |
| Vegtype | Motorveg klasse A | | |
| ÅDT | 10 000 | | |
| Fartsgrense | 90 | km/t | |
| Antall felt | 4 | | |
| Vegbredde | 23 | m | |
| Vegstrekningens totale lengde | 2 470 | m | |
| *Veg i dagen* | *1 420* | *m* | *57 %* |
| *Tunnel* | *540* | *m* | *22 %* |
| *Bru* | *510* | *m* | *21 %* |

| | Fordelt på livsløpsfase | | | | |
|---|---|---|---|---|---|
| | Klima | Forsuring | Eutrofiering | Fotokjemisk smog | Akkumulert energibruk |
| Livsløpsfase | tonn CO2e | kg SO2e | kg P-e | kg NMVOC | GJ |
| Materialproduksjon | 493 | 4 089 | 138 | 3 400 | 35 099 |
| Utbygging | 840 | 4 873 | 35 | 8 386 | 12 761 |
| D&V 60 år | 866 | 7 350 | 245 | 5 606 | 73 999 |
| **Sum** | **2 199** | **16 311** | **417** | **17 391** | **121 858** |

| | Utbygging | | | | |
|---|---|---|---|---|---|
| | Klima | Forsuring | Eutrofiering | Fotokjemisk smog | Akkumulert energibruk |
| Materialkategori | tonn CO2e | kg SO2e | kg P-e | kg NMVOC | GJ |
| Sprengning | - | - | - | - | - |
| Anleggsmaskineri | 613 | 3 716 | 14 | 6 429 | 8 913 |
| Massetransport | 227 | 1 157 | 21 | 1 956 | 3 848 |
| Elektrisitet | - | - | - | - | - |
| **Sum** | **840** | **4 873** | **35** | **8 386** | **12 761** |

| | D&V 60 år | | | | |
|---|---|---|---|---|---|
| | Klima | Forsuring | Eutrofiering | Fotokjemisk smog | Akkumulert energibruk |
| Materialkategori | tonn CO2e | kg SO2e | kg P-e | kg NMVOC | GJ |
| Asfalt | 615 | 6 277 | 117 | 4 533 | 60 818 |
| Betongelementer | - | - | - | - | - |
| Betonghvelv | - | - | - | - | - |
| Anleggsmaskineri | 36 | 216 | 1 | 373 | 518 |
| Elektrisitet | 66 | 191 | 31 | 148 | 10 279 |
| Grus/pukk | - | - | - | - | - |
| Kamstål | - | - | - | - | - |
| Plasstøpt betong | - | - | - | - | - |
| Sement | - | - | - | - | - |
| Sprøytebetong | - | - | - | - | - |
| Konstruksjonsstål | 149 | 666 | 96 | 552 | 2 384 |
| Trevirke | - | - | - | - | - |
| Annet | - | - | - | - | - |
| **Sum** | **866** | **7 350** | **245** | **5 606** | **73 999** |



***Procurement***
Contractors receive a bonus for using less $CO_2$ intensive materials (concrete, asphalt, steel) and using site plant and vehicles not powered by fossil fuel. The EPDs can be either certified EPDs obtained from third parties or self-produced by the contractors; to obtain the bonus they must be site-specific. Quantities and the carbon factor from the EPD are the basis for the calculation. NPRA will employ third party verification (by certified EPD verifiers) to carry out random checks on the contractor generated EPDs. Currently NPRA is only using EPDs for concrete and asphalt but eventually they also want to include construction steel.

Within the KraKK-project the EPD-bonus/malus-system is being piloted on selected projects. In principle the bonus is oriented on the extent of carbon emission reduction, based on the determined project specified requirements. The same applies - the other way around - for penalties paid by the contractors if the requirements are not met.

For example, the KraKK-project has proposed the following bonus payments for the use of zero carbon machines or vehicles and will test this in the different pilot projects:

- Emission free excavator > 25 tonnes receives 400kr./h (40€/h); Maximum 2 000h or 800 000kr (80.000€) This is a standard Caterpillar excavator rebuild in Norway. It can be used for approximately 5 hours work before charging the battery, the first few were delivered in late 2018.

The main objective is to get influence on the industrial production by establishing Norway as a sufficient test market for heavy electric/battery/hydrogen-equipment built elsewhere, in the same way as the country has been for small cars/family cars. This is based on the fact that Norwegian electricity is 96-98% renewable from waterpower and a strong grid.

NPRA sees the following advantages in using the bonus/malus system compared to a requirement based approach:

- No competitor will be excluded from the procurement/bidding process (otherwise: the competitor must be excluded if he cannot fulfil the requirements)
- Flexibility (project specific)
- Incentives to improve the performance constantly during the contract phase
- No formal limitation of paid results

The advantage of a bonus system is that contractors are incentivised to improve climate performance as part of the contract. It is intended that the contractor assumes they will receive the bonus when calculating their tender costs. The bonus needs to be greater than the high cost of low carbon materials.

VegLCA is also being used in the procurement process of the pilot projects. It is not connected to the bonus/malus system, but is used for environmental impact budgeting as part of the road administration procurement decision-making process.

**Adaptation**

NPRA have been carrying out climate impact assessment for the last 10 years. They started by identifying the risks from climate change for different types assets such as roads, bridges, culverts etc. More recently they have being assessing individual road sections together with the contractors using a virtual drive through and stopping to discuss problem areas. Representatives from different specialisms such as pavements, bridges, drainage etc.

attend. They use the VegROS tool to produce a risk score for each section of road. The assessment is carried out annually on road stretches covered by the various maintenance contracts. It is performed per geographical contract: looking at challenges already known and new ones occurring. One basis for the assessment is the results of the general vulnerability assessment carried out for the various type-categories of road asset elements. Actions for the road sections that have a high level of risk are agreed between NPRA and the contractors.

Based on those experiences, guidelines for design, operation and maintenance have been revised (e.g. flood proof alignment, upgraded drainage capacity, improved water management).Climate change adaptation is not currently included directly in the tender specification and evaluation processes, but NPRA and considering requiring a certain competency level from suppliers.

## 6. Assessment of impact and stakeholder engagement

The KraKK program will evaluate life cycle emissions in projects. To achieve this, NPRA works together with construction firms to create economic incentives to reduce environmental impacts through choice of machinery fuels and construction materials. The results were also used to determine GHG-baselines for the procurement process.

## 7. Summary

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, 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.

NPRA are piloting a new approach to reducing carbon through procurement. Initially it is targeting the largest sources of carbon during construction materials such as concrete, asphalt and steel and the emissions generated by fossil fuel 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 choose a tender value for the $CO_2$-factor of the main materials (concrete, reinforcement and asphalt) and use of alternatively powered plant. The difference from between the tender value and actual value determines the level of bonus or malus. The contractors need to provide EPDs for the materials used and the volume of material used must be under acceptable control for the buyer. The EPDs can be from manufacturers and/or self-generated using the EPD-generator system certified by EPD Norway (which is part of the ECO Platform group). Both the range of EPDs required and the magnitude of carbon reduction connected to the bonus will be increased with time and experience.

# Annex F: The Netherlands pilot study

Annex F provides a summary of the case study information gathered for procurement online collaboration platform from the Dutch NRA. It forms the basis for the information uploaded into the tool.

## 1. Case study description

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. This case study was based on interviews and information provided by RWS in summer/autumn 2018.

## 2. Climate change policies and targets

### 2.1 Carbon reduction policies and targets

#### 2.1.1 National

The Netherlands has a national policy to reduce its $CO_2$ emissions by 20% compared to 1990 values by 2020. The Dutch parliament is considering a new climate law which would set a 49% greenhouse gas emission reduction target by 2030 compared to 1990 levels and a 95% cut by 2050. As part of actions to achieve these targets sustainable procurement has been mandatory for all public authorities since 2015.

#### 2.1.2 Organisational

The RWS carbon reduction target is more ambitious than the national government. It aims to be climate neutral by 2030 and has set targets related to the use of asphalt (20% reduction in $CO_2$ emissions by 2025) and groundworks (10% $CO_2$ reduction in five projects by 2020). RWS has an annual carbon footprint of around 818 kilo tonnes with materials such as asphalt, concrete, steel, aggregates and groundworks the main contributors. As such materials are a major part of its green procurement policy. It aims to use its procurement process to challenge suppliers to be more sustainable, using more sustainable working practices and materials. It seeks value for money considering the whole life cycle of the infrastructure. The main drivers for carbon reduction actions by RWS are the Paris International Agreement, national targets and RWS board decisions.

### 2.2 Climate change adaptation policies and targets

#### 2.2.1 National

The Dutch National climate adaptation strategy (NAS), 2016 covers all sectors including infrastructure (English version). There is also a Government climate adaptation implementation programme as a result of the NAS, led by the Ministry of Infrastructure and Water Management. The Government has set a target in the Delta Program for the country to become climate resilience by 2050. This means having the right policies in place by 2020 and then making sure critical infrastructure is less vulnerable to climate change. Both RWS (national roads), and provinces and municipalities (local roads) need to take the NAS into account.

Another notable national influence is the Delta Programme, a national collaborative initiative focused on water management (reducing flooding, reducing salt intrusion, protecting drinking water, spatial adaptation to climate change) which includes taking into account the impact of climate change. The programme has produced a plan for spatial adaptation. This also takes into account other types of climate hazard in addition to flooding e.g. heatwaves and drought. One of the consequences is governments need to stress test the vulnerability to climate change.

*2.1.2 Organisational*

Within RWS, climate change action is primarily being led by the technical advisors, but with senior management support. It is understand that climate change can affect performance levels and RWS aim to be adaptive and not wait until impacts occur. However, the uncertainty of climate projections can inhibit action, making it difficult to convince people to take action. There are also budget restrictions, so they need to consider the cost-benefit of adaptation action. No regrets actions are preferred. RWS use cost-benefit analysis to review design options and potential payback on modifications to increase resilience. Transport is driven by costs and politics and it is not always easy to convince people to adapt, information/evidence is required. RWS make use of existing guidance and tools such as those from the EC and CEDR as much as possible.

## 3. Understanding the sources and quantity of carbon emissions

RWS have calculated their annual carbon footprint (818 kTonnes) and identify the key material/activities which contribute to this (Figure 25). It is focusing its efforts on these areas namely asphalt, concrete and groundworks (including dredging).

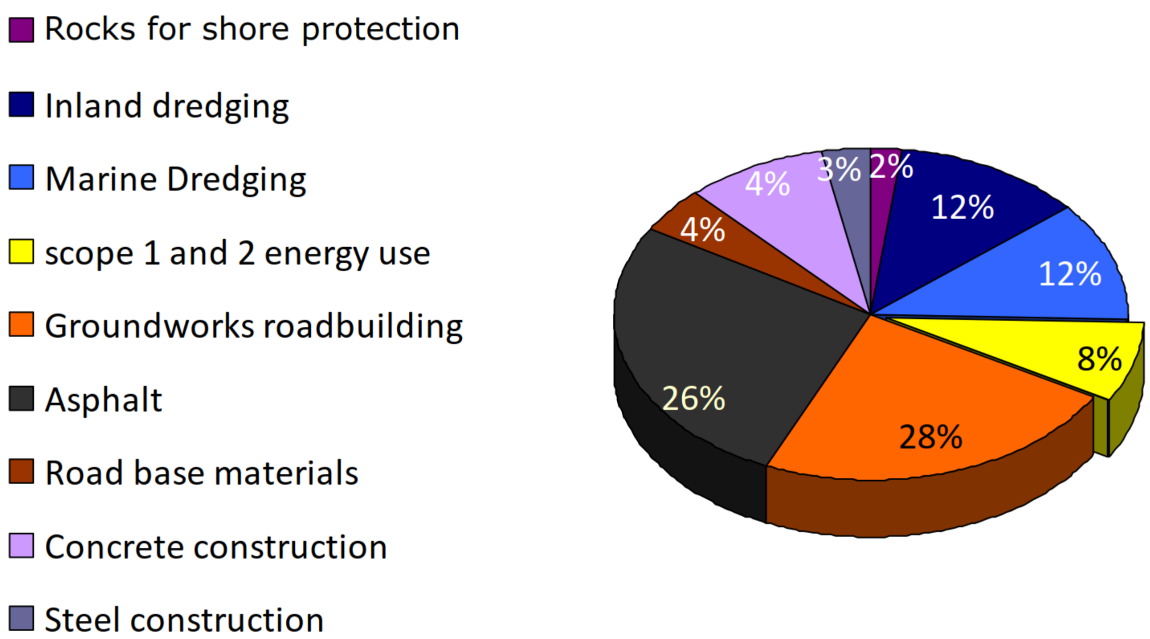



**Figure 25. RWS annual carbon footprint (source: RWS)**

# 4. Understanding climate change vulnerability and assessing risk

*4.1 Data availability*

The Royal Netherlands Meteorological Institute (KNMI), the Dutch national weather service, provides national climate projections. The current version was launched in 2014; an updated version is due in 2021. RWS has its own roadside weather information systems, which are mostly used to inform winter service decisions.

RWS collect information on traffic delays and the reasons behind congestion including those related to weather conditions. This information is analysed to identify vulnerable areas or hot spots. Data collection of reasons behind congestion is not automatic, but performed by traffic staff through CCTV etc. so is not 100% reliable. This data has been collected since 2000. In general RWS do not find a lack of data is a problem when assessing risk.

*4.2 Assessment of climate risk*

RWS plan to carry out a network wide (highway) risk assessment in 2019 for all climate hazards, working with a consultant. They have already carried a blue spot assessment (using the methodology developed in the CEDR SWAMP project) in 2012. Later on also waterways and water systems will be assessed.

They have implemented ROADAPT and the FHWA framework on a project (InnovA58) at the planning stage. The assessment of climate change and extreme weather included traffic, pavement and bridges and led to a change in design. The joint RWS and FHWA report on this can be found here https://international.fhwa.dot.gov/pubs/joint_report_resilient_infrastructure_fhwa_rws_january_2016.pdf

# 5. Procurement approach

*5.1 Mitigation*

RWS are required by national government to implement sustainable procurement and have set organisational targets related to the carbon footprint of the organisation and its supply chain. Its approach to achieving this is to use functional specifications for infrastructure projects, and create commercial incentives for suppliers to submit a more sustainable tender. This allows suppliers the flexibility to set their own sustainability goals and differentiate themselves from the competition though innovations to improve sustainability. RWS supplies the tools and framework for assessing sustainability, which means all suppliers/projects use the same methodologies and data so there is a fair comparison.

The formal procurement requirements are supported by efforts to work with the supply chain, encouraging innovation and sustainable working practices. This includes instigating targeted initiatives to address carbon intensive materials such as Asphalt Impuls (see Section 0).

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 main tools to support their sustainable procurement approach - DuboCalc and the $CO_2$ performance ladder.

**DuboCalc**

DuboCalc is a software tool developed by RWS which calculates the environmental impact of a construction design over its lifetime. The Life Cycle Analysis (LCA) methodology follows the ISO 14040 standard and calculates eleven environmental impacts including kg $CO_{2e}$. Weighting is applied to the different impacts, $CO_2$ has a 20% weighting. The tool is used to calculate the MKI value for four project phases: construction; use; maintenance; and end of life based on design, materials, transport distances etc. The output is a single value referred to as the Environmental Cost Indicator (MKI) based on the analysis. A lower value indicates a design with a lower environmental impact. This enables designers to compare design and material options, but it is also used by RWS as part of 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 criteria), and if their proposal is successful obtaining the promised MKI becomes a contract requirement.

RWS passed the development and management of DuboCalc over to the software developer Cenosco and the engineering consultancy Royal Haskoning DHV. The latest version of the tool launched in 2017 - DuboCalc 5.0 can be found here https://www.dubocalc.nl/en/

The tool is used not just for road construction, but all construction and civil engineering work. Having a single national method of calculating the environmental impact of construction underpins the approach as suppliers understand the requirements and the environmental impact of different proposals can be compared.

DuboCacl uses data from the national EPD database (see Section 0).

**Environmental impacts in DuboCalc**

- Global warming
- Ozone layer depletion
- Human toxicity
- Fresh water ecotoxicity
- Marine ecotoxicity
- Terrestrial ecotoxicity
- Photochemical oxidation
- Abiotic depletion
- Depletion of fossil energy carriers
- Eutrophication
- Acidification

**$CO_2$ performance ladder**

The $CO_2$ Performance Ladder (PL) is a concept developed by ProRail the Dutch rail infrastructure owner, but is now also used by RWS (and other companies). The PL is a sustainability tool to help organisations assess and improve their approach to reducing $CO_2$, but it is also used in procurement. Suppliers gain an advantage during the tendering process according to their level on the ladder. 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. To achieve the higher levels innovation and partnership with other organisations is required. 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. The PL assesses the sustainability of organisational working practices and DubCalc the environmental impact of the proposed design. 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.

RWS has assessed itself using the PL, initially it was level 3 now it is level 4.

The PL has had a large influence on Dutch construction industry, with many suppliers achieving a large reduction in $CO_2$. A handbook provides details of what is required at each level, and an organisation's level needs to be independently verified by a certification body. Organisations are awarded a $CO_2$ awareness certificate which is reviewed every 3 years.
SKAO are now the manager and owner of the ladder. A guide for clients wishing to implement the PL as part of their sustainable procurement policy is available on the website https://www.skao.nl/home_en

**National database of EPDs**

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.

Environmental Product Declarations (EPDs) are a form of environmental labelling for products and materials, whereby manufacturers provide information on the life-cycle environmental impacts associated with their product in a standard format. The LCA is carried out according to an internationally agreed methodology and independently verified (ISO 14025). The information can be used by purchasers to ensure materials meet specific procurement criteria and also as a data source for calculating the LCA of complex products containing multiple components. The provision of EPDs is voluntary, but whilst not all manufacturers currently produce them many do and their use is growing.

The Dutch EPD database is managed by an independent organisation (SBK) and was produced following a Government coordinated project to establish one LCA calculation methodology. There are three types of information categorises in the database:

- Brand data verified by an independent third party according to the SBK verification protocol
- Generic data for non-branded materials, verified by an independent third party according to the SBK verification protocol
- Generic data for non-branded materials which have not been verified.

EPDs for new materials can be submitted to SBK who manage the database via an online procedure. They will approve the submission. The EPD verification protocol can be found here http://www.milieudatabase.nl/imgcms/SBK_Verification_Protocol_version_2_0_TIC_versie.pdf

**Tender requirements and evaluation**

RWS evaluate tenders based on the price/ quality ratio. Quality criteria for each project are developed to align with the project objectives and RWS's overall policy. The assessment of quality includes sustainability. RWS provides functional specifications for the project including a maximum ECI value based on a reference design assessed using DubCalc. They also provide suppliers with access to the DuboCalc assessment tool, handbook and the calculation procedure which will be used to monetarise the MKI. The proposal submitted by the suppliers includes a description of their design, the bidding price, MKI value calculated using DuboCalc and PL level. As a result designers compare the environmental impact of different designs, suppliers try to use low temperature asphalt, more recycled and secondary materials and incorporate renewable energy projects into their design.

When comparing proposals, RWS monetarise the MKI value and minus this from the bidding price and apply the PL level discount. The suppliers offering the maximum MKI will receive no MEAT discount, while those offering less than this will obtain an increasing level of discount up to a maximum discount value for the minimum MKI submitted. MEAT discounts are given for other criteria too (as set out in the contract specifications). The adjusted prices of each proposal are compared and the supplier with the lowest value selected.

| |
|---|
| (Bidding price) – (%bidding advantage due to PL level) – (MEAT MKI value) – (other MEAT values) = adjusted bidding price |

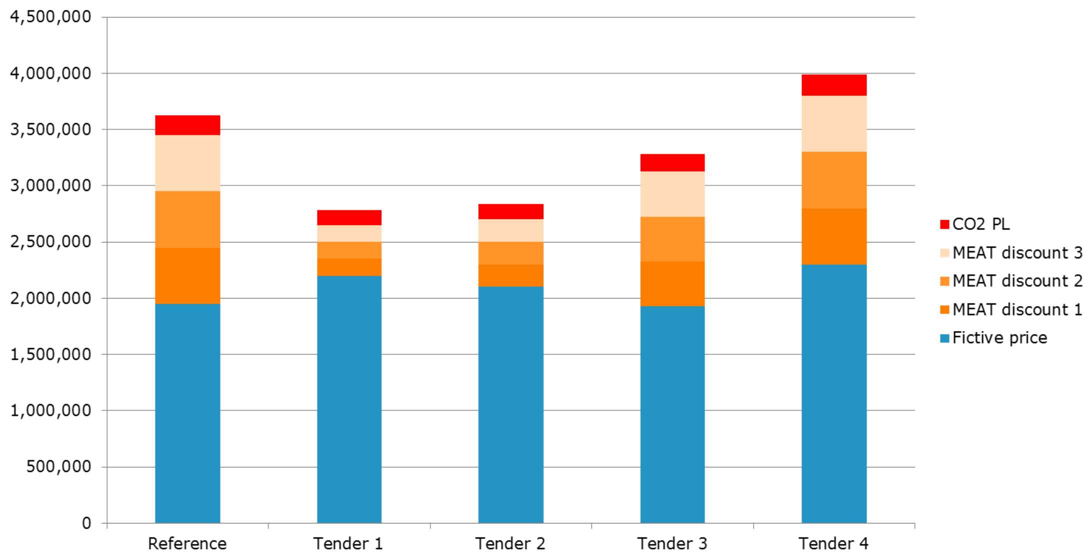



**Figure 26. Tender evaluation using MEAT criteria**

**Assurance and benchmarking**

Once awarded the MKI and compliance with the PL commitments of the stated level become contract requirements. 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. The fine imposed is normally 1.5 times the difference between the promised and delivered MKI value. If the MKI is lower a bonus is awarded.

The PL awareness certificate needs to be shown a year after the contract is signed.

RWS do not do any benchmarking of projects, but it does record the carbon reductions for each project. On average it has seen a 40% reduction in the carbon generated by projects as a result of this approach.

## *5.2 Adaptation*

RWS take several different approaches to including climate change in procurement e.g. in pre-qualification requirements, setting targets or as part of the environmental impact assessment. There are not any requirements in relation to climate change adaptation at tender evaluation stage. RWS produce functional specifications, and the tenderer determines how they can meet these.

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. For example it has increased drainage capacity requirements by 30% in line with climate projections in its design standards. EIA takes into account both climate change mitigation and adaptation.

RWS provides climate change adaptation guidance for their suppliers (in Dutch). This provides guidance on what should be included in different project stages; planning, design, construction etc. It also provides links to further information e.g. from the EEA or CEDR.

RWS review the quality of supplier plans and make sure they are climate resilient (as well as meeting other criteria such as noise, air quality). If not they will ask the design consultants to modify their plans. The designers should follow RWS guidance on climate change adaptation and make use of information from EEA or CEDR. This applies to large multi-year projects.

RWS are exploring how to include climate change adaptation in service level agreements, but are currently unsure how this will be done. There are multiple requirements in service level agreements.

Suppliers are not currently required to check drainage in vulnerable sites when heavy rain is forecast. It is up to suppliers to decide if this is required. Pumps in low lying area are checked when heavy rain is forecast.

Advice to other NRAs on adaptation:

- Good maintenance is the first step. Well maintained roads are less vulnerable.
- When designing new roads consider incorporating (cost-effective) features to make them more resilient.

- Assess the functionality of the present network and identify the vulnerable spots, so you can focus on these.

- Awareness raising within the organisations is important.

# 6. Examples of implementation

## *6.1 Mitigation*

### Procurement

**Case Study: Renovation of the N61 Hoek Schoondijke**
RWS tendered a project to renovate the N61, including new pavement construction (from foundation to surfacing), new lighting and vehicle restrain system.

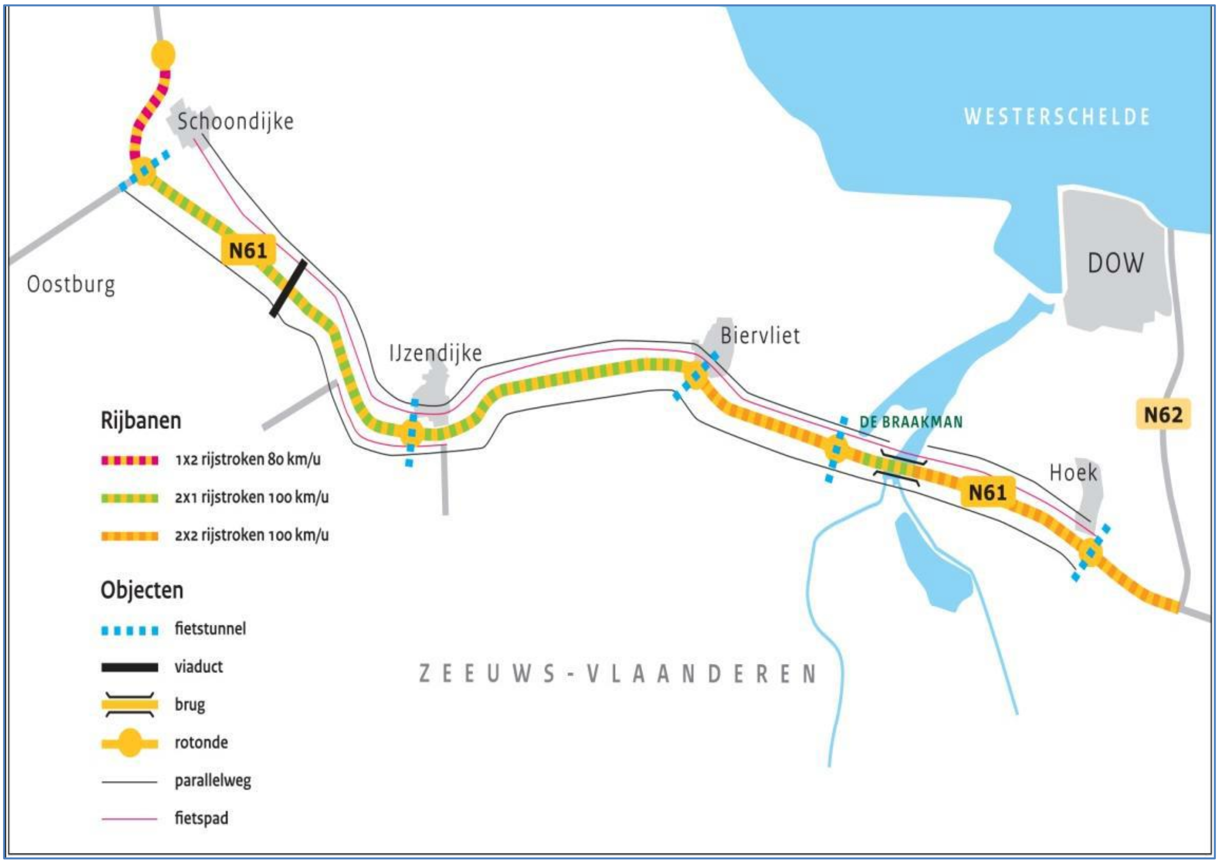



**Figure 27. Renovation N61 Hoek to Schoondijke (Source: RWS)**

The estimated cost of the renovation was €60 million and the MEAT criteria were:

1. External affairs management (traffic delay, vulnerable road users, planning and phasing).
2. Sustainability (Environmental Quality (MKI))

The maximum discount available due to sustainability was €2 million (0.8 million for minimising carbon) and for other MEAT criteria €8 million. The winning tenderer submitted a proposals for €55 million, received a 5% discount for their rating on the $CO_2$ PL, 1.5 million discount for their MKI score and €5 million for other MEAT criteria. This produced a corrected bidding price of 45.75 which was the lowest value.

**Case study: Reconstruction of motorway A6 Almere**
The DBFM contract for the expanding the capacity of a section of the A6 motorway used this procurement method. The wining tenderer was on the highest rung of the PL and submitted a design which is expected to produce 52,800 tonnes less CO2e emissions over the 50 year contract than the standard design as a result of using less asphalt, use of recycled materials and sustainable transport solutions. More information can be found here - http://www.gpp2020.eu/fileadmin/files/Tender_Models/GPP_2020_Tender_Model_Reconstruction_A6_Almere_RWS_April_2016.pdf

## Supporting initiatives

The LCA helped RWS to identify the major source of emissions; asphalt, concrete, groundworks including dredging. They have instigated initiatives to target these; the concrete agreement, asphalt Impuls and green deals. They are also focusing on the circular economy.

**Asphalt Impuls** – a sector wide programme - commitment of all partners in the asphalt supply chain includes sustainability and $CO_2$ reduction. Instigated by RWS, partners are contractors, designers, clients / road managers, suppliers of raw materials and equipment, quality managers and researchers. Contractors and suppliers have the opportunity to carry out research into new asphalt mixes and construction methods and have their innovations recognised by clients. https://www.crow.nl/thema-s/infratechniek/asfaltverharding/asfalt-impuls (in Dutch).

## *6.2 Adaptation*

**Case Study: InnovA58**
RWS trialled the use of the ROADAPT risk assessment methodology when planning a project to widen a section of the A58 motorway. They also worked with the USA to implement the Federal Highway Administration (FHWA)'s sensitivity matrix and Vulnerability Assessment Scoring Tool (VAST) for comparison. The FHWA also trialled the two approaches on a highway project in Washington State. The call for tenders for the design of the InnovA58 included a section on climate resilience requirements requiring tenders to develop climate change adaptation measures, make use of national climate projections and carry out cost-benefit analysis and other evaluation on the proposed adaptation measures. Accompanying the call was the results of the ROADAPT risk assessment. The tender requirements also included other sustainability criteria. Additional information is provided in the links below.

https://www.platformomgevingsmanagement.nl/wp-content/uploads/2018/06/artikelmyrtheleijstrakeesvanmuiswinkelwimleendertsetomasbles-developmentofaclimateadaptionstrategyfortheinnova58highwayinthenetherlands.pdf

https://international.fhwa.dot.gov/pubs/joint_report_resilient_infrastructure_fhwa_rws_january_2016.pdf

**Case study: A27**
RWS included climate change in the impact assessment of the planned work to widen a section of the A27. The impact assessment conducted in 2016 included an evaluation of the minimum and maximum climate risks and an adaptation strategy. It used national climate

projections and data on hydrology and geology in the assessment. The risk assessment identified three locations susceptible to increased water logging and adaptation actions were identified and included in the project requirements. More information is provided in the link below
http://conferences.iaia.org/2017/uploads/presentations/PAPER%20%20climate%20adaptation%20in%20IA%20for%20dutch%20road%20infrastructure.pdf

## 7. Assessment of impact and stakeholder engagement

Suppliers have broadly been accepting of the use of DuboCalc and happy to use it. They found that not only does it improve sustainability, but it also leads to better, smarter designs with reduced costs. RWS believe that the relationship with their suppliers should be built on support, trust and understanding. They recommended starting to include climate change in procurement slowly starting with the high value projects. Initially a low value discount should be awarded for sustainability criteria to minimize cost effects, once suppliers are used to this it can be increased. If suppliers are already used to a high proportion of the award criteria being related to quality it is easier expand this to include sustainability. As price is always a factor in project awards the participants will still work to minimise cost and be competitive.

## 8. Reviewing and improving/expanding the approach

### *8.1 Mitigation*

The importance of DuboCalc with RWS is growing and the approach has been broadened to link with Circular Economy goals. RWS are developing a strategy to work towards zero carbon emissions and are produce an integrated approach related to asset management, innovation and agreements with suppliers and other purchasers and governments.

### *8.2 Adaptation*

RWS are currently working on including climate change adaptation in replacement and renewal projects and on including it in service level agreements (maintenance).

## 9. Summary

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 have developed tools to support their sustainable procurement approach including the LCA tool called DuboCalc. Including adaptation in procurement is not straight forward and therefore less advanced, but RWS have piloted the use of risk assessment in the project planning phase and have modified their design standards. It is currently exploring how it can build on this to include adaptation in maintenance contracts.