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ROADAPT
Roads for today, adapted for tomorrow

QuickScan – A24 Portugal
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ROADAPT consortium:

Deltares (coordinator)

SGI

Egis

KNMI

CEDR Call2012: Road owners adapting to climate change

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Roads for today, adapted for tomorrow

Quickscan report : A24 motorway in Portugal

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Executive summary

The ROADAPT project is part of the Conference of European Directors of Roads (CEDR) Call 2012 “Road owners adapting to climate change”. The project is conducted by a consortium of European engineering and research companies: Deltares (leader), SGI, Egis, and KNMI. It addresses all objectives in the call in an integral approach following the RIMAROCC (Risk Management for Roads in a Changing Climate) framework that was developed for ERA-NET Road in 2010.

ROADAPT aims at providing:

1. methodologies and tools enabling tailored and consistent climate data information and a good communication between climate researchers and road authorities,
2. a preliminary and fast QuickScan method for estimating the climate change related risks for roads, to be translated in an action plan for adaptation,
3. a method for a socioeconomical impact analysis,
4. a method for detailed vulnerability assessments and
5. adaptation pathways plus strategy charts with specific input from adaptation techniques related to geotechnics and drainage, pavements and traffic management.

The present report focuses on the implementation of the QuickScan method on the A24 motorway in Northern Portugal. The A24 motorway linking the Portuguese cities of Viseu and Chaves is a 155 km link opening up the north of Portugal and providing ready access to Spain from the center of the country. It is operated by Norscut, while Operscut is in charge of the routine motorway maintenance and traffic security control.

The QuickScan method has been implemented through three workshops involving Norscut and Operscut staff, and pursuing the following objectives:

- Workshop 1: selection of the relevant climate threats, determination of the relative importance of the A24 motorway sections, discussion and ranking of the possible consequences of climate threats, scoring of the climate threats regarding their potential impact on each consequence criterion.
- Workshop 2: scoring of the probabilities of the threats, evaluation and prioritization of the climate risks, selection of the risks that can be mapped.
- Workshop 3: discussion on risk acceptability (which risks require action?), determination of a climate change adaptation action plan, prioritization of the actions.

Beside the technical outcome of the exercise, the brainstorming process of the method proved to be important in terms of team building. The approach also developed awareness on climate change issues, and climate related risks in general. As a result, a new section will be added to the 5-year repair and investment plan for dealing with climate-related risks.

1 Introduction

The ROADAPT project is **part of the CEDR Call 2012 Road owners adapting to climate change**. ROADAPT has an integral approach following the RIMAROCC (Risk Management for Roads in a Changing Climate) framework that was developed for ERA NET ROAD.
ROADAPT aims at providing:

1. Methodologies and tools enabling tailored and consistent climate data information for road owners. This will also ensure a good communication between climate researchers and road authorities.
2. A fast, preliminary quickscan method for estimating the climate change related risks for roads. Results of the quickscan can be translated in an action plan for adaptation.
3. A method for a socio economical impact analysis of climate change induced events.
4. A method for detailed vulnerability assessments.
5. Adaptation pathways plus strategy charts with specific input from adaptation techniques related to geotechnics and drainage, pavements and traffic management.

The ROADAPT consortium consists of the following partners:

- Deltares (coordinator)
- SGI
- Egis
- KNMI

This report consists of the results of the quickscan that has been performed for the A24 motorway in Portugal.

2 Presentation of the A24 Infrastructure and Operation

The A24 motorway linking the Portuguese cities of Viseu and Chaves is divided into 7 main sections. Two of them were built by the Portuguese Authority, one in 2002 and the other before 2000, when the concession contract was signed with **Norscut**, a subsidiary of Eiffage and Sonae. Other shareholders are Egis and BPCE. The other five sections were built by the concessionary and after 6 years of construction the last section was inaugurated in June 2007. This 157 km motorway section, included in the Trans-European road network, opens up the north of Portugal and provides ready access to Spain from the center of the country. It is operated by **Operscut** a subsidiary of Egis. Other shareholders are Eiffage and Sonae.

A number of large viaducts, long sections of steep grades and other engineering features were needed to fit the motorway into the mountainous topography of Northern Portugal (35 civil engineering structures and 4 tunnels). The longest structure is 1,350m long with a height above the valley floor of over 100m. Traffic levels averaged 7,200 vehicles per day (both ways) in August 2013, 4,332 vehicles per day for year 2012.

Chaves(fronteira) - Pedras Salgadas

Pedras Salgadas - Falperra

Falperra - Fortunho

Fortunho - Vila Real

Vila Real - Régua

Régua - Reconcos

Reconcos - Castro Daire Norte

Castro Daire Norte - Castro Daire Sul

Castro Daire Sul - nó com o IP5

Operscut is in charge of the routine motorway maintenance and traffic security control. The staff consists of 60 employees distributed in 4 departments:

- Operation and Maintenance Department, in charge of road maintenance and traffic management;
- Equipment and IT Department;
- Asset Management Department;
- Financial and Administrative Department.

The area of Quality, Environment, Health and Safety reports directly to the General Manager.

3 Organization of the A24 Quickscan

In consultation with the Norscut and Operscut, it was decided to plan **three days of workshops**, one for each workshop, scheduled as follows:

- Workshop 1 – 22 November 2013: Present ROADAPT / QuickScan approach + score the consequences of the climate threats
- Workshop 2 – 17 January 2014: Identify and locate the most important risks
- Workshop 3 – 28 January 2014: Determine an action plan

All workshops were held in Lamego (Portugal), Norscut and Operscut headquarters. **The same participants attended all workshops**:

- Yves Ennesser, Egis
- Catarina Gonçalves – Technician Cadre of Norscut (Concessionary)
- Luís Simão – Operscut, General Manager
- António Lucena – Operscut, Operation and Road Maintenance Manager
- Constantino Sousa – Operscut, Quality, Environment, Health and Safety Responsible
- Graça Correia – Operscut, Asset Manager
- José Regadas – Operscut, Asset Technician Assistant
- Luís Monteiro – Operscut, Equipment and IT Manager
- Paulo Barreto – Operscut, Asset Technician Cadre
- Rui Couto – Opercsut, Road Maintenance Technician
- Sérgio Pereira – Operscut, Accounting Technician

As Step 1 tasks (Workshop 1 preparation) were mainly performed at the beginning of the 1st workshop, the only activities executed for preparing the workshops were to send elements of information on ROADAPT and Quickscan prior workshop 1, then minutes of the workshop prior the next workshop. The workshops lasted 5 hours for the first one, 3.5 hours for the two others.

4 Workshop 1

4.1 Presentation of the ROADAPT approach and the Quickscan method

PowerPoint presentations of the ROADAPT approach and the QuickScan method were distributed to the participants and commented. The TRA article showing the QuickScan application to the Blue Spots study in the Netherlands was also distributed.

For a road network, under study in a QuickScan, **the following steps should be followed**:

Step 1 - Desktop 1 - prepare Quick scan
- Step 1.1 - Scope definition/ Establish context
- Step 1.2 - Identify risk sources and possible relevant threats
- Step 1.3 - Determine importance of road sections in road network (sensitivity)
- Step 1.4 - Prepare workshop 1

Step 2 - Workshop 1 - consequences
- Step 2.1 Agree with participants on Quick scan approach
- Step 2.2 Establish consequence criteria
- Step 2.3 Estimate the consequences of the threats
- Step 2.4 Evaluate the scoring of consequences

Step 3 - Desktop 2 - prepare workshop 2

Step 4 - Workshop 2 - probabilities, risk and locations
- Step 4.1 Agree on study method and share status of research
- Step 4.2 Score the probabilities of the threats
- Step 4.3 Evaluate the scoring of probabilities
- Step 4.4 Evaluate and prioritize the risks
- Step 4.5 Identify location of threats

Step 5 - Desktop 3- provide a risk overview

Step 6 - Workshop 3 – action plan
- Step 6.1 Wrap up of previous results
- Step 6.2 Determine unacceptable risk; which threats require action?
- Step 6.3 Determine action plan
- Step 6.4 Prioritize actions

4.2 Selection of the relevant climate threats (Step 1.2)

This selection was performed using the “reversed table” of ROADAPT Work Package 4. The resulting output is shown in **Appendix 1**. The selection criterion was the occurrence of the threats, whether already observed or deemed very likely on the A24 motorway. The threats were selected regardless of the climate parameters (e.g. whether landslides are caused by rainfall or drought). It should be noted that, at the present stage of the QuickScan, no consideration was given to possible climate changes. It should also be noted that, as the A24 is a rather recent infrastructure (only 6 years of operation), only a few notable climate events have already been observed.

Over a total of 36 threats, only 10 were considered as not relevant to the A24 and were removed from the table. This present situation showing many climate related threats can be explained by the geographical and topographical setting of the motorway: the A24 is located in Southern Europe and is therefore affected by heat and drought effects; however, the motorway is also located in a mountainous area (62% of the motorway is at an altitude of more than 500m), exposed to intense rainfalls, cold winters and slope instabilities.

4.3 Determination of the relative importance of the A24 sections (Step 1.3)

There are 23 interchanges on the A24 motorway, defining the same number of sections. However, **12 main sections** (with an average length of 13 km) may be determined according to the opening dates, as shown below:

Location	Section name	Judgment criteria		
		Traffic	Economy	Redundancy
	Chaves - Vidago	Low	High	Medium
	Vidago – Pedras Salgadas	Medium	Medium	Medium
	Pedras Salgadas – Vila Pouca de Aguiar	Medium	Medium	Medium
	Vila Pouca de Aguiar - Fortunho	Low	Low	Medium
	Fortunho – Vila Real	High	Medium	Low
	Vila Real - Regua	High	High	Medium
	Regua - Lamego	High	High	Medium
	Lamego - Bigorne	Low	Low	Low
	Bigorne – Castro Daire	Low	Low	Medium
	Castro Daire - Carvalhal	Medium	Medium	Low
	Carvalhal – S. Pedro do Sul	Medium	Low	Medium
	S. Pedro do Sul - Viseu	Low	Medium	Medium

Three judgment criteria were used to determine the respective importance of each section: traffic level, economic importance of the section for the surrounding territory, redundancy of the route. **Each section was scored low, medium or high** regarding the three criteria. A color code was then used to score each section, all criteria merged (N.B.: "low" redundancy was given "high" importance):

- Green: section of low importance
- Yellow: section of medium importance
- Red: section of high importance

Comments:

- The three judgment criteria are those commonly used by road administrations. They were considered relevant and sufficient by the workshop participants.
- Traffic levels towards the border are relatively low, but show the highest rates of heavy vehicles.
- The economic criteria were estimated based on the population density and economic activity in the motorway surroundings.
- On the whole, the redundancy is low, since there is no real alternative route. The motorway has been built to open up this part of the territory.

4.4 Discussion and ranking of consequences (Step 2.2)

To assess the effects of a climate event (threat), consequence criteria were proposed. These criteria stem from the **RAMS or RAMSSHEEP list of criteria** used by the Dutch Road. Administration for assessing the possible consequences of a given event on the road network. This list includes technical, economic, environmental and even psychosocial criteria (e.g. reputation).

4.4.1. Selection of the consequence criteria

A list of six criteria was proposed to the workshop participants: **availability, safety, surroundings, direct costs, reputation, and environment**. All participants agreed that the list is relevant. No additional criterion was proposed.

Definitions

- Availability: impact of the event on the motorway availability, in terms of traffic restriction or interruption.
- Safety: impact of the event on the motorway user safety, from light material damage to casualties.
- Surroundings: impact of a traffic interruption occurring on the motorway because of the event, over the surrounding road network, in terms of affected road length.
- Direct costs: direct technical costs incurred by the motorway operator because of the event (costs for managing the incident and repair).
- Reputation: dissatisfaction and loss of reputation of the motorway operator because of no, insufficient, or inadequate actions to anticipate and manage the event.
- Environment: indirect impact of the event on the surrounding natural environment, because of incidents occurring on the motorway (e.g. water pollution due to accidental spillage caused by the event on the motorway).

4.4.2. Ranking of the consequence criteria

All participants were requested to rank the criteria by order of importance, from the less to the most important. To this aim, 21 points had to be distributed over all the criteria. The ranking proposed by the 9 participants is presented below.

Criteria	**Ranking**								
Availability	4	5	4	4	4	4	4	5	1
Safety	6	6	6	7	5	6	5	7	8
Surroundings	3	3	3	3	4	3	4	2	1
Direct costs	3	4	4	3	4	3	3	3	5
Reputation	2	1	2	2	2	2	2	2	1
Environment	3	2	2	2	2	3	3	2	5
Total	21	21	21	21	21	21	21	21	21

Average values are given below and normalized for getting a sum of 1 (to make easier the comparison between the average and weighted scores of the threats in Step 2.4):

Criteria	Ranking sum	Average ranking	Normalized score
Availability	35	3.9	0.186
Safety	56	6.2	0.295
Surroundings	26	2.9	0.138
Direct costs	32	3.6	0.171
Reputation	16	1.8	0.086
Environment	24	2.6	0.124
Total	189	21	1

On a rather predictable way, **the safety criterion comes first**, followed by availability and direct costs. The environment criterion ranking was not expected so high, but it stems from the sensitive environmental setting of the motorway (several nature protected areas and mineral water sources).

Comments:
- The rankings are rather homogeneous over the panel of participants.
- The following skills were represented around the table: road engineering, economics, environment, transport safety, traffic management, and equipment. Half of the participants were road engineers. It should be noted that there was no expert in communication, but the concessionary company (Norscut) was represented at the workshop. The panel composition can therefore be considered as adequate.

4.5 Scoring of the consequences of climate threats (Steps 2.3 and 2.4)

The aim of the present step was to score every climate threat selected during Step 1.2 regarding their potential impact on each consequence criterion. This exercise was carried out **irrespective of the road section importance and location**. The purpose was therefore only to determine what threats are considered the most detrimental, all things being equal.

Each threat was scored according to the following impact classes:

A24 availability
1. A negligible impact on availability (< 6h of complete traffic interruption, or temporary traffic restrictions)
2. A minimal negative impact on availability (6-24h of complete traffic interruption)
3. A serious impact on availability (1-3 days of complete traffic interruption)
4. A catastrophic impact on availability (> 3 days of complete traffic interruption)

A24 safety
1. A negligible impact on the user safety (light material damages)
2. Only material damages and slight injuries
3. Some serious material damages, heavy injuries, and some casualties

4. Several serious material damages, many heavy injuries and casualties

A24 surroundings (effects on the surrounding road network)

1. A negligible impact on the surrounding road network use, only a road segment is at stake (< 10 km)
2. A minimal negative impact on the surrounding road network use, a road section is at stake (10-20 km)
3. A serious impact on the surrounding road network use, a road stretch is at stake (20-50km)
4. A catastrophic impact on the surrounding road network use, the road network is at stake (50-500 km)

Direct technical costs of the event for both Norscut and Operscut (costs for management the incident and repair)

1. Less than k€ 25
2. Between k€ 25 and k€ 100
3. Between k€ 100 and k€ 500
4. More than k€ 500

A24 operator's reputation

1. No to slight loss of reputation (due to proper actions); no complaints
2. Slight to moderate loss of reputation (due to inadequate actions on some aspects), notices in media with attention to (fictive) loss for road users
3. Substantial loss of reputation (due to inadequate actions on numerous aspects), reputation has a set-back, notices in media with attention to physical damage / hardships of road users, gets attention in nationwide politics
4. Extreme loss of reputation (due to completely inadequate acting), position of minister at stake

Surrounding natural environment

1. No to slight impact to the natural environment directly surrounding the A24
2. Slight to moderate impact on the natural environment in the near vicinity of the A24
3. Major impact on the natural environment in the near vicinity of the A24
4. Extreme impact on the natural environment in the wide vicinity of the A24

Impact categories: water pollution due to accidental spillage, forest fires, worsening of flooding conditions, worsening of landslides…

The scoring results are shown in the table presented in **Appendix 2**. The table gives the score for each threat regarding each consequence criterion, then all criteria together. The table shows the total score (sum of each criterion score), the average score, and the weighted score for taking the criteria respective importance into account (using the ranking coefficients obtained in Step 2.2)

The main findings are presented below:

- **Erosion of road embankments and foundations by overloading of hydraulic systems crossing the road is the main threat**. It is given the highest score for availability and direct costs, as it can result in the complete destruction of the structure and the road base on the whole cross section.
- **In second position comes the loss of driving ability due to reduced visibility by fog**, which is given the highest score for the safety criterion. The high ranking of this threat is explained by the the severity of the accidents related to this event: casualties, costs related to these casualties, pollution risks of the surrounding environment.
- **Reduced ability for maintenance because of snow or ice removal costs** comes in third position.
- **The other main threats**, by decreasing order of importance, are:
    - Erosion of road base (it is assumed by the participants that one lane can show serious damage), with the highest scores for direct costs and reputation.
    - Landslides (whatever their origin), with also the highest score for direct costs. It is assumed that landslides may only affect one carriageway, so the other will remain available.
    - Flooding of road surface as a result of intense precipitation. This threat gets the highest score for the environment criterion, due to the sensitivity of the surrounding natural environment (protected natural areas, mineral water sources) to accidental pollution likely to be induced by the event.
    - Susceptibility to wildfires that threaten the transportation infrastructure directly. Like in many other south European countries, Portugal is often affected by severe wildfires (especially in summer 2013).
    - The scores show a gap between the last threat and the other threats identified on the A24 motorway in Step 1.2. These threats may therefore be considered of secondary importance, i.e. not taken into consideration in the next steps of the QuickScan method.
    - It should be noted that the ranking of the threats doesn't vary much whether total score or weighted score is considered. However, when two threats have the same score, using the criteria weighting may help determining what the most detrimental is.

Comments:

- For bridge scour, it is considered that there is no collapse (so the infrastructure is still available, even if some traffic restriction may happen, e.g. for heavy vehicles).
- It is assumed that landslides are not likely to cause viaduct collapse on the A24 motorway.
- Loss of road structure integrity: it is assumed that this threat may affect up to 1 km of motorway segment.
- On the A24, reduced visibility because of snowfall and heavy rain is less frequent than by fog.
- Aquaplaning in ruts: there is no rut on the A24 motorway.
- Icing and snow: icing is considered more hazardous than snow on the A24 motorway (but much less than fog).
- Damage to electric station and transformers by lightning may cause pollution by spillage of toxic liquid components.

5 Workshop 2

5.1 Reminder and discussion of Workshop 1 outputs

Changes and corrections were incorporated in Workshop 1 minutes after Operscut and ROADAPT Partners comments. These changes are quickly presented to the participants.

Scoring of the threats (**Appendix 2**) is further examined in order to make sure that the final ranking fully reflects the opinion of the participants. It is checked that threat frequency is not taken into account in the scoring (the threat occurrence being dealt with further in Step 4.2 of the QuickScan method). **It is decided to remove "secondary" threats for the next steps of the analysis**. Out of the 24 threats analysed in Workshop 1, only 10 of them are therefore selected and will be further analysed in workshop 2.

5.2 Presentation of climate change projections

Based on data as collected by KNMI (Janette Bessembinder), **the following information is presented**: current climate situation in Northern Portugal, observed trends, projected climate changes, and related impacts on climate threats for the A24 motorway. The PowerPoint presentation is attached to the workshop minutes.

The climate change trends for the end of the century are summarized below:
- Increase in temperature of 3 ºC to 7 ºC for the summer season;
- Reduction in annual rainfall by 20% to 40% of current levels;
- Moderate increase in rainfall in the North for the winter season;
- No noticeable change for heavy rains.

It should be noted that Portuguese climate specialists (Pdero Viterbo from the Institute of Meteorology, and Voytech Bliznak from the Lisbon University) were invited to the workshop but didn't come. However, it is assumed that their participation to the workshop wouldn't have brought much more information on climate changes.

5.3 Integrating the relative importance of the A24 sections in the scoring of climate threats

During Workshop 1, the relative importance of the A24 sections was determined, based on three criteria: traffic level, economic importance of the section for the surrounding territory, redundancy of the route. Each section was scored low, medium or high regarding the three criteria (N.B.: "low" redundancy is given "high" importance). A color code was then used to score each section, all criteria merged:
- Green: section of low importance
- Yellow: section of medium importance
- Red: section of high importance

The table below is an updated version of this scoring, discussed during Workshop 2:

Location	Section name	Judgment criteria			Impor-tance	Weight
		Traffic	Economy	Redundancy		
	Chaves - Vidago	Low	High	Medium	Medium	1
	Vidago – Pedras Salgadas	Medium	Medium	Medium	Medium	1
	Pedras Salgadas – Vila Pouca de Aguiar	Medium	Medium	Medium	Medium	1
	Vila Pouca de Aguiar - Fortunho	Low	Low	Medium	Low	0.7
	Fortunho – Vila Real	High	Medium	Low	High	1.3
	Vila Real - Regua	High	High	Medium	High	1.3
	Regua - Lamego	High	High	Medium	High	1.3
	Lamego - Bigorne	Low	Low	Low	Medium	1
	Bigorne – Castro Daire	Low	Low	Medium	Low	0.7
	Castro Daire - Carvalhal	Medium	Medium	Low	Medium	1
	Carvalhal – S. Pedro do Sul	Medium	Low	Medium	Medium	1
	S. Pedro do Sul - Viseu	Low	Medium	Medium	Medium	1

To each importance category is given a weighting, for making possible to combine motorway section importance and climate threats. This combination exercise is performed in Step 4.4. A "neutral" weighting is given to sections of medium importance. Sections of high importance are weighted 1.3 and sections of low importance 0.7, so as to keep a medium value around 1. The weighting values have been proposed to the workshop participants and validated.

5.4 Scoring of the probability per threat (Step 4.2)

This step can be divided in two sub-steps: determining a probability scale, and scoring the probability of the threats.

5.4.1. Determining a probability scale

The purpose of this sub-step is to **determine 4 classes of probability, based on the likely frequency of the events (climate threats)**. As the A24 motorway has only a few years of existence, no statistics about climate-related events are currently available. So the exercise mainly relies on the participants' experience and judgment capability.

It should be noted that the judgment capability regarding frequency of events (e.g. notions such as "often" or "seldom") strongly depends on people personality, and is therefore rather subjective. However, this **subjectivity** is tempered when doing the exercise with a panel of 10 persons, like in the present case.

There are **two principles established for determining the probability scale**:

- 4 classes of probability have to be defined (often, sometimes, seldom, very seldom)
- Threat probabilities have to be scored irrespective of the location on the A24 route.

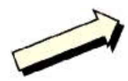
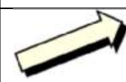
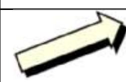
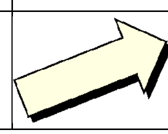
Based on these instructions, the participants agreed on the following definition:

Score	Probability class	Definition
4	Often	several times per year
3	Sometimes	no more than once every 5 years
2	Seldom	no more than once every 20 years
1	Very seldom	no more than once every 100 years

It should be noted that "very seldom" was first (spontaneously) considered as being no more than once every 5 years. However, taking the infrastructure design standards into account (the infrastructure hydraulic and drainage systems are designed for a 100-year event), the probability scale has been afterwards corrected**. It has been further adjusted during the next sub-step**, when scoring the probability of the threats.

5.4.2. Scoring the probability of the threats

The purpose of this sub-step is to determine the probability class for each threat, **first in the present situation, and then taking climate changes into consideration**. Concretely, the participants had to agree about the probability class that best represent the frequency of the climate threats and fill the following table.

Threat		**Probability in the present situation**	**Climate change trends**	**Probability with climate change**
Flooding of road surface (assuming no traffic is possible)	Pluvial flooding (runoff after precipitation, rise of groundwater levels)	1	**?**	1
Erosion of road embankments and foundations	Overloading of hydraulic systems crossing the road	2	**?**	2
	Erosion of road base	2	**?**	2
Landslips, avalanches, ground subsidence or collapse	External slides, ground subsidence or collapse affecting the road	3		3
	Slides of the road bed	2		3
	Rock fall	4		4
Loss of driving ability due to extreme weather events	Reduced visibility by fog	4	**?**	4
Reduced ability for maintenance	Snow removal costs	3	**?**	3
	Ice removal costs	1	**?**	1
Susceptibility to wildfires that threaten the transportation infrastructure directly		4		4

Comments about climate change trends:

- As above indicated in section 2, no climate change projections show clear trends with respect to extreme rainfall events in northern Portugal.
- Fog is a very local meteorological phenomenon that is still impossible to incorporate in climate change models.
- About snow and ice, two opposite mechanisms are likely to take place with climate change. On one side, more winter precipitation is likely to generate more ice and snow. On the other side, global warming is likely to generate rainfall instead of snowfall in wintertime, making snow and ice events shorter. It's therefore difficult to determine the change direction if any.

- More humid winters together with dryer summers are likely to generate more slope instability (landslides and rock falls).
- Dryer and hotter summers will strongly increase wildfire threats.

Comments about probability of the events in the present situation:

- The most usual threats are rock falls, fogs and wildfires (several times per year).
- At the opposite, it is considered that flooding of road surface (the drainage system is designed for a 100-year rainfall) and exceeding the present deicing capacity are very unlikely (no more than once per century).

Comments about probability of the events with climate change:

- Probability classes don't change for threats that don't show clear trends in the future.
- For threats that show trends, the first question is the time horizon to be considered. Indeed, whether short or long term is considered, climate change effects will be more or less significant. **The workshop participants agreed about a 50-year time horizon (2060)**, in line with the average age expectancy of the motorway assets. For this horizon, climate changes will be already significant.
- Climate change effects will especially impact wildfires. However, as this threat is already given the highest class of occurrence, its score doesn't change.
- In the end, the probability class only changes for one threat (slides of the road bed).

5.5 Evaluation and prioritization of the risks (Step 4.4)

The purpose of this step is to evaluate climate-related risks according to **a two-tiered approach**:

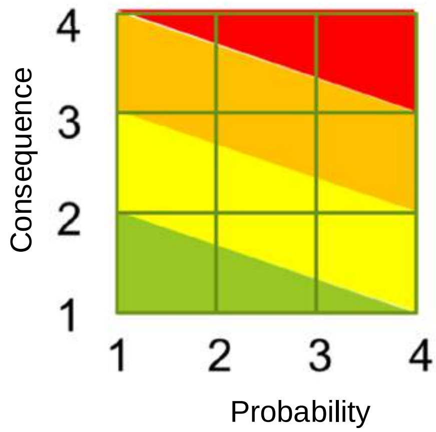
1. Combine threats as estimated in Step 2.4 (see Workshop 1) and probabilities estimated in Step 4.2. The combination of both information allows a first risk evaluation (risk = threat x probability).
2. Refine the risk evaluation through incorporating the respective importance of motorway sections into account (see Step 1.3 and the above section 3).

5.5.1. Combining threat and probability

The table in **Appendix 3** shows the final score (see “Risk level”), combining the scores of threats (see “Weighted score / consequence”) and the scores for probability classes (see “Probability”). The three major climate-related risks affecting the A24 motorway are (by order of decreasing importance):

- Fog
- Rock fall
- Wildfire

At this stage of the analysis, the stakeholders have to decide what risk is acceptable and what is not. This step often makes use of risk matrices for making risk acceptability assessment easier. In the present case, the matrix combines the 4 classes of consequences with the 4 classes of probabilities, as shown below:



The code of colours is explained in the table below:

Score with respect to		Designation	Colour
Consequence - Probability	Risk		
1 – ≤ 1,75	1 - ≤ 4,75	Low	Green
1,75 – 2,5	4,75 – 8,5	Moderate	Yellow
2,5 – 3,25	8,5 – 12,25	High	Orange
≥ 3,25 - 4	≥ 12,25 - 16	Very high	Red

The workshop participants first agreed about considering only high and very high risk classes. So, the minimum score for considering the risk as not acceptable was set at 8.5. However, this value was too restrictive as only 3 climate risks exceeded this threshold. It was therefore decided – arbitrarily – to lower the threshold value to 7. This allowed broadening the range of non-acceptable risks to 6.

A contrario, **4 climate risks listed as "serious" or "major" threats in Step 2.4 were considered as acceptable**:

- Flooding of road surface (assuming no traffic is possible)
- Erosion of road embankments and foundations
    - either by overloading of hydraulic systems crossing the road
    - or erosion of road base (by longitudinal flows)
- Reduced ability for maintenance regarding ice removal costs

These risks are therefore not included in the next steps of the analysis.

5.5.2. Taking the importance of the motorways sections into account

As shown in **Appendix 3**, each risk valuation can be refined through incorporating the relative importance of the A24 sections, making use of the weighting defined in section 3.

Here the section "importance" can be understood as the **section "sensitivity" to climate risks**. Indeed, the more the sections are important (i.e. high traffic level, high economic importance of the section for the surrounding territory, low redundancy of the route), the more they are vulnerable to infrastructure damage or traffic disruption related to climate risks.

The table in Appendix 3 shows that, **apart from fog-related risks, the other climate risks may be considered as acceptable for low importance A24 sections**.

5.6 Mapping of the main threats (Step 4.5)

Using the risk level per section category, it is already possible to carry out a basic risk mapping over the whole A24 corridor. This exercise would however remain rather theoretical, and it is advisable to refine and consolidate it through more detailed analyses. This is the purpose of the present step.

As shown on the photo below, **the workshop participants were provided with topographical maps of the A24 corridor (1/25000 scale), and were asked to specify the location of the six main risks, section by section**.

6 Workshop 3

6.1 Preparatory works (Step 5)

The draft risk mapping produced at the end of Workshop 2 was copied out neatly for supporting Workshop 3 discussions. It is presented in **Appendix 4**.

6.2 Reminder and discussion of Workshop 2 outputs (Step 6.1)

A draft mapping of the climate related risks is presented. Some corrections are proposed by the participants. **The final risk score for each A24 section is estimated as follows**:
Risk = Importance x Number of threats x % of the section affected by threats
with:

- Road importance, classified in three categories (low, medium, high)
- Number of threats, classified in three categories (low = less than 2 threats, medium = 2 threats or more, high = 4 threats or more)
- % of the section affected by threats, classified in three categories (low = less than 1/3, medium = between 1/3 and 2/3, high = more than 2/3).

It is decided to test two sets of weighting for the risk criteria:

1. Giving the same weight to all criteria. As two criteria are related to threat, this implies giving more weight to threat than to road importance;
2. Giving the same weight to threat and road importance, as follows:
   R = 0.5 I + 0.5 (Nb T + % T)

The results are shown in the table below:

Location	Section name	Impor-tance	Nb of threats	% of section	Risk level (1)	Risk level (2)
	Chaves - Vidago	Medium	M	H	H	M
	Vidago – Pedras Salgadas	Medium	L	L	L	L
	Pedras Salgadas – Vila Pouca de Aguiar	Medium	M	H	H	M
	Vila Pouca de Aguiar - Fortunho	Low	H	H	H	M
	Fortunho – Vila Real	High	M	M	H	M
	Vila Real - Regua	High	H	H	H	H
	Regua - Lamego	High	M	H	H	H
	Lamego - Bigorne	Medium	H	H	H	H
	Bigorne – Castro Daire	Low	M	H	M	M
	Castro Daire - Carvalhal	Medium	L	H	M	M
	Carvalhal – S. Pedro do Sul	Medium	M	H	H	M
	S. Pedro do Sul - Viseu	Medium	M	H	H	M

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The two set of weightings **show rather different outcomes**: the first one results in high risk levels for most of the A24 sections, while the second one mainly results in medium risk levels. **The second set of weightings seems preferable as it is more discriminant regarding high risk levels**.

6.3 Infrastructure components or operational procedures concerned by climate risks (Step 6.2)

According to the QuickScan method, this task is the first sub-step of Step 6 intended to determine an action plan. The purpose is to identify the assets or operational procedures influenced by the 6 main climate-related risks selected in Workshop 2. The outcome is presented in the table below:

<table>
<tr><th colspan="2">Threat</th><th>Concerned components of the infrastructure</th><th>Concerned operational procedures</th></tr>
<tr><td rowspan="3">Landslips, avalanches, ground subsidence or collapse</td><td>External slides, ground subsidence or collapse affecting the road</td><td>Whole infrastructure</td><td>Slope maintenance (cuts and fills), drainage and erosion control, inspection / monitoring</td></tr>
<tr><td>Slides of the road bed</td><td>Whole infrastructure</td><td>Maintenance of retaining walls and fill slopes, drainage and erosion control</td></tr>
<tr><td>Rock fall</td><td>Pavement, shoulders, barriers, ditches, signalization</td><td>Maintenance of cut slopes, inspection / monitoring</td></tr>
<tr><td>Loss of driving ability due to extreme weather events</td><td>Reduced visibility by fog</td><td>None</td><td>Maintenance of horizontal and vertical signalization, surveillance (video, patrols)</td></tr>
<tr><td>Reduced ability for maintenance</td><td>Snow removal costs</td><td>None</td><td>Winter maintenance, meteo forecast</td></tr>
<tr><td colspan="2">Susceptibility to wildfires that threaten the transportation infrastructure directly</td><td>Pavement, signalization, fences, guard rails…</td><td>Roadside maintenance (vegetation)</td></tr>
</table>

6.4 Life span of infrastructure components VS critical time horizons

The purpose is to determine if and when climate changes may become critical regarding the life span or maintenance frequency of the infrastructure components. The outcome is presented in the table below:

Concerned components of the infrastructure	**Maintenance frequency / life span**	**Critical time horizon regarding damages related to climate changes**
Roadbed *	50 years	0 year less than the asset life span
Pavement	10 years	/
Shoulder	10 years	/
Drainage (ditches)	1 per year for maintenance / 5-10 years for life span	/
Equipment (guard rails)	30 years	10 years less than the asset life span
Fence	15 years	/
Signalization (horizontal / vertical)	2 /10 years	/

* Roadbed represents the whole infrastructure

Comments about the maintenance frequency / life span:

- For the assets under consideration, life span is deemed more relevant than maintenance frequency, except for ditches, which requires significant annual maintenance.
- There is no possible maintenance for roadbed: if damaged, the whole infrastructure has to be rebuilt.

Comments about the critical time horizons:

- **In the present situation of climate change uncertainties, it is rather challenging saying when it will become critical**. Moreover, depending on the infrastructure construction time, climate changes may be critical or not. For example, if the infrastructure has been built a long time ago and has to be rebuilt in the next years, climate changes may not be considered as an issue: 1) because no significant climate changes are likely to happen in a few years' time period; 2) climate change impacts can be incorporated in the design when rebuilding the infrastructure.
- **So the question should be asked the other way round**: knowing the asset life span, when climate changes could become a risk? If climate changes become significant only beyond the asset life span, it cannot be considered as critical.
- **Thus, for assets the life span of which is less than 20 years, it is assumed that climate changes will not be strong enough for generating significant damages**. Indeed, climate changes are supposed to become significant only in the second half

of the century. In addition, in the first or two next decades, the natural climate variability may hide climate changes due to global warming.

- **For assets of longer life span, the question can be refined as follows**: if climate changes are likely to cause major damages to the asset, when these damages may be considered unacceptable?
- Given that any significant damage to the roadbed requires rebuilding the whole infrastructure, the workshop participants considered that **no climate change damage likely to reduce the asset life span for even a few years is acceptable**.
- **For assets of less importance and cost**, such as guard rails, the workshop participants considered that damage related to climate changes would become critical if occurring more than 10 years before the equipment life expectancy. In other words, **a reduction of more than 1/3 of the life span of this asset is considered unacceptable**.

6.5 Action plan for climate risk adaptation

The purpose is to determine:

1) if actions need to be taken before end of life span / next maintenance period,
2) the category of adaptation measures, and
3) priority levels for the action plan.

The last sub-step is referred to in the QuickScan Method as **Step 6.3**.

6.5.1. Timing for the required actions

The above section 3 showed that, given all uncertainties governing climate changes, it's impossible to specify critical time horizon regarding damages related to climate changes. It was however possible to determine if climate change effects will be acceptable or not, depending on the infrastructure component life span and the supposedly time horizon for significant climate changes to happen.

It is therefore possible to build on these results to **determine if actions have to be taken by the end of the asset life span**. By definition, all risks deemed unacceptable during the asset life span have to be managed through an action plan. The main question is when these actions have to be planned.

As a consequence, all risks related to landslides (external, internal, or rock falls) or wildfires likely to worsen with climate changes require actions. At the opposite, fog and snow related risks, for which no clear link can be established with climate change, and which do not affect the integrity of infrastructure components, do not require specific actions regarding climate changes. We will see in the next sections that it doesn't mean that they do not deserve attention.

For risks requiring actions regarding climate changes, the workshop participants considered that it is **necessary starting to incorporate these new (or changing) risks in the current maintenance and investment plans**. The A24 is provided with a 5-year plan for major repairs and investments, which is updated every year. The workshop participants agreed about introducing a new section on climate change related risks in the plan. This new section will establish objectives and actions to be taken by the end of the plan, i.e. a 5-year horizon.

6.5.2. Categories of adaptation measures

In the present QuickScan method implementation, **the purpose is not defining precise adaptation measures**. This preliminary vulnerability analysis to climate change cannot reach this level of detail. The purpose is **rather defining categories of actions that will have to be further investigated** when implementing more detailed studies on climate change effects. In other words, the goal is to set a strategy for dealing with climate change issues.

Five categories (strategies) of adaptation measures, which can be combined, were proposed and validated by the workshop participants:

1) **Do minimum** (traffic management, business as usual). In this strategy, it is assumed that the risk can be managed through the current procedures, and in particular through traffic management (information of drivers, traffic restrictions). This strategy especially concerns fog, snow and wildfire related risks, for which possible damage to the infrastructure is assumed to be low, while safety of the motorway users may be at stake;
2) **Research to reduce uncertainty, and monitoring**. In this strategy, it is assumed that risk knowledge has first to be improved before taking specific actions. This is especially the case with landslide and rock fall related risks, which result from complex combinations of parameters and interactions between these parameters (slope, geology, climate, etc.);
3) **Develop contingency plans for being better prepared to manage emergency situations** (improving resilience). This is a “reactive” strategy especially relevant for risks showing more impact on traffic than on infrastructure (fog, snow, wildfire);
4) **Strengthening preventive maintenance**. This is a “proactive” strategy mainly aimed at avoiding major damage to the infrastructure. This is especially relevant for rock falls;
5) **Retro-fit investments / strengthening infrastructure**. When the integrity of the whole infrastructure is at stake and strengthened maintenance may not be enough, it may be necessary to plan investments for strengthening the infrastructure itself (especially in case of probable landslide).

6.5.3. Priority levels (Step 6.4)

The workshop participants were asked to rank the risks by priority level. In other words, the risks were ranked from 1 to 6, **from those that require the most urgent actions to those that may be addressed secondly**.

The 1st priority risk is wildfire, because of its frequency in the present situation, its potential impact on both the infrastructure and traffic safety, and the strong negative impact of climate changes in the future. It is emphasised that fight against wildfires is under the responsibility of national and local authorities, that’s why the A24 operator can only develop reactive strategy for addressing the problem. At the opposite, slide of the roadbed is deemed to be the less urgent issue, mainly because the A24 infrastructure is new and the occurrence of such event is unlikely to happen in near future, even with possible climate change effects.

6.5.4. Outcome

The table shown in **Appendix 5** provides a synthesis of the adaptation plan.

7 Main Learning Points

7.1 From Workshop 1

Both Step 1 and Step 2 of the Quickscan were conducted during Workshop 1. Step 1 is supposed to be a desk study. Given the limited data that were made available before the meeting, it was decided to conduct Step 1 during the first workshop. In the end, it seems to be relevant and appropriate, as most of the expertise required for preparing Workshop 1 was around the table. In addition, conducting Step 1 as a desk study would have taken much more time. The main drawback is that, instead lasting 3 hours, the meeting lasted almost 5 hours.
Consequence for the QuickScan method: as an alternative option to the methodology, it may be proposed to conduct Step 1 and Step 2 during Workshop 1, i.e. replacing Step 2.1 by the 3 first steps. However, in that case, it is not recommended conducting Workshops 1 and 2 in the same day because of time constraints.

The scoring of the threats was a collective exercise: instead of leaving all participants marking each threat independently, the marks were discussed and decided together. This approach showed two main advantages:

1. Enable the participants having the same perception of the consequences and the same understanding of the impact classes (so as to avoid inconsistencies and mistakes in the marking);
2. Save time : no waste of time for calculating the average scores and no need for network of computers for doing it; possibility for conducting Step 2.3 (Estimate the consequences of the threats) and Step 2.4 (Evaluation of the consequence scoring) at the same time.

Knowledge about climate change effects is not necessary for conducting this workshop.

7.2 From Workshop 2

Participants to Workshop 2 were the same as for Workshop 1. The participants' professional profiles were therefore not as specialised as those expected in the QuickScan methodological approach. However, it didn't seem to pose problems, and as the participants were already acquainted with the QuickScan method and had Workshop 1 results in mind, it was possible to deal with the various points of the agenda pretty fast and finish ahead of schedule.

Though there were **no experts for specific climate-related threats** around the table, Workshop 2 reached its goals.

Finally, we can wonder if having « experts » at QuickScan workshops is necessary or even advisable. **The purpose of the QuickScan method is to take advantage of the "collective intelligence" that can be developed with brainstorming meetings**. In other words, the workshops enable to compare the points of views of several persons involved in road design and maintenance. None of them is an expert in climate-related risks, but thanks to this collective intelligence, in the end a real expertise comes out.

Anyway, it seems that involving such experts in these workshops is difficult, because they seldom can be found in the owner's or operator's staff.
It is at least advisable having around the table both owner's (for design-related issues) and operator's representatives (for operation and maintenance-related issues).

7.3 From Workshop 3

It is considered that **Step 6.2 of the QuickScan method** (Finalize discussion on risk acceptability and identify what risks require action) **was dealt with in Workshop 2** (Step 4.4).

In the present situation of climate change uncertainties, it is rather challenging saying when it will become critical. Moreover, depending on the infrastructure construction time, climate changes may be critical or not. For example, if the infrastructure has been built a long time ago and has to be rebuilt in the next years, climate changes may not be considered as an issue: 1) because no significant climate changes are likely to happen in a few years' time period; 2) climate change impacts can be incorporated in the design when rebuilding the infrastructure.
So the question should be asked the other way round: knowing the asset life span, when climate changes could become a risk? If climate changes become significant only beyond the asset life span, it cannot be considered as critical.

7.4 Feedback from the participants

At the end of the 3rd workshop, the participants were asked to express their opinion on the QuickScan process and outputs in the framework of the A24 case study, in terms of strengths and weaknesses. A synthesis is given below.

☞ **Strengths**

- The brainstorming process of the method is important in terms of team building. It was the first time that the Operscut's staff was working together so closely.
- The approach develops awareness on climate change issues, and climate related risks in general. This helps developing prevention approaches.
- A new section will be added to the 5-year repair and investment plan for dealing with climate related risks.

☞ **Weaknesses**

- The purpose of the QuickScan when starting Workshop 1 was not clear. Giving the innovative nature and the condensed form of the QuickScan method, more information should have been provided to the participants before the workshop. During Workshop 1, illustrations of climate related damages should have been provided.
- Ideally, the exercise should have incorporated technicians working in the field, for gaining insight on actual risks for the infrastructure.
- A climate specialist should have contributed to the talks.
- The approach focuses more on the infrastructure operation and maintenance than on design issues. It should more encompass design problems in a context of climate change.

9 Acknowledgement

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The consortium thanks Norscut and Operscut for providing all information and effort for performing this quickscan. We are especially grateful for all participants that attended the workshops.

10 References

None

11 Appendices

Appendix 1 – List of Threats

Appendix 2 – Scoring of the Threats

Appendix 3 – Climate Risk Assessment

Appendix 4 – Map of Climate Risks

Appendix 5 – Adaptation Plan

Appendix 1 – List of Threats

Threat		Comments	Climate parameter	Concerned components of the infrastructure	Contextual site factors
Flooding of road surface (assuming no traffic is possible)	Pluvial flooding (runoff after precipitation, rise of groundwater levels)	Not already occured, but possible, in relation to culvert overload (N.B.: 100-year design capacity)	Short rainfall events (heavy showers)	Culverts, ditches	Brooks, talwegs
			Long rainfall events	Vertical alignment (trench or cut sections)	Low lying areas, shallow groundwater
Erosion of road embankments and foundations	Overloading of hydraulic systems crossing the road		Short rainfall events (heavy showers)	Culverts	Brooks, talwegs
	Erosion of road base		Short rainfall events (heavy showers)	Embankments	Brooks, talwegs
	Bridge scour	Observed for the Pileio river bridge, but the Douro river bridge is the most exposed to this threat	Long rainfall events	Bridge (pier, abutment)	Rivers, upstream dams
Landslips, avalanches, ground subsidence or collapse	External slides, ground subsidence or collapse affecting the road	Is already a maintenance issue on the A24	Long rainfall events	Road base, embankment, slopes	Geology, soil, vegetation, natural slope, underground cavities
			Drought (consecutive dry days)		
	Slides of the road bed		Long rainfall events	embankment, cut and fill slopes, retaining walls	
			Drought (consecutive dry days)		
	Rock fall		Long rainfall events		Geology, soil, vegetation, natural slope, underground cavities
			Frost-thaw cycles (number of days with temperature zero-crossings)		
Loss of road structure integrity	Impact on soil moisture levels, affecting the structural integrity of roads, bridges and tunnels	Many mixed cross sections (cut and fill) interfering with groundwater	Seasonal and annual average rainfall	Road base, embankment, retaining wall	Low lying areas, high watertable
	Weakening of the road base by standing water or watertable rise	On specific spots	Seasonal and annual average rainfall	Road base	Low lying areas, high watertable
	Unequal settlements of roads by consolidation in case of severe droughts		Drought (consecutive dry days)	Road base	
Loss of pavement integrity	Cracking, rutting, embrittlement during heat waves		Maximum and minimum diurnal temperature and number of consecutive hot days (heat waves)	Pavement	
	Frost heave, aggregate loss and detachment of pavement layers, cracking due to weakening of the road base by thaw		Frost, frost-thaw cycles (number of days with temperature zero-crossings)	Pavement	
Loss of driving ability due to extreme weather events	Reduced visibility by fog	All the year long, in some places of the A24 (60% of the A24 in winter)	Fog days		Altitude, topography
	Reduced visibility during snowfall, heavy rain including splash and spray	N.B.: hail is frequent.	Snowfall or rainfall		
	Reduced vehicle control by strong wind	Especially on some viaducts	Extreme wind speed (worst gales and wind gusts)		Topography
	Decrease in skid resistance on pavements from slight rain after a dry period	First autumn rains make the pavement very slippery	Drought (consecutive dry days)	Pavement	
	Aquaplaning in ruts due to precipitation on the road	Not related to ruts	Extreme rainfall events (heavy showers)	Pavement	
	Icing and snow	7-8 days of snow per year	Snowfall	Pavement	
		Approx. 30 days of icing per year	Frost and rainfall	Pavement	
Reduced ability for maintenance	Snow removal costs		Snowfall	Pavement	
	Ice removal costs		Frost		
Susceptibility to wildfires that threaten the transportation infrastructure directly		Make slope unstability issues worse	Drought (consecutive dry days)	Traffic	Forest cover
Damage to signs, lighting fixtures, supports, pylones, canopies, noise barriers, etc., because of strong winds		On the upper parts of the A24	Extreme wind speed (worst gales and wind gusts)	Equipement	Topography
Damage to energy supply and communication networks (e.g. pylones)		Electric substations damaged by lightnings 2-3 times per year	Wind, snow, or lightning	Energy and communication networks	
Trees falling on the road			Extreme wind speed (worst gales and wind gusts)	Trees	Slopes

Appendix 2 – Scoring of the Threats

Threat		Consequences for the A24						Total score	Average score	Weighted score
		Availability	Safety	Effect on surrounding network	Direct costs	Reputation	Environment			
Flooding of road surface (assuming no traffic is possible)	Pluvial flooding (runoff after precipitation, rise of groundwater levels)	1	3	2	2	1	4	13	2,17	2,271
Erosion of road embankments and foundations	Overloading of hydraulic systems crossing the road	4	3	2	4	3	1	17	2,83	2,971
	Erosion of road base	1	3	2	4	4	1	15	2,50	2,499
	Bridge scour	1	1	1	2	2	1	8	1,33	1,257
Landslips, avalanches, ground subsidence or collapse	External slides, ground subsidence or collapse affecting the road	1	3	2	4	3	1	14	2,33	2,413
	Slides of the road bed	1	3	2	4	3	1	14	2,33	2,413
	Rock fall	1	3	2	4	3	1	14	2,33	2,413
Loss of road structure integrity	Impact on soil moisture levels, affecting the structural integrity of roads, bridges and tunnels	1	1	1	4	2	1	10	1,67	1,599
	Weakening of the road base by standing water or watertable rise	1	1	1	4	2	1	10	1,67	1,599
	Unequal settlements of roads by consolidation in case of severe droughts	1	1	1	4	2	1	10	1,67	1,599
Loss of pavement integrity	Cracking, rutting, embrittlement during heat waves	1	1	1	3	2	1	9	1,50	1,428
	Frost heave, aggregate loss and detachment of pavement layers, cracking due to weakening of the road base by thaw	1	1	1	3	2	1	9	1,50	1,428
Loss of driving ability due to extreme weather events	Reduced visibility by fog	1	4	2	3	2	3	15	2,50	2,699
	Reduced visibility during snowfall, heavy rain including splash and spray	1	2	2	1	2	1	9	1,50	1,519
	Reduced vehicle control by strong wind	1	3	1	1	2	1	9	1,50	1,676
	Decrease in skid resistance on pavements from slight rain after a dry period	1	3	2	1	2	1	10	1,67	1,814
	Aquaplaning in ruts due to precipitation on the road	1	3	2	1	2	1	10	1,67	1,814
	Icing and snow	1	2	2	1	2	3	11	1,83	1,767
Reduced ability for maintenance	Snow removal costs	2	3	3	2	3	2	15	2,50	2,519
	Ice removal costs	2	3	3	2	3	2	15	2,50	2,519
Susceptibility to wildfires that threaten the transportation infrastructure directly		2	2	2	3	1	3	13	2,17	2,209
Damage to signs, lighting fixtures, supports, pylones, canopies, noise barriers, etc., because of strong winds		1	2	1	2	2	1	9	1,50	1,552
Damage to energy supply and communication networks (e.g. pylones)		1	2	1	3	1	2	10	1,67	1,761
Trees falling on the road		1	3	1	1	2	1	9	1,50	1,676
	Coefficients	0,186	0,295	0,138	0,171	0,086	0,124			

(orange)	Major threat
(yellow)	Serious threat
(white)	Secondary threat

Appendix 3 – Climate Risk Assessment

Threat		Consequences for the A24						Total threat score	Average threat score	Weighted score / consequence	Probability	Risk level	Importance of A24 sections	Weighting of sections	Risk level per section category
		Availability	Safety	Effect on surrounding network	Direct costs	Reputation	Environment								
Flooding of road surface (assuming no traffic is possible)	Pluvial flooding (runoff after precipitation, rise of groundwater levels)	1	3	2	2	1	4	13	2.17	2.271	1	**2.271**			
Erosion of road embankments and foundations	Overloading of hydraulic systems crossing the road	4	3	2	4	3	1	17	2.83	2.971	2	**5.942**			
	Erosion of road base	1	3	2	4	4	1	15	2.50	2.499	2	**4.998**			
Landslips, avalanches, ground subsidence or collapse	External slides, ground subsidence or collapse affecting the road	1	3	2	4	3	1	14	2.33	2.413	3	**7.239**	High	1.3	**9.4107**
													Medium	1	**7.239**
													Low	0.7	**5.0673**
	Slides of the road bed	1	3	2	4	3	1	14	2.33	2.413	3	**7.239**	High	1.3	**9.4107**
													Medium	1	**7.239**
													Low	0.7	**5.0673**
	Rock fall	1	3	2	4	3	1	14	2.33	2.413	4	**9.652**	High	1.3	**12.5476**
													Medium	1	**9.652**
													Low	0.7	**6.7564**
Loss of driving ability due to extreme weather events	Reduced visibility by fog	1	4	2	3	2	3	15	2.50	2.699	4	**10.796**	High	1.3	**14.0348**
													Medium	1	**10.796**
													Low	0.7	**7.5572**
Reduced ability for maintenance	Snow removal costs	2	3	3	2	3	2	15	2.50	2.519	3	**7.557**	High	1.3	**9.8241**
													Medium	1	**7.557**
													Low	0.7	**5.2899**
	Ice removal costs	2	3	3	2	3	2	15	2.50	2.519	1	**2.519**			
Susceptibility to wildfires that threaten the transportation infrastructure directly		2	2	2	3	1	3	13	2.17	2.209	4	**8.836**	High	1.3	**11.4868**
													Medium	1	**8.836**
													Low	0.7	**6.1852**

Appendix 4 – Map of Climate Risks

Appendix 5 – Adaptation Plan

Threat		Concerned components of the infrastructure	Concerned operational procedures	Timing for defining objectives	Strategies to be implemented *	Priority level
Landslips, avalanches, ground subsidence or collapse	External slides, ground subsidence or collapse affecting the road	Whole infrastructure	Slope maintenance (cuts and fills), drainage and erosion control, inspection / monitoring	5-year plan	2, then 4 or 5	5
	Slides of the road bed	Whole infrastructure	Maintenance of retaining walls and fill slopes, drainage and erosion control	5-year plan	2, then 4 or 5	6
	Rock fall	Pavement, shoulders, barriers, ditches, signalization	Maintenance of cut slopes, inspection / monitoring	5-year plan	2, then preferably 4, or 5	2
Loss of driving ability due to extreme weather events	Reduced visibility by fog	None	Maintenance of horizontal and vertical signalization, surveillance (video, patrols)	None	1 and 3	3
Reduced ability for maintenance	Snow removal costs	None	Winter maintenance, meteo forecast	None	1 and 3	4
Susceptibility to wildfires that threaten the transportation infrastructure directly		Pavement, signalization, fences, guard rails…	Roadside maintenance (vegetation)	5-year plan	1 and 3	1

* Simultaneously, successively, or alternatively, as specified in the table

Adaptation strategy:

1) do minimum (traffic management, business as usual);
2) research to reduce uncertainty / monitoring changes;
3) develop contingency plans for being better prepared to manage emergency situations / improving resilience;
4) strengthening preventive maintenance;
5) retro-fit investments / strengthening infrastructure.