CLIMATE RESILIENCE IN THE MONTENEGRIN ROAD NETWORK

Climate Resilience Strategy and Action Plan

Project Number: 49075

DATE:

09/2019

European Bank
for Reconstruction and Development

SWECO

Contents

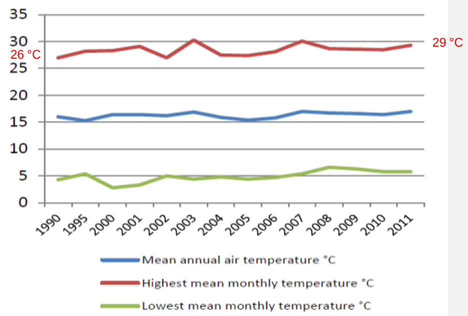
1 TRENDS & PREDICTIONS OF CLIMATE CHANGE IN MONTENEGRO

Montenegro is expected to face major climate changes over the next 30 – 70 years. The country is likely to experience an increase in average temperature of 3°C by 2050[1], associated with frequent droughts, decrease in precipitation of -10% by 2050[1] with frequent and intensive storms and a rise of the level of world seas of +65cm[1], bringing about soil erosion.[1]

Even though Montenegro has started to prepare for the negative impacts of climate change, there are imminent threats and damages to economy, society and environment in case no mitigation actions are taken on vulnerable road infrastructure.

Pro-active climate adaptation responses mitigate adverse effects of climate change and are, in the long-run less costly than maintenance or repair of non-resilient roads.

In general, the trends of climate change have been visible in Montenegro over the past decades. For example, there was a visible trend of increasing of the highest mean monthly temperature from 1990 to 2011 by almost 3°C (see graph on the right).[2]



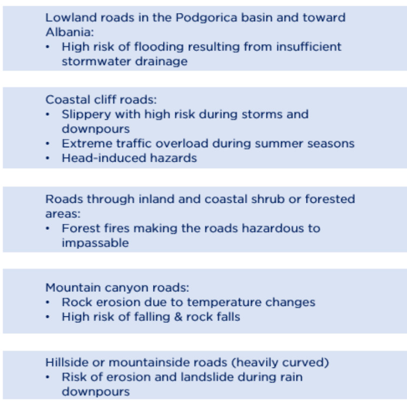
Source: Indicator-based state of the environment report of Montenegro 2013 – Montenegro SOE 2013

As such, if no mitigation actions are taken, 9 road sections will be severely impacted by climate events in the near future with expected impact on more than 10% of local population and expected international disruption of basic services, reduction of tourism income, more frequent traffic jams and rising road accidents.[3]

2 PROBLEM DEFINITION

Montenegro is likely to experience a dynamic growth of motorization in the future. As such, the road network in Montenegro is not fully prepared for the expected climate changes and climate impacts, risking humans lives and economic costs. The government of Montenegro has adopted a disaster risk reduction strategy (in accordance with the Sendai Protocol) and EU codes are being introduced in the construction industry, which should significantly reduce the risk of catastrophe and negative economic impacts. These documents do not focus specifically on road infrastructure.

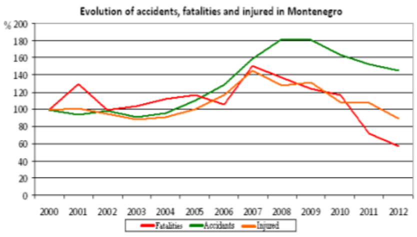
Different regions experience different climate impacts, all of which is likely to generate several social and economic problems.



[1] Country Note
[2] Indicator-based state of the environment report of Montenegro 2013 – Montenegro SOE 2013
[3] Results of the initial climate impact assessment of the working group based on the PIARC framework

In general, it is estimated that 82% of total costs is due to harms by weather on road infrastructure (6.7 mil EUR of current costs)[4]. Extreme weather increases the costs of maintenance & repair by 30-50% yearly (increase of 3.3 mil EUR/year for Montenegrin budget). It is estimated that 67% of the damage is activated by rain & surge[4] and avoiding the implementation of climate resilience measures in the road infrastructure could result in an increase of average annual costs of road maintenance by almost 124% by 2050 (increase of 10.2 mil EUR/year for Montenegrin budget).[4]

Regarding social impacts, climate change contributes to the frequency of accidents. Even though the number of accidents in Montenegro decreases, the risky road sections contribute to the significantly higher rate of road deaths per 100 000 habitants in Montenegro compared to other European countries (29.6 per 100k inhabitants). The number is expected to rise due to under-developed climate resilience measures, as the number of fatalities is estimated to rise by 9% on a day warmer than 26°C and by 15% on a day with 1.5-3cm of snowfall.[5]



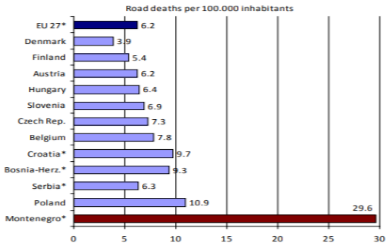


Fig. 4 Fatalities per 100,000 head of population (2010/2011)

2.1 IMPACTS OF CLIMATE CHANGE ON ROAD INFRASTRUCTURE

Extreme climate events have a direct, immediate and negative effect on transportation and the road infrastructure. They lead to increased transportation time, frequency of accidents and infrastructure damage with the associated costs of maintenance and repairs.

Climate Impact	Consequences
Increased precipitation	Overloading of drainage systems, scouring of roads and concrete/metal structures
Weather Storms	Inland storms & coastal storms damaging road structures
Changing ground water levels and increased soil moisture levels	Increased instability of structures
Landslides (due to precipitation, rapid ice/snow melting)	Damage to roads & safety risks
Flooding (due to increased precipitation or increased ice/snow melting)	Damage to roads, drainage systems, closure of road sections, increased probability of accidents
Extreme temperatures	Heat damage and deterioration & thermal erosion (pavements, expansion of metal structures such as bridges, longer vegetation growing season
Extreme heat (Drought)	Thermal erosion & heat damage
Wildfire risks	Environmental damage, roads closure
Road damage from slush flow	Damage to roads, roads closure
Natural rocks falling	Damage to roads, roads closure, increased probability of accidents
Extreme wind speeds	Instability of structures, increased probability of accidents

[4]Estimate according to a study conducted by the Department of Civil Engineering, Near East University, Nicosia, Northern Cyprus, Turkey. Retrieved from: http://www.annexpublishers.com/articles/JEPC/1105-The-Economic-Impact-of-Climate-Change-on-Transportation-Assets.pdf
[5] https://www.resourcesmag.org/archives/how-climate-change-affects-traffic-accidents/

Increased sea levels and coastal erosion and submersion	Coastal erosion of roads base, submersion causing roads closure, Roads damage
Extreme snow precipitation & avalanche risk	Damage to roads, roads closure
Earthquake	Damage to roads, increased probability of accidents

An outline of the consequences on each climate impact can be seen below:

3 INITIAL CLIMATE IMPACT ASSESSMENT RESULTS

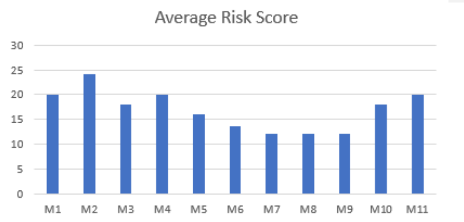
Based on the initial climate assessment of 52 road sections, performed by the working group, it is clear that Montenegro is vulnerable to climate impacts resulting from climate change (for detailed information on how the assessment is performed, please refer to Annex 11.22).

The working group has identified:

- 9 road sections with an extreme risk score of 25[6]
- 19 road sections with a very high risk score of 20
- 11 road sections with a higher risk score of 16
- 4 road sections with a high risk score of 15
- 9 road sections with a high risk score of 12
- 0 road sections with a low risk score of less than 12

For detailed information on how the risk of a road section is defined, please refer to Annex 10.2.

The average score is above 12 for all main roads.



The 9 most risky road sections are outlined below, with the specific climate risks defined.

Road Section/Area	Climate Risk
M2 | Petrovac (raskrsnica sa M1) - Sotonići - Virpazar 1 (raskrsnica sa M1.1) **(Technical documentation for reconstruction already in preparation phase)**	- Extreme precipitation - Flash flood - Weather Storms - Landslides - Fires (especially for this section of the M2)
M2 | Virpazar 1 (raskrsnica sa M1.1) - Virpazar 2 (raskrsnica sa R15)	- Fires - Extreme heat - Wind - Flash flood
M2 | Virpazar 2 (raskrsnica sa R15) - Golubovci (obilaznica) - Podgorica 1 (raskrsnica sa M3)	- Fires - Extreme heat - Wind
M2 | Podgorica 1 (raskrsnica sa M3) - Podgorica 2 (raskrsnica sa M4)	- Fires - Extreme heat - Wind - Flash flood

6 As per July 2019. Since then, 4 road sections already have developed technical documentation for reconstruction.

M2 | Podgorica 2 (raskrsnica sa M4) - Bioče (raskrsnica sa R13)	- Natural rock falling - Fires - Extreme heat - Wind - Flash flood
M2 | Bioče (raskrsnica sa R13) - Mioska (raskrsnica sa R21)	- Snow - Flash flood
M2 | Mioska (raskrsnica sa R21) - Kolašin (raskrsnica sa R13) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides - Flash flood
M2 | Kolašin (raskrsnica sa R13) - Mojkovac (raskrsnica sa R10) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides - Flash flood
M2 | Mojkovac (raskrsnica sa R10) - Slijepač Most (raskrsnica sa R11) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides

4 EXISTING ISSUES & SOLUTIONS

There are several existing issues that impede improvements in climate resilience of roads in Montenegro.

4.1 TECHNICAL ISSUES

4.1.1 NO SYSTEM FOR MONITORING DATA

Currently, there is no implemented system for real-time monitoring, forecasting and reporting of climate data on road sections and climate events.

The solution would be to introduce 10 autonomous hardware weather stations along road sections, covering the needed are and providing precise data and forecasts (already in progress as extension to the project).

The risk may be the lack of technical expertise for procurement and implementation of the system.

4.1.2 NO CENTRALIZED DATABASE

Currently, there is no centralized database where data is easily accessible, slowing down the reaction time in implementing climate resilience measures and in emergency situations.

The solution would be a website with Data/information on climate events accessible in real-time, including forecasts of upcoming weather conditions.

The risk may be low engagement on the website, i.e. lack of use.

4.1.3 NO SYSTEM FOR COORDINATION

Increasing climate resilience is a process involving many different stakeholders, which need to collaborate and coordinate their efforts efficiently.

To better facilitate internal communication, a solution would be an internal portal for long-term collaboration and knowledge sharing (part of the website).

Similarly, the risk may be low engagement on the portal due to insufficient institutional collaboration

4.1.4 ROAD QUALITY

As of now, there is a low penetration of climate resilient measures. This is true especially on mountainous & coastal regions where the probability of climate impacts on roads is relatively high.

Road lifecycle and residual value can be increased by introducing climate resilience measures. Drone surveillance of forest areas can detect wildfires in early stages. In general, the investment plan for road maintenance & repair ought to include a budget for introduction of climate resilience measures to increase the lifecycle of the road sections and a budget for early detection of climate events (e.g. drones for wildfire detection; for more examples of climate resilience measures, please refer to Annex 10.5).

The risk may be low perception and not understanding of the importance of increasing climate resilience and the associated long-term benefits.

4.2 FINANCIAL ISSUES

4.2.1 CAPACITY NEEDS

Collaboration and pro-active climate impact adaptation will need additional human resources to develop adaptation measures and oversee the implementation of climate resilience measure

Incorporation of additional workforce in key institutions and establishing of a new coordinator position at Transport Administration would greatly improve the capacity for overseeing the implementation of climate resilience measures.

The risk may be lack of funding or willingness to hire additional human resources.

4.2.2 LACK OF FUNDING

In general, lack of funding of climate resilience measures is one of the most pressing issues.

However, construction of climate mitigation measures can be classified/defined as introduction of climate resilience adaptation measures, which allows for advantageous funding options (e.g. lower interest rates).

The risk may be the lack of administrative expertise when it comes to utilizing funds from international & development banks.

4.3 REGULATORY ISSUES

4.3.1 LACK OF CLIMATE RESILIENCE STANDARDS

Currently, there are no policy toolkits and analytical frameworks for (proactive) improving climate resilience of road infrastructure, i.e. no legislative standards for the construction of climate resilient road infrastructure.

Working group organization adopted through the first iteration of the impact assessment should be kept intact to ensure active cooperation of all institutions/stakeholders. Through the work of the working group, members will be able to develop and optimize policy toolkits during the pilot projects and update regularly as new projects emerge. Based on the recommendations from the working group, Montenegro should adapt road standards which reflect the situation as well as best practices obtained from previous iterations (with defined penalties in case of non-compliance). In this way, the existing process of implementation of new road standards will not be impacted, yet will take into consideration the suggestions from the working group.

The risk may be a slow implementation of regulatory changes – road standards not defined properly and timely.

4.3.2 LACK OF LONG-TERM BUDGETARY PLANNING

Montenegro does not have a defined budget allocation for climate resilient road infrastructure.

Legislative changes need to be introduced to ensure that the national budgetary plan for road infrastructure maintenance, repair & construction considers the costs for introduction of climate resilience measures.

The risk may be a low perception of the long-term economic, social & environmental benefits of the extra costs allocated for introduction of climate resilience measures.

4.3.3 NON-EXISTENT SMART POLICY MAKING

Currently, there is no smart policy making in Montenegro (e.g. smart regulation of road traffic). Smart policy making builds on top of informed policy making which relies on effective, real-time situational awareness a data analysis. Whereas informed policy making considers what has happened and what is happening, data-driven smart policy making adopts a more pro-active future oriented approach, integrating (historical and predicted) data into decision-making process.

Introducing standards for informing the general public on climate events & emergency situations would greatly improve the capability to react to climate change.

4.4 INSTITUTIONAL ISSUES

4.4.1 LACK OF INTER-SECTORAL COOPERATION

There is no institutional framework for planning and designing of road infrastructure resilient to climate change impacts.

Inter-sectoral cooperation for efficient implementation of climate resilience measures is needed, in the form of a coordination mechanism including process-oriented approach based on policy toolkits in support of the European perspective of Montenegro.

The risk may be slow responsiveness and delays in the tasks assigned to the stakeholders.

4.4.2 INSUFFICIENT COASTAL ZONE MANAGEMENT

Montenegro ought to develop high quality and very operational services for monitoring the condition of the shore and waves, as the biggest potential danger, and early warning of the existence of danger, several days in advance. Amendments to the applicable legislation in the field of spatial planning are needed in order to include the problem of climate change in coastal areas during the preparation of spatial planning documentation. For future collaboration of the working group, it is suggested that the institute for sea microbiology be involved in future working group meetings.

The risk may be a slow incorporation of coastal zone management into existing legislation, reducing the capability to react efficiently and swiftly.

4.4.3 LACK OF OWNERSHIP OF INSTITUTIONS

In case a task along the collaborative process does not have a specified owner, the transport administration should accept ownership in case of confusion, distributing the work to relevant parties if internal capacity is insufficient.

Potentially no risk (e.g. in the form of extra funding), as the working group for climate resilience on road infrastructure will be merged with the national working group on climate adaptation and mitigation, whereas the climate resilient road infrastructure will become another point of agenda for the national working group, which oversees all other sectors.

4.5 SOCIAL ISSUES

The existing social issue is the lack of awareness and understanding that building climate resilient roads is more cost-effective than rebuilding after climate impacts/events.

This can be solved by awareness raising through website and case studies outlining the benefits of climate resilience measures in the short & long-run and successful implementation of pilot projects and monitoring/reporting of the performance, outlining the direct/indirect benefits of climate resilience measures. Awareness raising materials will also greatly improve the visibility and outline the positive benefits of climate resilience measures.

5 KEY OBJECTIVES

The overall objective of the Climate Resilience assignment is to improve climate resilience of road infrastructure in Montenegro by introducing climate resilience elements in project planning and design and establishing an institutional framework for all future and existing projects.

Implementing this strategy will make roads more resilient through a series of measurable actions:

I. **All road sections are assessed based on their climate resilience capabilities by 2022. New standards are adapted and optimized by the stakeholders by 2023 and 53 main road sections are climate resilient by 2040.**[7]

II. **Decrease the rate of road accidents (especially fatal accidents) attributable to non-resilient road sections to a minimum by half (corresponding to EU average).**[8]

III. **Ensure sustainable increase in road maintenance/repair costs by avoiding unexpected expenditures on road sections impacted by climate events, i.e. plan for adaptation costs of climate resilience measures which increase the costs of construction by estimated 10-15%** (for 2019 – 2023 period estimated maintenance costs are at 10 mio EUR annually[9])**.**

IV. **Ensure the continuity of road traffic in the coastal region throughout all seasons as sea levels rise.**

V. **Decrease the occurrence of severe climate events (fires, landslides, flooding, rocks falling) currently imminent on 48 main road sections (**as per initial climate impact assessment conducted in 2019, excluding roads with technical documentation for reconstruction prepared**) by 2040.**[10]

VI. **Decrease the severity of climate events on the riskiest 5 road sections from very high to low, resulting in**
   a. **Less than 2% population affected by climate impacts**
   b. **Only local disruption of services in case of a sever climate impact**

VII.

Commented [N1]: If all road section are becoming climate resilient by 2022, how can 50% of all main road section be climate resilient in 2040? Not logical… Please look more carefully into this. Again no answer was given why this percentages? And what is happening with regional roads??

Commented [EB2R1]: Rephrased. Focus on the riskiest main roads as they are the priority.

Commented [N3]: Please indicate what would be an acceptable level of increase in road maintenance.

Commented [EB4R3]: Done. 8.2mio EUR in 2015 – 2019 increased to 10mio EUR for the next 4 year period + 10-15% estimated for incorporation of climate resilience measures.

Commented [N5]: Indicate the percentage and the number of road sections

Commented [EB6R5]: Done. 48 risky main road sections which lack technical documentation for reconstruction incl. climate resilience measures (i.e. excluding those which have technical documentation for reconstruction as you mentioned in other comments)

Commented [N7]: Please indicate the number of sections and their locations.

Commented [EB8R7]: Done. Locations detailed in chapter 3.

Commented [N9]: Should an objective be the setting up of an database where data is easily accessible, slowing down the reaction time in implementing climate resilience measures and in emergency situations .

Commented [EB10R9]: This is an enabler for the rest of the objectives, listed under chapter 4. Not an objective.

7 Standards developed throughout the iterations of the working group, reflecting best practice experience and the EU Directive 2008/96/EC on road safety infrastructure management. Only main roads considered at this stage, as they are the priority. Including the 5 main roads for which technical doc. is prepared.

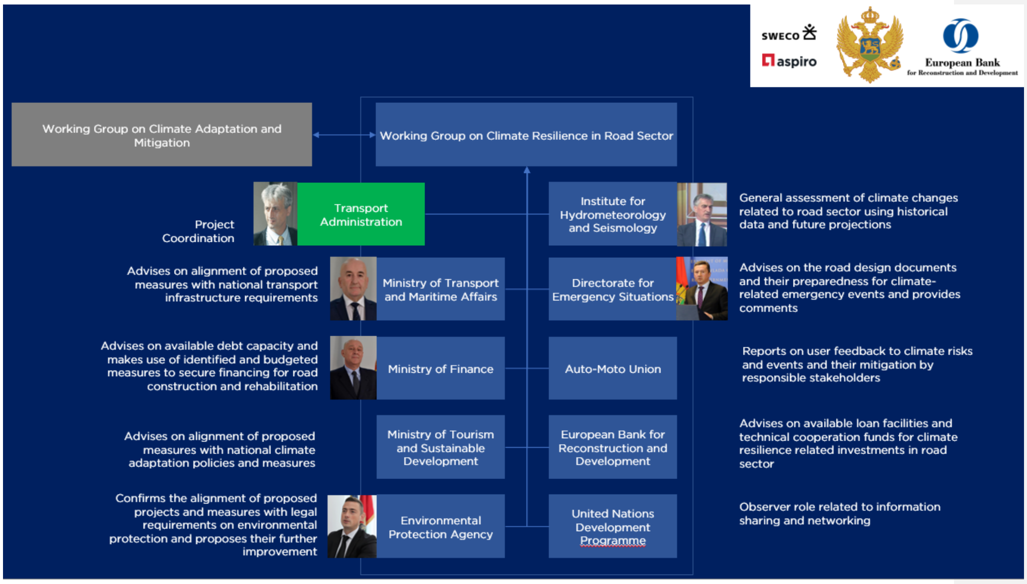
8 Reducing the number of fatal accidents is dependent on various factors. It should therefore be systematically observed which accidents are attributable to non-resilience of the roads and the climate impacts. The goal is to decrease the percentage of fatal accidents attributable to non-resilient roads to EU levels

9 Transport Development Strategy – Montenegro 2019-2035

10 Decrease the vulnerability of these road sections to low/very low (According to PIARC framework)

6 INSTITUTIONAL COMPETENCES

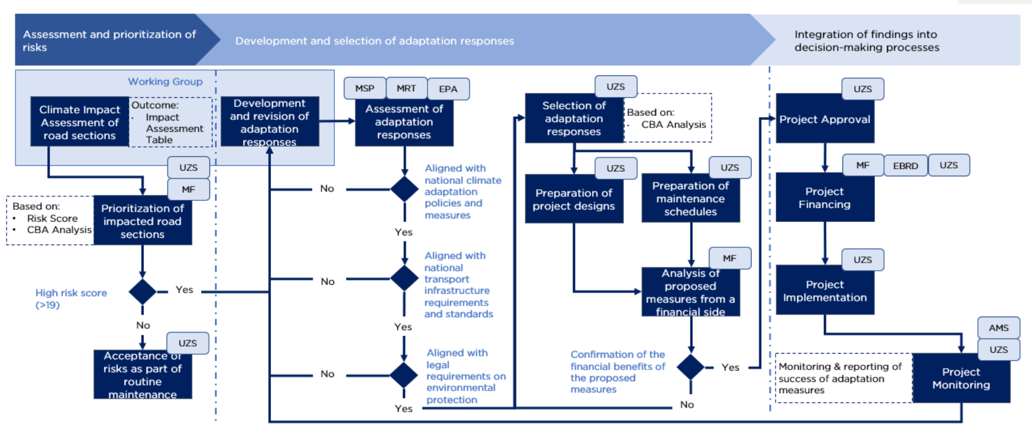
Several institutions need to actively cooperate on implementing the strategy. The overview of each institution's competences can be found in Annex 10.3.



7 INSTITUTIONAL COOPERATION

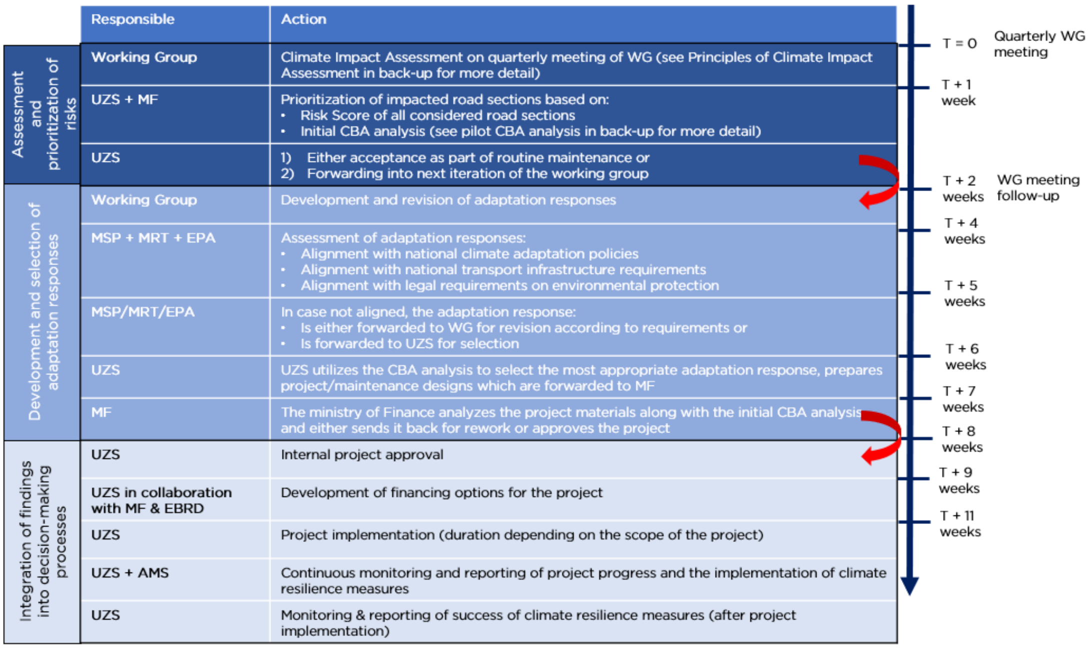
To enable most effective planning and implementation of climate change adaptation strategy, it is fundamental to integrate the incorporation of relevant stakeholders and focus on interdisciplinary approach. This approach seeks to outline the responsibilities and KPIs of each institution in their respective contribution to the process.

The working group on climate change will serve as the main cooperation platform and each institution needs to have a precisely defined responsibility to make prompt decisions. The process-driven cooperation overview can be seen below:



The main principle of the whole strategy is to increase the cooperation and coordination of the institutions performing the climate impact assessment with institutions devoted to planning and maintenance of the road infrastructure by introducing robust internal processes and delegating responsibilities & ownership. In the end, this will ensure a timely implementation and successful collaboration.

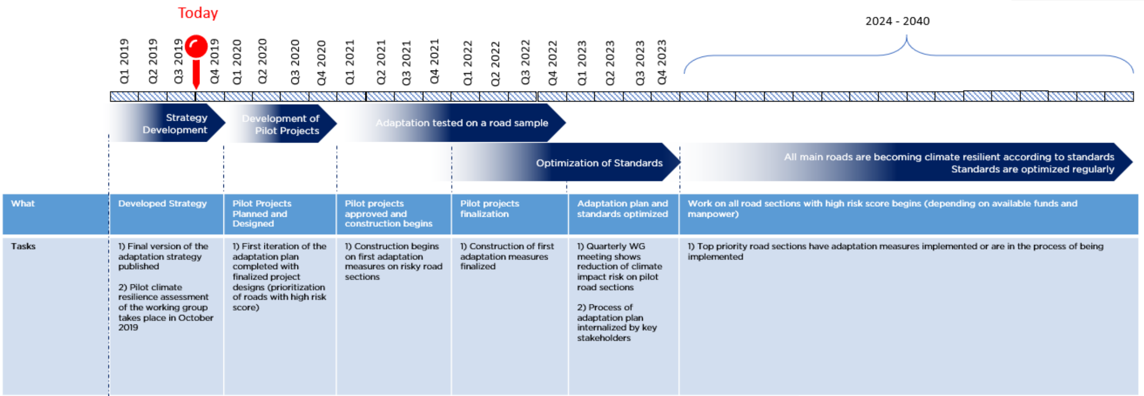
If deadlines for processes and decisions are met, specific results can be achieved every quarter. An overview of all actions with specified responsible stakeholder and the ideal time-



frames for finalizing the specific tasks is outlined below:

8 ROADMAP

After this strategy is adopted, 2020 ought to see the launch of a systematic preparation of measures.



Until end of 2019, the final version of the adaptation strategy should be published. It will also mark the pilot meeting of the working group – climate resilience assessment, resulting in a table of road sections and their respective risk scores and vulnerabilities.

In 2020, the first iteration of the adaptation plan should be completed with finalized project designs of pilot roads (high risk score).

2021 will see the beginning of the construction of adaptation measures on the prioritized pilot projects, effectively testing the adaptation on a road sample.

Depending on the project scope, the implementation should be finalized by the end of 2022, which will also mark the first working group meeting after an implementation of climate resilience measures. This meeting should serve two purposes. First of all, it will evaluate the pilot projects and their climate resilience after implementation, showing the reduction of vulnerability and risk. Secondly, it will outline the potential improvements and updates of existing standards and processes (after several iterations of the working group, the optimization measures should be clear). This is a process which can potentially last until end of 2023.

Beginning 2024, the process of adaptation plan should be fairly internalized by the stakeholders. This will allow for the official start of implementation of resilience measures on all main roads in Montenegro, taking into account the prioritization principle (risky roads first).

8.1 PRIORITIES

The following table links the key objectives to the specific road sections (based on initial assessment) with outlined adaptation response which need to be implemented to off-set the negative effects. Solving these issues would greatly improve the resistance to climate impacts.

KPI	Coverage	Adaptation Responses	Outcome
Ensure the continuity of road traffic in the coastal region throughout all seasons as sea levels are expected to rise by +65cm by 2050	11 road sections	Construction of seawalls, jetties, offshore breakwaters, groins, ripraps to protect shorelines from coastal erosion and submersion and re-siting of critical infrastructure from areas that are forecast to be most at risk from rising sea-levels, especially on 11 road sections (with high exposure to sea level rise)	I. Most vulnerable road sections become climate resilient II. Reduction of fatal road accidents caused by non-resilient & un-safe road infrastructure III. Reduction of the expected increase in yearly maintenance costs of 3.3 mil EUR and reduction of the expected increase in yearly maintenance & reconstruction increase of 10.2 mil EUR (by 2050) IV. Ensured the continuity of road traffic in the coastal region V. Decreased occurrence of severe climate events (fires, landslides, flooding, rocks falling) currently imminent on 53% of all road sections VI. Reduction of severity of impacts on population and only limited disruption of services (allowing to re-open a closed road section swiftly)
Decrease the occurrence of severe climate events:			
Flooding	41 road sections	Increasing water retention capacity by introducing natural or bioengineered systems and water storage systems and construction of levy banks with drainage on 41 of all main road sections (with very high exposure to flooding)	
Fires	37 road sections	Use of heat and fire-resistant materials & coverage of fire-fighting equipment on 37 road sections (with very high exposure to fires)	
Extreme heat & drought	35 road sections	Implementation of resilient materials which have heat-resistant properties on 35 road sections	
Wind	25 road sections	Installation of windbreaks on 25 road sections (with very high exposure to high wind speeds) and implementation of forecasting of wind speeds into website for drivers	
Snow & Avalanche	12 road sections	Use of a pavement surface having a high albedo (surface solar reflectivity) in order to minimise heat transfer to the underlying subgrade and enclosing materials to protect from avalanches on 12 road sections	
Natural rock falling & landslides	30 road sections	Introduction of debris flow barriers and enhancement of slope stability and prevent landslides and rock fall on 30 road sections (with very high exposure and sensitivity)	

The initial assessment can provide direction and outline priorities for financing in 2020-2022 state budget. These 9 road sections have been defined as the most vulnerable to climate change & climate impacts. This list is updated based on quarterly working group assessment meetings. Focusing on the riskiest 9 road sections, the strategy proposes the following measures to be taken.

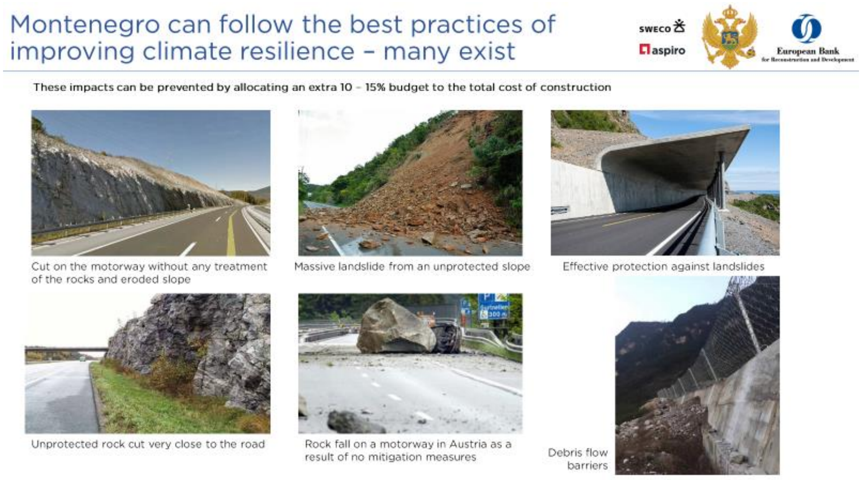
Road Section/Area	Climate Risks*	Adaptation Responses
M2 | Petrovac (raskrsnica sa M1) - Sotonići - Virpazar 1 (raskrsnica sa M1.1) **(Technical documentation for reconstruction already in preparation phase)**	- Extreme precipitation - Flash flood - Weather Storms - Landslides - Fires (especially for this section of the M2)	- Increasing water retention capacity by introducing water storage & drainage system - Enhancement of slope stability & debris flow barriers - Use of heat-resistant surface materials & increase fire-extinguisher coverage
M2 | Virpazar 1 (raskrsnica sa M1.1) - Virpazar 2 (raskrsnica sa R15)	- Fires - Extreme heat - Wind - Flash flood	- Use of heat-resistant surface materials - Enhanced cooling of electrical equipment - Construction of windbreakers - Increased frequency of gully maintenance activities; - Use of anti-corrosion paint due to increase in surface salt levels in some locations
M2 | Virpazar 2 (raskrsnica sa R15) - Golubovci (obilaznica) - Podgorica 1 (raskrsnica sa M3)	- Fires - Extreme heat - Wind	
M2 | Podgorica 1 (raskrsnica sa M3) - Podgorica 2 (raskrsnica sa M4)	- Fires - Extreme heat - Wind - Flash flood	
M2 | Podgorica 2 (raskrsnica sa M4) - Bioče (raskrsnica sa R13)	- Natural rock falling - Fires - Extreme heat - Wind - Flash flood	- Use of heat-resistant surface materials - Installation of rockfall netting - Construction of windbreakers - Installation of strength mesh suitable for reinforcement and protection of slopes
M2 | Bioče (raskrsnica sa R13) - Mioska (raskrsnica sa R21)	- Snow - Flash flood	- Use of a pavement surface having a high albedo (surface solar reflectivity) in order to minimize heat transfer to the underlying subgrade - Use of heat drain to facilitate heat extraction from the - embankment during winter
M2 | Mioska (raskrsnica sa R21) - Kolašin (raskrsnica sa R13) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides - Flash flood	- Avalanche protection by concrete gallery - Tunnel structures protecting from landslides & rock fall - Installation of rock fall netting - Construction of debris flow barriers
M2 | Kolašin (raskrsnica sa R13) - Mojkovac (raskrsnica sa R10) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides - Flash flood	
M2 | Mojkovac (raskrsnica sa R10) - Slijepač Most (raskrsnica sa R11) (Technical documentation for reconstruction already prepared)	- Snow - Natural rock falling - Landslides	

The full list of road sections with PIARC scores can be found here:

Climate_Impact_Asse
ssment_03072019_EN

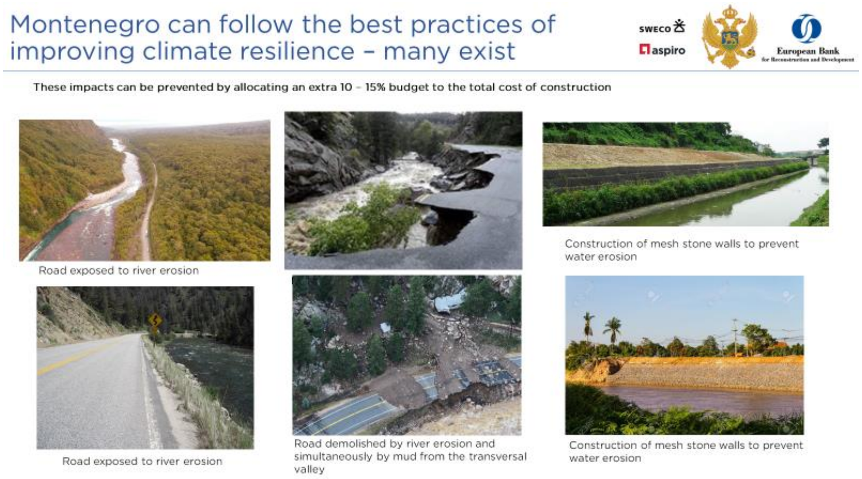
9 BEST PRACTICES

Landslide & Rockfall

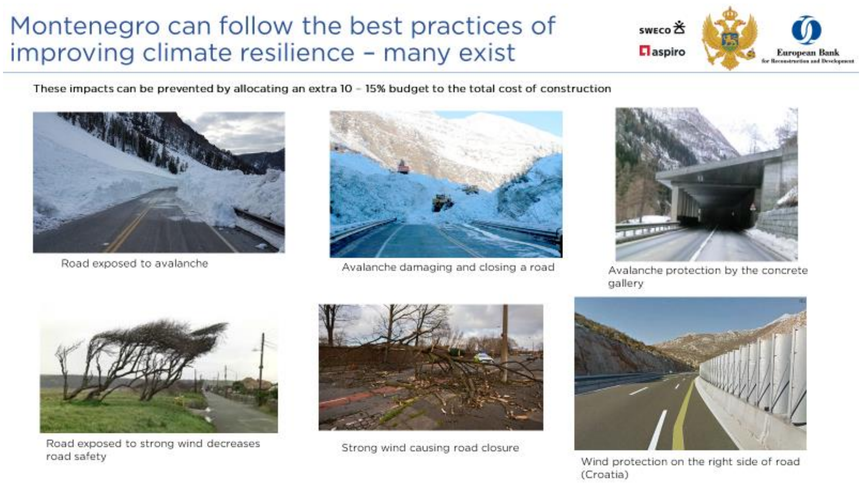


Extreme Heat

Water Erosion



Avalanche & Extreme Wind



10 QUICK WIN OPTIONS & NEXT STEPS

Quick wins can be achieved today by simple actions:

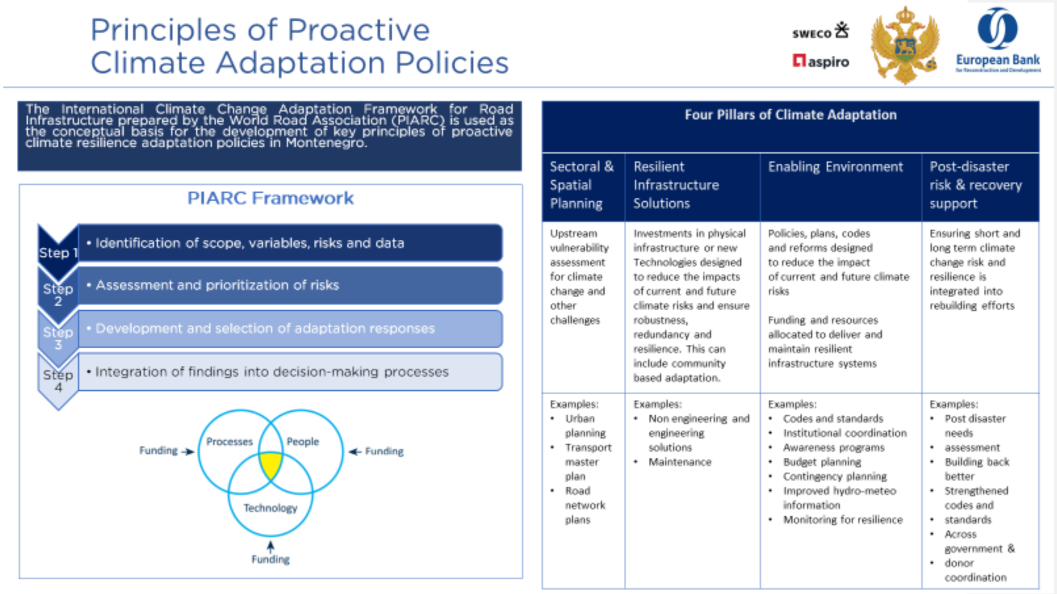
1) Working group members meet in October 2019 and evaluate the current state of roads in Montenegro – second climate impact assessment
2) Transport Administration begins the preparation of designs for pilot projects after the results of the climate impact assessment are finalized
3) Institute for Hydrometeorology and Seismology presents the climate resilience website through available channels to increase general awareness and gain political support
4) Distribution of awareness raising materials to ministries and conferences focusing on climate adaptation as of October 2019

We have identified certain capacity gaps in the working group and believe the following can improve the likelihood of proper implementation of this strategy.

Technical assistance	Expert time input estimates
Roadside meteorological stations and Road weather information system – procurement and implementation support (Already in impementation phase)	Up to 2 man-months
Preparation of climate resilience construction measures – designs for 9 high-risk road sections	Up to 12 man-months
Preparation and capacity-building for climate resilience related maintenance measures and schedules	Up to 6 man-months
Integration of RWIS with the climate resilience portal developed under this TC	Lump sum up to 20,000 EUR
Long-term investment plan related to road sector climate resilience – preparation and project packaging support	Up to 4 man-months

11 ANNEX

11.1 PRINCIPLES OF PROACTIVE CLIMATE ADAPTATION POLICIES



Sectoral & Spatial Planning	Resilient Infrastructure Solutions	Enabling Environment	Post-disaster risk & recovery support
Upstream vulnerability assessment for climate change and other challenges	Investments in physical infrastructure or new Technologies designed to reduce the impacts of current and future climate risks and ensure robustness, redundancy and resilience. This can include community based adaptation.	Policies, plans, codes and reforms designed to reduce the impact of current and future climate risks Funding and resources allocated to deliver and maintain resilient infrastructure systems	Ensuring short and long term climate change risk and resilience is integrated into rebuilding efforts
Examples: • Urban planning • Transport master plan • Road network plans	Examples: • Non engineering and engineering solutions • Maintenance	Examples: • Codes and standards • Institutional coordination • Awareness programs • Budget planning • Contingency planning • Improved hydro-meteo information • Monitoring for resilience	Examples: • Post disaster needs • assessment • Building back better • Strengthened codes and • standards • Across government & • donor coordination

11.2 PRINCIPLES OF CLIMATE IMPACT ASSESSMENT

The climate impact assessment a standardized assessment developed by the World road association with the aim to provide a framework for assessing roads and their vulnerability to climate change & climate impacts.

The principles of climate impact assessment have been studied by the working group before assessing Montenegrin road network. The criteria for assessing and an example of the outcome of the assessment can be seen below.

Principles of Climate Impact Assessment

Exposure can be categorized trough assessing existing exposure levels based on historical data, recent events and observations, local technical knowledge and existing research. You can also consider expected future exposure levels to different climate change effects. This may indicate assets which are currently not exposed to the effects of climate change but may be in the future	**Exposure Matrix**	0	No or negligible exposure now and/or in the future
		1	Low exposure now and/or in the future
		2	Medium exposure now and/or in the future
		3	High exposure now and/or in the future
Sensitivity can be categorized as a degree to which an asset is affected by climate-related stimuli. You should consider experience of recent or historical events (e.g. road flooding on a certain section has greater adversary effects than elsewhere), geographical location (e.g. slope areas more sensitive to landslides) and asset condition and design life (e.g. poor road condition are more sensitive to climate-related stimuli).	**Sensitivity Matrix**	0	No infrastructure service disruption or damage
		1	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required.
		2	Widespread infrastructure damage and service disruption requiring moderate repairs. Partial damage to local infrastructure.
		3	Permanent or extensive damage requiring extensive repair

Vulnerability is calculated as the **sum of exposure and sensitivity scores.** It is a degree to which a system is susceptible to adverse effects of climate change.

Vulnerability Matrix

Exposure \ Sensitivity	Low	Medium	High
High	4 (Medium)	5 (High)	6 (Extreme)
Medium	3 (Low)	4 (Medium)	5 (High)
Low	2 (Very Low)	3 (Low)	4 (Medium)

Impact probability is the likelihood of an impact occurring in a given timeframe. Using climate change predictions, evidence of past events and vulnerability levels you can make an approximation of the probability of an impact for a specific time period.

Probability of effect	Definition	Score
Almost Certain	More likely to happen than not (probability close to 100%)	5
Likely	Fairly likely to occur (probability greater than 50%)	4
Unlikely	Possible it may occur (probability less than 50%)	3
Rare	Low, but not impossible (low, but noticeably greater than zero)	2
Highly Unlikely	Very low, close to zero	1

Impact severity is a judgement about the severity of the impact if it were to happen (e.g. landslide in a certain location), i.e. the severity of consequences of a climate-related impact. Severity should be assessed based on knowledge, estimation and evidence of past events. Reason for a specific score should be recorded in the notes section.

Criteria \ Score	1 (Very Low)	2 (Low)	3 (Medium)	4 (High)	5 (Very High)
Population and communities	Less than 1% of the population affected	Between 1-2% of the population affected	Between 2-5% of the population affected	Between 5-10% of the population affected	More than 10% of the population affected
Economic impact	Less than US $1m	Between US $1m and $2m	Between US $2m and $5m	Between US $5m and $10m	More than US $10m
People and employees	Employees within a local works/depot affected	Employees within an major office affected	Employees within a function affected (e.g. within maintenance)	Employees within a Business Unit affected	All employees affected
Society	Local disruption of essential services, social practices and events	Regional disruption of essential services, social practices and events	Regional disruption of essential services, social practices and events	National disruption of essential services, social practices and events	International disruption of essential services, social practices and events
Stakeholders and Supply Chain	One stakeholder or element of supply chain affected	More than one stakeholder or element of supply chain affected	One group of stakeholders or elements of supply chain affected	More than one group of stakeholders or element of supply chain affected	All stakeholder or supply chain elements affected

Principles of Climate Impact Assessment

The outcome of the Climate Impact Assessment is a table outlining the vulnerability of a road section, the probability and severity of a climate impact and the resulting **risk score**.

This table shall be included in the project documentation of every road infrastructure investment plan.

In case the road section doesn't have a significant vulnerability and the risk score is low, it is possible to end the formal review of climate impacts on this section.

In case the road section is highly vulnerable to climate change and the risk score is high (equal or higher than 12), it is important to take counter-measures to off-set the negative impacts.

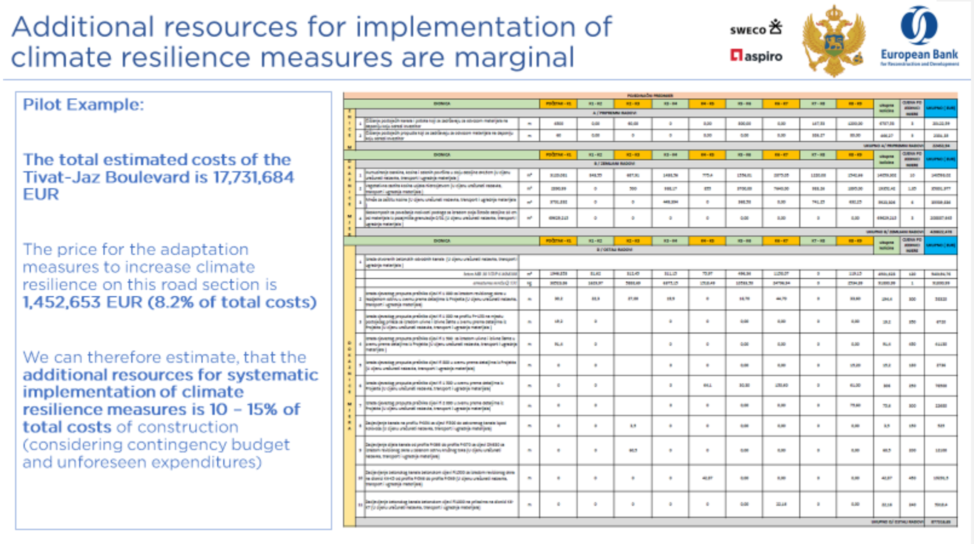
Risk Matrix is the combination of probability and severity. A risk score of between 1 and 25 shows the absolute risk at the time it might occur. This can be used as a starting point when seeking to understand and prioritise climate change impacts according to their probability and severity.

	Severity				
Likelihood	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Road Name & Description	EXPOSURE / IZLOŽENOST	SENSITIVITY / OSIETLJIVOST	VULNERABILITY / RANJIVOST	IMPACT PROBABILITY / VIEROVATNOĆA UTICAJA	IMPACT SEVERITY - OZBILNOST UTICAJA	RISK SCORE / OCJENA RIZIKA	NOTES (Optional) / NAPOMENE
M2 | Petrovac (raskrsnica sa M1) - Sotonići - Virpazar 1 (raskrsnica sa M1.1)				5	5	25	
Increased precipitation (Overloading of drainage systems, scouring of roads and concrete/metal structures) / Povećana količina padavina (preopterećenje drenažnih sistema, spiranje puteva i betonskih / metalnih konstrukcija)	3	2	5				
Storms (inland storms & coastal storms damaging road structures) / Oluje (unutrašnje oluje i obalne oluje koje oštećuju putnu strukturu)	2	1	3				
Changing ground water levels and increased soil moisture levels (instability of structures) / Promjena nivoa podzemnih voda i povećana vlažnost zemljišta (nestabilnost struktura)	2	2	4				
Landslides (due to precipitation, rapid ice/snow melting) / Klizišta (usljed padavina, usljed brzog otapanja leda/snijega)	2	3	5				
Flooding (due to increased precipitation or increased ice/snow melting) / Poplave (usljed povećanih padavina ili povećanog topljenja leda/snijega)	3	2	5				- Increased precipitation - Storms - Landslides - Fires
Increased average temperature - heat damage and deterioration & thermal erosion (pavements, expansion of metal structures such as bridges, longer vegetation growing season) / Povećana prosječna temperatura - oštećenje usljed toplote, propadanje i termička erozija (trotoari, širenje metalnih konstrukcija kao što su mostovi, veći rast vegetacije	3	2	5				
Extreme heat (Drought) / Ekstremna toplota (suša)	3	2	5				
Wildfire risks / Rizici od požara	3	2	5				
Road damage from slush flow / Oštećenje puta usljed debritnih tokova izazvanih jakim snijegom	2	0	2				
Natural rocks falling / Prirodni odroni	2	1	3				
Increased wind speeds (instability of structures) / Povećane brzine vjetra (nestabilnost struktura)	3	1	4				
Increased sea levels and coastal erosion and submersion / Povećan nivo mora i obalna erozija i potapanje	0	2	2				
Increased snow precipitation & avalanche risk / Povećane snježnih padavina i rizik od lavina	1	0	1				
Earthquake / Zemljostresi.	3	2	5				

11.3 OVERVIEW OF INSTITUTIONAL COMPETENCES

11.4 COST OF IMPLEMENTATION OF CLIMATE RESILIENCE MEASURES



11.5 AWARENESS RAISING MATERIALS

CLIMATE CHANGE DEVELOPMENT IN MONTENEGRO

Temperature

Mean temperatures are predicted to increase throughout Europe. The annual maximum temperature is expected to increase much more in southern and central Europe. In Montenegro, the average temperature is expected to increase by 3°C by 2050, contributing to increased deterioration of roads and thermal erosion (especially metal structures).

Hot weather causes concrete to buckle

Precipitation

Mean annual precipitation decreases in the south for all scenarios, on average by -10% by 2050. An increase in the intensity of daily precipitation is likely. Prolonged droughts will be more frequent. An estimated 67% of all road damages are linked to rain & surge and brings about other impacts (landslides, flooding, slush, river erosions) when not properly dealt with.

Road demolished by river erosion and simultaneously by mud from the transversal valley

Wind

Extreme wind speeds are found to increase and will severly affect approximately 50% of all road sections in Montenegro, damaging structures and decreasing road safety.

Sample of windbreakers on a motorway in Croatia

Sea-level

Global mean sea-level is expected to rise by 0.09 to 0.88 by 2100, negatively affecting road bases with coastal erosion, submersion of roads and road damage.

Additional hazards

Climate events such as landslides, slush flow, wildfire, natural rocks falling, avalanches and earthquakes are expected to increase in intensity in the next few decades.

BENEFITS OF CLIMATE RESILIENCE ADAPTATION MEASURES

In case the construction of mitigation measures to off-set climate impacts is linked to increasing climate resilience, it allows for utilization of advantageous financing options to accelerate the implementation.

Examples of climate impacts on non-resilient road infrastructure and possible mitigation actions

Cut on the motorway without any treatment of the rocks and eroded slope

Massive landslide from an unprotected slope

Effective protection against landslides

Unprotected rock cut very close to the road

Rock fall on a motorway in Austria

Suspension mechanism to prevent rock fall

Adaptation Assessment

Based on the initial asessment of climate risks to the road network, we have discovered:

- 9 road sections which are extremely vulnerable to climate change and need immediate attention and introduction of mitigation actions
- 19 road sections which are highly vulnerable to climate change
- 11 road sections which are moderatly vulnerable to climate change
- 4 road sections which are fairly vulnerable to climate change
- 9 road sections which are reasonably vulnerable to climate change. Possible mitigation actions may be included in normal maintenance
- No road sections qualify for a medium or low risk score according to the PIARC framework.

This defines the road infrastructure in Montenegro as highly vulnerable to climate impacts of climate change.
Detailed data with specific risks and vulnerabilities (including a scoring matrix for potential climate impacts for 52 road sections) will be presented on the website/portal, which will be the reference area for outlining the climate impact risks on road sections in Montenegro.
The main attributes of the website include an interactive map allowing users to select relevant information on climate change and consequences in each of the regions/ road sections, technical capabilities to allow for continual refinement as new information and data is available and information about institutions involved in the process.
The portal also aims to advertise project information/data on climate change from various donors to foster knowledge sharing and information spreading, ultimately aiding local and international institutions in their efforts on climate change and resilience agenda in Montenegro.

ADAPTATION RESPONSES TO DIFFERENT CLIMATE IMPACTS

Sea level rise and storm surges - adaptation responses

- Using appropriate structural materials and providing lateral protections;
- Raising road and pavement levels;
- Constructing levy banks with drainage/seawalls;
- Road realignment;
- Including additional longitudinal and transverse drainage systems;
- Construction of seawalls, jetties, offshore breakwaters, groins, ripraps to protect shorelines from coastal erosion and submersion;
- Protecting levy bank with suitable mangroves;
- Planting artificial reefs;
- Replacing metal culverts with reinforced concrete;
- Development or strengthening of flood risk management plans;
- Re-siting of critical infrastructure from areas that are forecast to be most at risk from rising sea-levels;
- Development of a Coastal Strategy which identifies the most appropriate shoreline management plan and whether coastal defences are required/ need managing/need implementing etc.

European Bank

Reduction in rainfall and increased drought - adaptation responses

- Using flexible pavement structures;
- Increasing water retention capacity and slowing infiltration through environmental measures and bio retention systems to recharge aquifers and reduce surface flow runoff;
- Re-vegetating with drought tolerant species;
- Using matting/erosion control blankets;
- Applying granular protection;
- Ensuring the selection of materials with high resistance to dry conditions;
- Implement a reactive landscape and maintenance regime which accommodates for reduced rainfall;
- Maintenance of soil moisture and nutrient levels;

Hot weather causes concrete to buckle

Dry weather makes the environment sensitive to fires fires

Increase in precipitation - adaptation responses

- Applying a safety factor to design assumptions such as reducing the gradient of slopes;
- Increasing size and number of engineering structures (hydraulic structures, high river crossings);
- Increasing water retention capacity and slow infiltration through natural or bioengineered systems;
- Raising pavements and adding additional drainage capacity;
- Using water capture and storage systems;
- Realigning natural water courses;
- Enclosing materials to protect from flood water (impermeable linings);
- Using materials that are less affected by water;
- Allowing for alternative routes in the event of a road closure;
- Highway drainage plan;
- Gully and pumping station renovation;
- Mapping of flood hotspots;

Flood on the Missouri river (USA), Highway No 54.

- Updated design standards for drainage systems;
- Production of a Surface Water Management Plans, Local Flood Risk Management Plans;
- Pollution prevention control methods due to increased volumes of diffuse pollution resulting from increased runoff;
- Implementation/ broadening of emergency warning systems in the instance of flooding;
- Improved communication methods for network users in the event of an emergency;
- Improved coverage of street lighting due to reduced visibility;
- Slope stability studies in an attempt to minimise landslides as a result of increased precipitation;
- Measures to enhance slope stability and prevent landslides and rock fall;
- Soil moisture removal techniques to prevent the deterioration of the structural integrity of roads, bridges and tunnels;

4

Debris Flow Barriers

As a flexible dam, a debris flow barrier can intercept the debris flow within the design scope and minimize the risk of debris flow and its secondary disasters. Debris flow flexible protection nets are installed in diversion trenches where debris flow must pass through, intercepting debris flows and carrying substances to protect bridges, roads and buildings.

Debris flow barriers

High Strength Mesh

High strength mesh is generally suitable for reinforcement and protection of soil or rock slopes with potential geological disasters such as slipping, collapse, shallow movement, weathering, and rockfall.

Rockfall Netting

Flexible Rockfall Netting is mainly composed of steel wire rope Netting, steel wire grids, wire rope anchors, support ropes, and sewing ropes. In general, the construction process should first clear the floating soil and pumice in the protection area of the slope, and then take the line measurement, design the hole of the anchor, and then hang the wire rope net. Generally, it is based on the actual situation of the slope surface.

Rockfall Hazard Analyses and Rockfall Protection

Large rockfalls occurred on the steep limestone slopes along the Adriatic Coast of Croatia, causing serious damage to buildings and traffic facilities, injury to people and delayed traffic on roads. Settlements and transportation facilities in coastal areas with steep rock slopes are vulnerable to rockfalls. In recent years, a number of highways have been or are scheduled to be built in the coastal regions of Croatia that carry significant risk of increasing rockfall hazard events.

The rockfall events along the limestone slopes were caused by unfavourable rock mass characteristics, rock mass weathering in combination with heavy rainfalls and the influence of improper slope interventions during highway construction. The rockfall protection projects were conducted to ensure the protection of human lives and facilities from future rockfalls. The rockfall protection projects started with rockfall hazard analyses to identify the potential of rockfalls to occur and the potential consequences, i.e., risk. At the locations where hazards with related risk were determined, detailed field investigations were provided. Based on the identified characteristics of potentially unstable rock mass blocks, analyses of the motion and resulting pathways of rockfalls were conducted. Rockfall trajectories, impact energy and height of bouncing depend on the slope geometry, slope surface roughness and rockfall block characteristics. Based on these analyses, rockfall protection measures were designed. Two design approaches were adopted:

(1) prevention of rockfall by removing potentially unstable rock mass or by installing a rock mass support system, and;

(2) suspending the running rockfall mass with rockfall protection barriers.

5

Most of the occurred rockfalls were registered on the engineered cuts and natural slopes near old roads. The consequences of these rockfalls induced a systematic approach to reduce or/and restrain the rockfall hazards. Old road slopes, where different types of rockfalls had been registered in the past, were subjected to rockfall hazard analysis, and on the basis of these analyses, rockfall protection projects were conducted. The significant advancement in rockfall hazard analysis and rockfall protection over the last ten years resulted from the design and construction of new roads and highways in Croatia. An appropriate rockfall hazard rating system incorporating local rockfall conditions in Croatia was never developed, and there are no official recommendations for rockfall hazard analysis. Under these conditions, scientists and geotechnical engineers used existing rockfall hazard rating systems based on experiences from neighbouring countries. The new requirements for rock mass properties and rock mass behaviour for rockfall hazard analysis were obtained during field investigations and the construction of highways on steep limestone slopes along the Adriatic coast. Any higher highway cut in the steep slope required significant slope stability and rockfall hazard analyses. It was also necessary to provide appropriate analyses of possible constructions influences on rockfall hazards.

Massive landslide completely demolished the Motorway D8 (Prague – Berlin) before opening to traffic

Landslide on the D8 motorway demolished section between bridge (under construction) and tunnels for animals' migration. Motorway opening delayed for 3 years. Costs of rehabilitation grew during works; railway track was not reopened till now;

Massive rock fall from the unprotected rock slope

Tunnel structure protecting road against landslide or rock fall

Road demolished by river erosion and simultaneously by mud from the transversal valley

Construction of mesh stone walls to prevent water erosion

Increased wind strength - adaptation responses

- Modifying the design of supports and anchorages;
- Installing protection systems such as windbreaks;
- Planting coastal forest and mangroves;
- Increased frequency of gully maintenance activities;
- Improved communication systems and warnings for network users;
- Structural assessment of suspension bridges, signs and tall structures;

Protection against strong wind (Croatia motorway)

Increased temperatures - adaptation responses

- Using more resilient materials and processes which have heat-resistant properties;
- Relocation of street traffic control equipment;
- Development and implementation of emergency and resilience plans and changes to working practices and policies;
- Improved conditions for vegetative growth may require an increased level of management;
- Increased use of heat and fire-resistant materials;
- Improved coverage of fire-fighting equipment;
- Enhanced cooling and ventilation of electrical equipment;
- Use of anti-corrosion paint due to increase in surface salt levels in some locations;
- Maintenance of soil moisture and nutrient levels;

Pavement deformation by hot temperature and overload

Changes to snowfall, permafrost and ice coverage - adaptation responses

- Soil stability studies;
- Production of a Surface Water Management Plans, Local Flood Risk Management Plans etc.;
- Development and implementation of emergency and resilience plans and changes to working practices and policies;
- Heat extraction using air convection in embankments on permafrost (this involves cooling embankments in an effort to maintain or cool frozen ground conditions);
- Use of heat drain to facilitate heat extraction from the embankment during winter;
- Insulating the permafrost to mitigate thawing;
- Soil stabilization techniques used to reduce frost action in subgrade soils;
- Use of a pavement surface having a high albedo (surface solar reflectivity) in order to minimize heat transfer to the underlying subgrade;
- Structural assessment of road and structure integrity as a result of subsidence and weakening as a result of permafrost thaw;

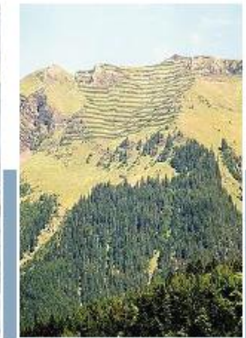
Avalanche protection (Austria)

8

Avalanche protection in the Alps valley

Considering the long-term timeframe, the results of risk analyses serve as a basis for designing and optimising protection measures, mostly based on cost-benefit-analyses (Wilhelm, 1999). Short-term risk analyses serve as a decision basis whether or not organisational measures, such as road closures, should be implemented. This decision basis is provided by means of short-term avalanche risk simulation. The risk is calculated starting with the analysis of hazard potential, taking into account the current environmental conditions and the estimated number of persons at risk on the basis of the effective traffic volume. In a further step, the quantitative value for the current fatality risk resulting from avalanche risk can be compared to the fatality risk resulting from traffic accidents in the study area. If the risk due to road accidents is assumed to be the level of accepted risk, this comparison may serve as a decision-making tool whether or not additional risk reducing measures have to be implemented.

Avalanche protection by the concrete gallery



Forest and structures to protect against avalanches

Avalanche protection by the steel fencing