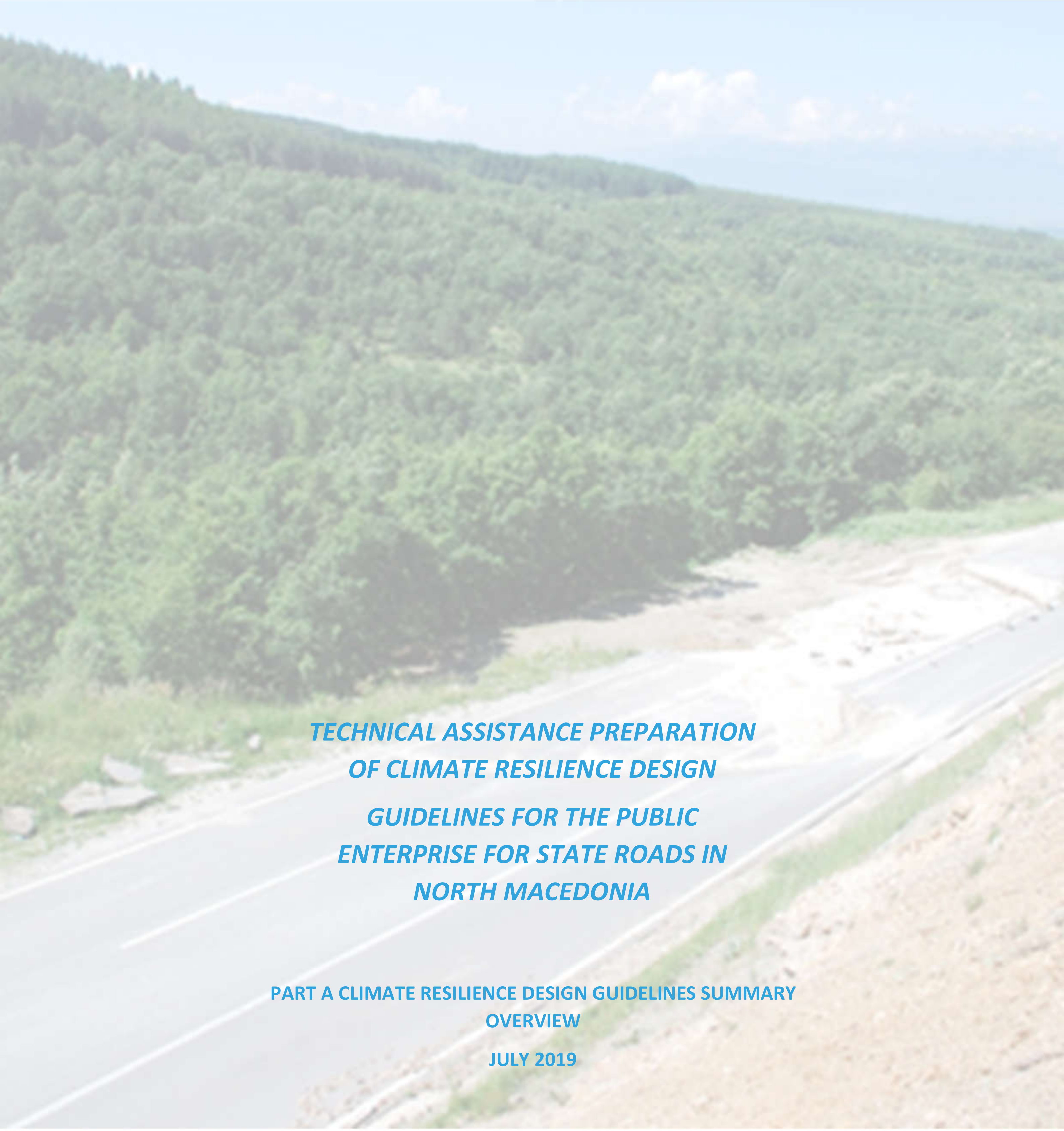

TECHNICAL ASSISTANCE PREPARATION OF CLIMATE RESILIENCE DESIGN

GUIDELINES FOR THE PUBLIC ENTERPRISE FOR STATE ROADS IN NORTH MACEDONIA

PART A CLIMATE RESILIENCE DESIGN GUIDELINES SUMMARY OVERVIEW

JULY 2019

Client : Republic of North Macedonia – Public Enterprise for State Roads Project financed by the World Bank

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ABBREVIATIONS

AHP	Analytic Hierarchy Process
CBA	Cost Benefit Analysis
CEDR	Conference of European Directors of Roads
CRDP	Climate-resilient development pathway
CVRA	Climate Vulnerability and Risk Assessment
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi-criteria Analysis
PESR	Public Enterprise for State Roads
RAMS	Road Asser Management System

TERMINOLOGY

Terminology is important to follow assessment process and these Guidelines follow that adopted by the IPCC AR5. The basic concepts and terms used are explained below.

Natural hazards - are naturally occurring physical phenomena caused either by rapid or slow onset events which can be geophysical, hydrological, climatological and meteorological.

Geological Hazards*:* Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Geological hazards include internal earth processes, such as earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses, and debris or mud ows. Hydro-meteorological factors are important contributors to some of these processes.

Hydrological hazards - process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Landslides[1] - In the broadest sense, landslides are the movement of rock, debris or earth down a slope over stable surfaces under the influence of gravity.

Landslide Susceptibility[2] – Spatial probability of an event (e.g. landslide) in an area expressed in qualitative terms (scale from low to high susceptibility) or quantitatively.

Landslide Hazard - In general terms, a space-time probability of occurrence of an event, substance, human activity or condition that can lead to loss of life, injury or other health impacts, property damage, loss of livelihoods and work, social and economic disturbances and damage to the environment. Landslide hazard is a probability of processes in a certain area of a specified magnitude / intensity in a given time period.

Conditioning Factors - Factors inducing hazards by creating favourable conditions for their development, such as unfavourable geological settings, unfavourable morphology of the terrain, poor physical and mechanical parameters of rock masses making up the terrain, unfavourable hydrological conditions, inappropriate land use, etc. A set of unfavourable conditioning factors makes specific area a subject to the event.

Triggering Factors – Factors such as heavy rainfall, rapid snowmelt, dynamic impacts (e.g. earthquakes), which directly lead to hazardous event.

Flood - is a temporary covering by water of land normally not covered by water. This shall include floods from rivers, mountain torrents, and floods from the sea in coastal areas, and may exclude floods from sewerage systems.

Flash floods occur when excessive water fills normally dry creeks or river beds along with currently flowing creeks and rivers, causing rapid rises of water in a short amount of time. They can happen with little or no warning and combine the destructive power of a flood with incredible speed and unpredictability.

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[1] According to international terminology, it is noteworthy that *Landslides* in English encompasses the entire group of gravitational processes of different mechanisms of movement that do not imply only sliding as a process or landslides as an event. A closer general term, also frequently used is "mass movements". Macedonian language has no sufficiently precise and comprehensive linguistic terms except for sliding, falling and flowing.

[2] In the spirit of local language, the term *Susceptibility* can be translated as sensitivity, proneness.

Flood risk - is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with a flood event.

Flood hazard maps shows areas which could be flooded according to three probabilities (low, medium, high) complemented with: type of flood, the flood extent; water depths or water level where appropriate; where appropriate, flow velocity or the relevant water flow direction.

Flood risk maps indicate potential adverse consequences associated with floods under several probabilities, expressed in terms of: the indicative number of inhabitants potentially affected; type of economic activity of the area potentially affected; installation which might cause accidental pollution in case of flooding.

Flood plain maps indicate the geographical areas which could be covered by a flood (from all sources except sewerage systems – see above definition of flood) according to one or several probabilities: floods with a very low probability or extreme events scenarios; floods with a medium probability (likely return period >=100y); floods with a high probability, where appropriate.

Elements at risk - People, assets, systems or other elements present in hazard zones that are affected or subject to potential losses.

Vulnerability - Characteristics and conditions of exposed elements that make them susceptible to the harmful effects of danger. Vulnerability is expressed as the potential extent of the loss of value of a given element or set of elements exposed to geological and climate-related hazards of a corresponding intensity or magnitude.

Risk - The combination of the probability of a hazardous event and its negative consequences on the exposed elements over time. It is assumed that is combination of hazard, and vulnerability of exposed elements.

Risk Assessment - The methodology for determining the nature and extent of risk by analysing potential hazards and the assessment of the existing conditions of vulnerability that together could cause damage to exposed persons, property, services, living conditions and environment that the population is dependent on.

Landslide risk - a combination of the likelihood of a landslide-related hazard event and its adverse effects on exposed elements over time. It is assumed to be a combination of hazard and vulnerability to exposed elements.

Resilience - The ability of a system, community or society exposed to hazards to resist, absorb, and respond to the effects of hazards in a timely and efficient manner and to recover, including the preservation and restoration of its essential basic structures and functions.

Road Link (also referred to as segment) - a section of road between clearly defined points.

Road infrastructure asset – a distinct structure within the road corridor. Examples include a drainage structure (e.g. culvert), bridge, retaining wall and other supportive structures. These structures tend to enhance the resilience of the road corridor and reduce the vulnerability of the road network as specific locations.

Road element. This is a distinct part of the road corridor or road infrastructure asset. For example, this could be a bridge abutment, embankment or road pavement.

1 EXECUTIVE SUMMARY

1.1 Use of the Guidelines

These guidelines and the associated methodology statement have been produced for PESR to enable the organisation to better understand the impacts of climate related events on North Macedonia's road network, the appropriate courses of action that are available and the priorities in terms of investment. The guidelines have been designed as a series of linked documents, each of which is targeted at a different audience within PESR and North Macedonia's road sector organisations.

As stated in the CEDR 2012 Climate Change DoRN: "Road authorities need to evaluate the effect of Climate Change on the road network and take remedial action concerning design, construction and maintenance of the road network. The prioritization of measures in order to maximize availability with reasonable costs is one of the most important tasks of the road owners".

The main questions of road owners and operators that need to be answered include:

- **Is climate change really affecting roads?** - It is in principal accepted that climate change is already having a negative effect on road infrastructure and the level of service.
- **How and where will the roads be affected?** - The vulnerability to extreme weather conditions is a key issue for all road agencies. For road owners and operators, it is important to know which unwanted events might happen in the future and how weather poses a risk to road transport.
- **How likely is it to happen and what are the consequences?** - When knowing which unwanted events might occur on a road network, it is important to know the likelihood and consequences in order to gain insight in the risk profile. The uncertainties make the risk-based approach, adopted in these guidelines, a scientific approach for mitigating the risks and saving money for the road authorities.
- **What should be done to mitigate the risks and when?** - If unwanted events are present with an unacceptable risk profile, mitigating actions need to be taken. Road owners and operators need to use the CVRA methodology and the economic assessment tools to assist in the selection and prioritisation of measures.

1.2 The Purpose of the Guidelines

The aim of the work presented here is, based on experience gained in the Republic of North Macedonia and Western Balkans, to support policy and decision makers in establishing a foundation for taking climate hazard resilience considerations in the road transport management and response plans. To this end, this work proposes a flexible methodological framework that can be used by authorities to assess sensitivity of their road networks to natural hazards, in particular to floods and landslides. The methodology allows application even in conditions of less ideal data availability and capacities of national institutions, enabling them to address risk and resilience to develop corresponding investment plans. In order to support decision makers in PESR in extending vulnerability assessment and improve their response capacities, a particular approach to assess the road network vulnerability to the aforementioned hazards is developed, supplemented by "tool" that will support the processes of selecting/designing of most appropriate engineering and non-engineering measures by the contractors hired by PESR.

The main purpose of these Guidelines is through their application PESR to advance the overall design process at all stages of the project management. The resilient designs of the new and the roads to be reconstructed, need to be informed by the climate effects as well as be adopted to the international best practices.

The methodology presented here has been designed to largely rely upon secondary data. However, data collection for the implementation of the entire methodological approach may include:

- Existing (secondary) data acquired (or inputted directly) from different responsible institutions; and
- Acquisition of new data (including using proxies as appropriate) such as through field surveys and stakeholder interviews (e.g. for knowledge of location/extent of historic hazard events). Templates for data collection have been developed and included in the Methodology Statement (Part B).

The overall assumption is that PESR would be responsible for periodic updates, and ensuring data availability, quality assurance/screening and additional collection. The roles of different disciplines are set out in Table 1 below.

1.3 Audience

The overall process of delivering climate resilient design of roads requires different expertise to be brought together. This process is expected to be led by engineers (the prime audience for this report) but involve climate scientists, GIS experts, geologist/geotechnical engineers and hydrologists. The roles of these different specialists are summarised in Table 1 below.

Table 1 Summary of the Expertise and Activities Required at Each Step

Step	Expertise required	Role/responsibility
Step 1. Data collection to create layers in GIS, including climate modelling and hazard analysis	Climate Scientist, Hydrologist and Geologist, GIS expert	Select climate scenario(s). Determine 'climate uplift' to input to hydro-meteorological data. Use this to add uplift flood risk. Analyse flood and flood-related landslide risk (within GIS environment). Survey roads to update and validate flood and landslide risk locations (as required).
	Engineer	Collect all other datasets including road asset and condition.
Step 2. Create CVRA model in GIS environment to produce 'hotspot' maps	GIS expert	Lead on creation of GIS model with road network, topography, hazards, vulnerabilities/asset information etc on different layers. Cleanse data layers, address data accuracy issues. Produce hazard maps and hotspot maps highlighting level of climate-uplifted natural hazard risk at different locations. Input datasets (digitising if required) on road/affected assets, hazards, socio-economic aspects.
	Economist and Engineer	Consult local stakeholders to choose weightings (e.g. different hazards, vulnerabilities). Map road condition and planned rehabilitation. Assess (economic) criticality of different roads and map social vulnerability and social infrastructure.
Step 3. Use CVRA output and site visits to select	Hydrologist and Geologist, Road/Structure/Drainage	Visit 'hotspot' locations and validate hazard risks (Hydrologist for flooding, Geologist/geotechnical

engineering and non-engineering interventions	Engineer (working together)	engineer for landslides). Assess sufficiency of existing infrastructure, considering future risks (Engineer). Identify intervention options (which may be outside of road corridor and could be non-engineering measures) – all.
Step 4. Prioritise measures and develop investment plan	Economist and Engineer	Develop CBA Framework Confirm and detail options to be assessed Complete CBA Prepare Project Fiche for Identified Options Prepare Investment Plan

These guidelines and the associated documents have been written with these different experts and other road sector professionals in mind. This document (Part A) is mainly targeted at road sector managers and decision makers and gives a brief overview of the process and key aspects of the methodology and requirements. The methodology statement (Part B) is designed to provide relevant technical specialists, and those managing consultancy contracts in this area, with sufficient information and guidance to enable them to complete the various tasks required as part of this process. Part C of these guidelines provides more detailed information regarding the potential solutions that might be implemented in North Macedonia, for engineers operating in the road sector. Part D of these guidelines summarises the institutional and legal reviews undertaken in the development of the guidelines and methodology.

It should be noted that, as part of the contract to develop these guidelines, Step 1 has been completed, in conjunction with PESR. This involves the completion of national level flooding and landslide risk assessments. The inputs used in this process and the results of Step 1 have been fully incorporated into PESR's existing Road Asset Management System.

1.4 The Structure of the Guidelines

The Guidelines produced have been divided into three parts:

- Part A – summary guidelines on how to conduct a CVRA
- Part B – detailed methodology on conducting a CVRA
- Part C – how to select appropriate engineering measures
- Part D – Institutional review and non-engineering measures and legal review with recommendations

Part A (this document) sets out, the overview of the tasks to complete a CVRA, an analysis of the current situation in North Macedonia and assessments of institutional and non-engineering interventions, as well as necessary legal changes.

Part B (Methodology Statement) provides details of the data requirements, models used and overall processes, to enable relevant technical specialists to complete tasks, and for contract managers to provide robust management of outside consultants. This part provides details of how to interpret the results of the tasks involved in the overall CVRA process, as well as providing guidance on changes to management practices and processes that are necessary to incorporate the CVRA process in decision making.

Part C (Engineering Solutions) provides guidance to highway, geotechnical and hydrology engineers on potential measures that could be implemented in North Macedonia.

Part D (Institutional and Legal Review) provides a summary of the situation within the road sector in relation to the roles and capabilities of the organisations within the sector, and the laws pertaining to the management of climate related events and interventions.

These guidelines are structured in such way to enable appropriate application of the best possible interventions and responses, depending on the extend/size of the road asset/link that is considered. In this regard, for each specific case, the following aspects should be taken in consideration depending on:

- Scale: National level, Regional level or Local level (site specific)
- Scope of the intervention: Site Specific Road Asset or Larger part of Road Network

2 Overview of methodology

2.1 Introduction - why is it important to consider climate impact for PESR road transport network

If not understood and prepared for, current and potential future climate patterns are likely to result in increased disruption of road traffic in the Republic of North Macedonia. Natural hazards and climate change affect the planning, design, construction, maintenance, safety, and performance of roads throughout their service life. Flooding has been identified as a primary natural risk affecting the roads in the country, followed by landslide (gravitational mass moving) processes. According to the relevant climate scenarios, there will also be an increased risk of scour affecting bridge footings. The key initiatives that are outlined in this document, aim at identifying and minimising the risk of disruption and damage to the road assets due to climate influence.

To minimise future disruption and ensure that the road network in the Republic of North Macedonia is resilient to the impacts of the climate and the future potential climate change, action must be taken to understand where, how and when the impacts are likely to be felt, and also how effective adaptation and resilient construction and reconstruction building can be achieved. The challenges of adapting to a changing climate cannot be considered in isolation. Climate change needs to be a routine consideration, factored into PESR day-to-day decision-making processes rather than a discrete risk to be managed independently. Although many PESR activities are affected by climate, few decisions can be made taking only climate considerations into account. Consideration must be given to the adaptation of road design, construction, operation and maintenance processes and procedures to reduce vulnerability and the potential impact of these effects.

Therefore, with this report we are aiming to assist PESR to:

- Understand the effects of climate and its impacts on road assets;
- Provide the knowledge, skills and tools to manage climate impacts on PESR road assets; and
- Increase the resilience of road infrastructure networks to sustain and enhance the benefits and services provided.

Total protection against climate effects cannot be achieved, but based on the results of this work, PESR can identify areas with the potential for disruptive effects of the climate and ensure that suitable exposure-management contingency plans are put in place, including monitoring, non-engineering and engineering measures.

Case Study: Rockfall near Kamenica, in Tetovo Region

The case for pre-emptive action by PESR to reduce climate related events was highlighted by the recent rockfall at Kamenica in July 2019, during the preparation of these guidelines. This rockfall occurred at a known location, one of those visited for the field visits. The problem of rockfalls at the location is well documented, which had led PESR to undertake additional field visits and preliminary design studies.

After the rockfall, which closed the road, PESR was quickly able to use its emergency powers, to request tenders from 3 qualified road contractors to implement clear up and mitigation measures to prevent future rock falls. Because initial studies had already taken place, it was possible to get clearances to adopt a rapid tender process, which meant that a contractor was appointed within 3 days and was on site within 5 days. This would not have been possible without pre-existing assessments and designs.

Despite this the road section was practically closed for more than 1 week, with restrictions on movement for more than 2 weeks, with temporary and partial road closures.

2.2 Resilience and Climate Change

The main two ways that climate change impacts upon the challenge of improving the overall resilience of the road transport network are to increase risk and vulnerability and increase uncertainty as to what risks might exist in the future.

Changes to the global climate are already changing the uncertainty, severity and frequency of weather events. This in turn is impacting the risk and vulnerability of hazard events, such as flooding and landslides. For example, in North Macedonia, even though overall annual rainfall may not increase the nature of extreme events is changing. The way climate change impacts extreme rainfall events could be summarised as:

- Firstly, the **severity** of these events is increase;
- Secondly, the **frequency** of the most extreme rainfall events will increase; and
- Finally, the **uncertainty** of these is increased – both in terms of when they occur over the course of a year and also how well the frequency and severity of extreme events can be predicted into the future.

This complexity makes the importance of integrating resilience into infrastructure planning and design, budgets and asset management more difficult and more important. This applies to both the resilience of new infrastructure (e.g. a new bridge, or road improvement) and the road network that exists already. The overall challenge is how this growing priority is integrated into the way infrastructure is financed and managed. Instead of just optimising maintenance and operation of infrastructure and then responding to the impacts of disasters after they occur, it is prudent to target both maintenance and improvement at the most vulnerable (least resilient) locations. This should improve the overall cost-effectiveness of the asset management – as less money needs to be spent in recovery, and access is restored sooner after a disaster event. This points to a need for a more sophisticated approach to mapping climate-related risks and optimising actions.

2.3 Introducing Climate Resilience

The rapidity and extent of future climate change will impact on the extent to which improvements are required to make infrastructure systems more resilient. That is why climate resilience necessarily includes both adaptation measures (the main focus of these guidelines) to be considered alongside measures to reduce the operation and maintenance of transport infrastructure to become zero carbon. These two aspects, and how they inter-relate are introduced below. The rest of these guidelines then focus on the former aspect (adaptation).

The International Panel on Climate Change (IPCC) present **climate-resilient pathways** as sustainable development pathways that combine the goals of adaptation and mitigation (Denton et al., 2014), more broadly defined as iterative processes for managing change within complex systems in order to reduce disruptions and enhance opportunities associated with climate change (IPCC, 2014a).[3] The IPCC Special Report on 1.5°C Global Warming states that "Transforming our societies and systems to limit global warming to 1.5°C and ensuring equity and wellbeing for human populations and ecosystems in a 1.5°C warmer world would require ambitious and well-integrated adaptation-mitigation-development pathways that deviate fundamentally from high-carbon, business-as-usual futures."

The IPCC describe climate resilient development pathways as those that allow CO2 emissions from 2020 to reach net zero by 2055 or 2040 (see Figure 1 below left). The proposed CVRA methodology set out in these guidelines are consistent with the approach proposed within the IPCC's AR5 framework for adaptation, as the most recent international agreed framework (see Figure 1 below right). This draws on hazards, exposure and vulnerability (and overlaying these to determine risk) and then exploring how this is impacted by climate change and related to socio-economic aspects.

[3] www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_Low_Res.pdf, Cross-Chapter Box 1.

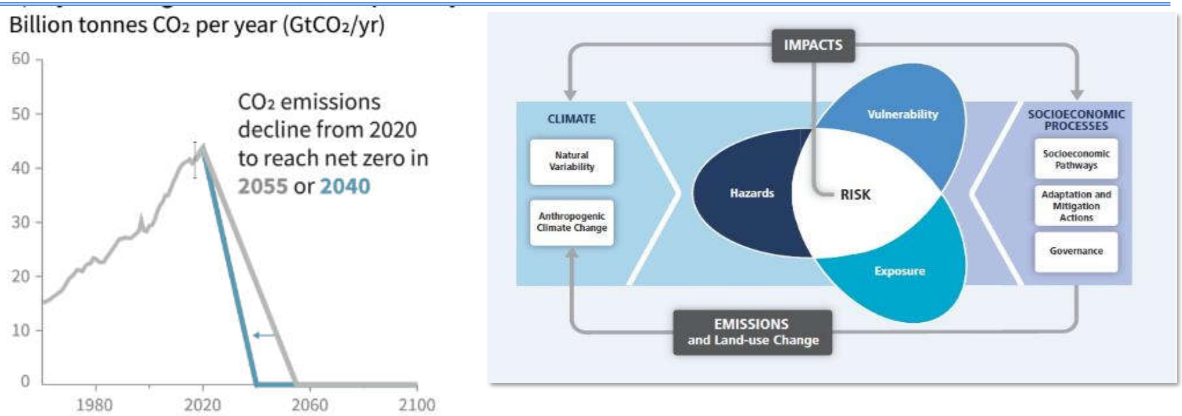


Figure 1 The IPCC AR5's definition of climate resilience (left: mitigation pathway for net global CO_2 emission pathway for 1.5°C climate change[4]; right: adaptation framework[5])

These two aspects, the climate adaptation and carbon reduction aspects of how infrastructure is developed in all countries are interconnected. These two aspects both require to be addressed together as the degree to which adaptation is 'climate resilient' depends the overall climate pathway, which is the sum total of greenhouse gas climate emissions worldwide, as highlighted in the Figure 2 below.

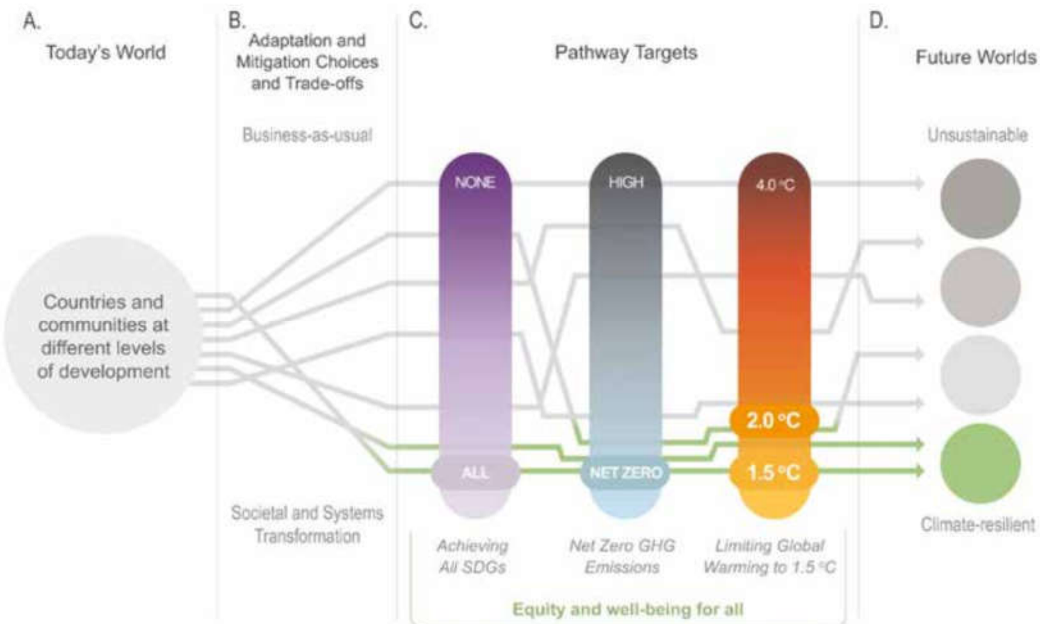


Figure 2 Climate Resilient Development Pathways

4 Source: IPCC Special Report on Global Warming of 1.5°C, https://www.ipcc.ch/sr15/, Figure 1b).

5 Field, C.B., et al.: Technical summary. In: Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 35-94, 2014.

Source: Figure 5.1 of IPCC, Special Report on 1.5C of Climate Change. https://www.ipcc.ch/sr15/chapter/chapter-5/.

How this affects infrastructure investment decisions is illustrated in Figure 3 below, which shows the decision-making diagram developed for Thames 2100. Looking at the Thames Barrier.

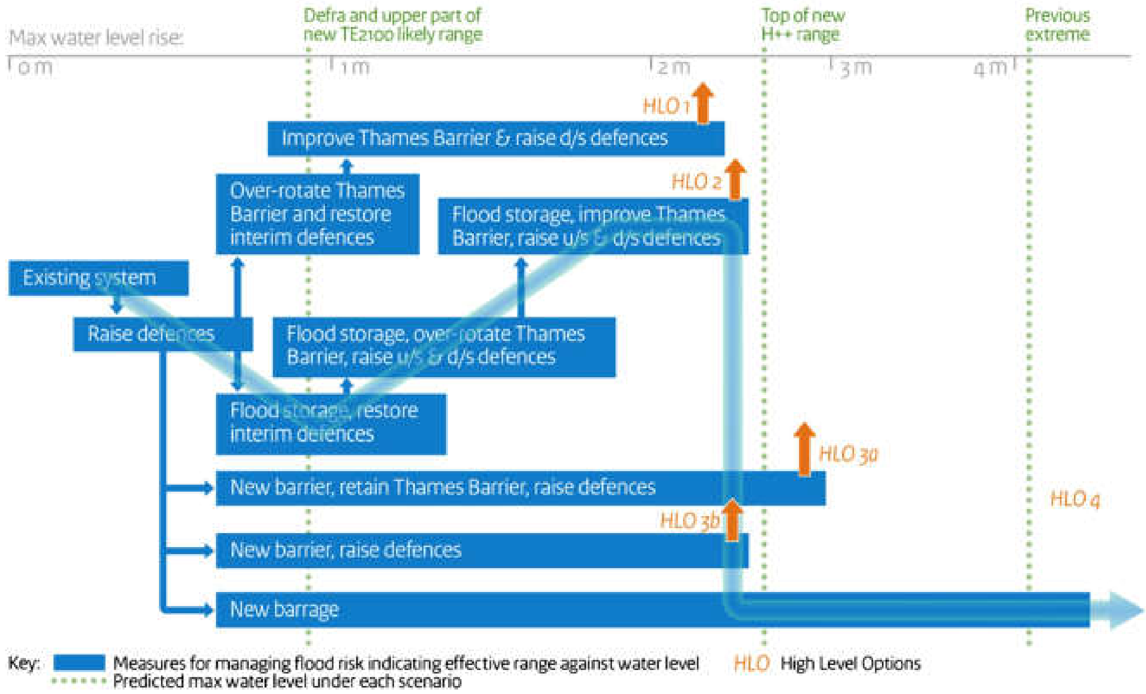


Figure 3 Adaptation pathway map for the Thames Estuary

Source: Environment Agency, UK (2012) Thames Estuary 2100 Plan.

The horizontal axis shows that depending on the timescale or severity of climate change (in this case considering sea level rise) the amount of investment to make infrastructure resilience (and/or the risk of catastrophic failure) changes. This is termed an *adaptive pathway* for climate resilience. This means the extent of climate mitigation and the design life of infrastructure affects the types of engineering and non-engineering measures chosen. For example, with regard to road transport infrastructure, this will particularly impact on longer-term investment decisions (e.g. re-alignment of road, major bridge structure) as the size of extreme flood events will, crucially, depend on the extent of future climate change – and point to the need for decision-making to integrate climate mitigation and mitigation, so building in measures that both reduce carbon *and* increase resilience.

2.4 Methodology for Climate Vulnerability and Risk Assessment (CVRA).

2.4.1 Introduction to the Methodology

This CVRA methodology assesses the hazard, exposure and vulnerability across the road transport network, uplifted for climate change and prioritised based on stakeholder consultation. This methodology is robust, scalable, flexible and based on objective criteria to the extent possible:

- **Robust and Scalable**. The methodology is now tried and tested as a way to link climate information and hazard information to engineering decision-making in many different countries[6]. It can be used to assess climate resilience adaptation needs at different scales on all types of roads (local, regional, national, etc.).

- **Flexible and Objective**. The criteria included in the GIS model (algorithm) can be adjusted based on stakeholder engagement and priorities. The methodology can be adjusted to suit the level of data availability and can be extended in case data availability increases of where greater functionality is required (e.g. addition of sensitivity analysis to algorithm).

The **overall aim** of this CVRA is to identify locations under various levels of risk, in a way that aids the targeting and prioritization of recommendations for structural and non-structural risk reduction measures. This can be applied both to existing road network management practices in North Macedonia, integrating this methodology with the existing RAMS (Road Asset Management System), as well as applying this more locally to complete a climate audit of new transport sector investments.

[6] For example, it has also been applied by the Consultant in a number of different contexts with different combinations of natural hazards (including flooding, landslides and climate impacts) on the road networks of Serbia, St Lucia, Guyana, Bangladesh and Tanzania.

2.4.2 Application in the Republic of North Macedonia

The methodologies are for increasing resilience from landslides and floods on different scales: on the country level and on a local level. The methodology for the landslide CVRA and the flooding CVRA take different parameters, then are combined to provide PESR with the tools to make informed decisions that incorporates climate impact on their road assets.

For the local level application, we have used Polog region as a case study, as described in Box 1 below. We have developed maps that will guide PESR through the process and Study Area will be used as the case study in the capacity building and field survey study with the PESR beneficiaries and relevant stakeholders.

Box 1 Polog Region

The Polog region is located in the northwest part of the Republic of Macedonia. This region covers ~2420 km2 including the densely populated towns of Tetovo and Gostivar (parts of which were developed on rugged hilly terrain). It includes many villages on the steep Mt. Shar Planina, and important infrastructure including railways, a highway, well developed network of regional and local roads (mostly in the mountains), ski centers, and a very important hydro energy system consisting of 130 km of water distribution channels accompanied by 167 km of service roads. In a geological context, the study area belongs to a larger regional tectonic unit called the Western Macedonian Zone (WMZ). In this unit rock masses from the Palaeozoic, Mesozoic, Pliocene and Quaternary periods are represented. Igneous rock masses include granodiorites, granites, diorites, rhyolites, serpentinites, gabbros, diabases etc. The Palaeozoic is represented by a thick complex of metamorphic rocks, rarely igneous rocks. The rocks from the Devonian age are the commonly occurring ones in the area, and here belong to the phyllitic schists, meta-conglomerates, metasandstones, quartzites, quartz-chlorite schists, carbonate schists and marbles. It is important to note that most landslides in the study area have been reported to occur at the contact of the weak schist type rocks and the soil debris which covers them.

On 3 August 2015, a severe storm and intense rainfall in the Polog region affected more than 85,000

2.4.3 Introduction to tools: why Climate Vulnerability and Risk Assessment?

Climate Vulnerability and Risk Assessment (CVRA) is useful as a tool in two ways. Firstly, it is a tool that can help to improve decision making of where to direct investment to improve resilience of infrastructure (through both engineering and non-engineering outcomes). Secondly, in doing so it brings together different areas of expertise needed to think differently about resilience, to change the way that such decisions are made. Also, conducting vulnerability and impact assessments as inputs to master planning in the transport sector ensures protection of the infrastructure, minimizes the creation of vulnerability, and ensures that mobility goals can be met. This tool assists with the improvement of integrated spatial planning with respect to road alignments to ensure that adjacent critical ecosystems, which serve as buffers against floods, droughts, earthquakes, and other extreme events, are maintained and protected.

One way to think about CVRA is a way to bridge the gap between economists/budget holders and engineers responsible for managing a transport network, with academics, researchers, geologists and hydrologists, and climate scientists with knowledge of hazards and climate change impacts. Making this connection will help engineers to make decisions involving climate-related natural hazards in ways that better respond to risks and vulnerabilities, and how these change into the future.

2.4.4 Use of GIS

The value of the GIS environment to bring together different datasets to spatially map the resilience of an infrastructure network is highlighted in Figure 4 below.

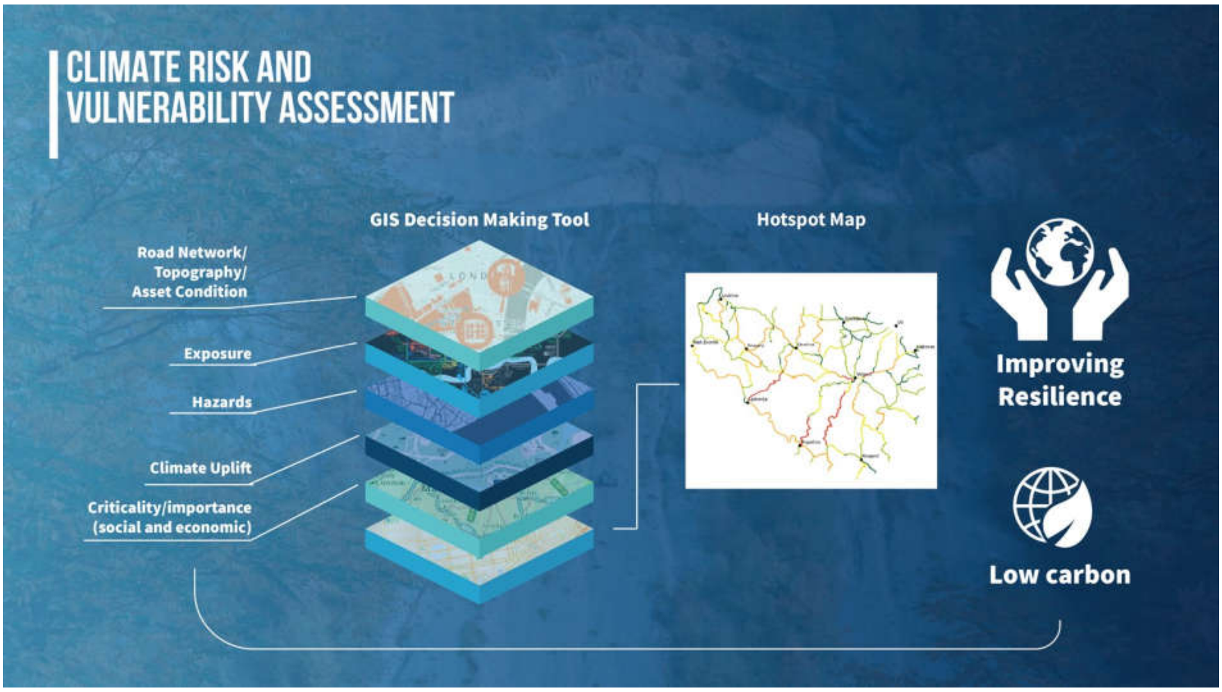


Figure 4 The Structure of a GIS Model

All of the data required to complete the CVRA and the algorithms used to assess the level of risk and the importance of different road links and infrastructure assets (economically, socially) are held within a GIS environment.

1. Physical infrastructure and topography. The topography should include vertical elevation of the road as distinct from the surrounding area. Information on the road transport infrastructure should be linked from the existing RAMS databases (so that the latest dataset is viewed, rather than out of date information copied). The road network asset information should include the location of physical structures (e.g. bridges, culverts, retaining walls). Details of the condition of the road network assets (road surface, bridges etc) and planned major maintenance/rehabilitation/improvement works should be included where this information is digitally available.
2. Spatial distribution of different hazards and exposure, accounting for different future climate scenarios. This will allow the current and future distribution of hazards to be overlaid over the road network. Historic hazard events are also mapped (as a separate layer), which will allow the GIS model to be reviewed and checked. Once the criticality assessment is completed an overall CVRA map is created that considers the hazards, exposure and vulnerability, social and economic criticality/importance of the road network to be considered together. An algorithm is created to link these aspects together with weighting agreed with stakeholders.
3. The criticality (economic importance) of different links within the road transport system are determined as well as the social vulnerability – based on the location both of populations of interest, and the location of social infrastructure (e.g. schools, hospitals) on the road network.

The criticality analysis will be conducted with data exported from GIS and then reimported so this is able to be displayed as information along the road network.

Data collection (together with its ongoing maintenance) and analysis and modelling requires across to a range of different areas of expertise. This includes climate information, hazard information (flooding and landslides are considered here), road network information and socio-economic aspects. These are brought together into a GIS environment as separate 'layers'.

The GIS database model enables all these aspects to be assessed together. An algorithm (formula) defines the way that the different aspects are considered together. The algorithm allows the 'hot spots' – the locations that have the highest combined risk and vulnerability – to be identified. The overall GIS database enables hazards, exposure and vulnerability of the transport network to be all viewed together (overlaid, each layer over each other, like tracing paper). The modular nature of the GIS system allows the read/write permissions of different datasets to be managed separately, allowing potentially wide input and use of the GIS model, and as such the CVRA methodology. This makes this a powerful tool which could be used for CVRA not just by those responsible for the road sector but other parts of government (for example considering the resilience of assets whose locations are identified by the road network, such as communities or schools).

This approach allows (for example) climate scientists and hydro-meteorological specialists, landslide researchers and flood modelers to maintain the latest hazard information, whilst road engineers maintain the latest road asset aspects within a common GIS database. This model has been incorporated in active links to other databases, such as a Road Asset Management System (RAMS) in PESR.

2.5 Main Steps in the Methodology

The main aspects of this methodology are grouped in four main steps:

- **Step 1.** Climate modelling and hazard analysis to create layers at a national scale for input into GIS, to inform the identification of hot spot areas;
- **Step 2**. Create CVRA model in GIS environment to produce hotspot maps to identify priority road sections for further study and interventions;
- **Step 3**. Use CVRA output and field studies to select engineering and non-engineering interventions; and
- **Step 4**. Prioritise measures on an economic basis and develop an investment plan.

These activities in each step are graphically presented in figure 5, where outputs of each step are the entry information for the following:

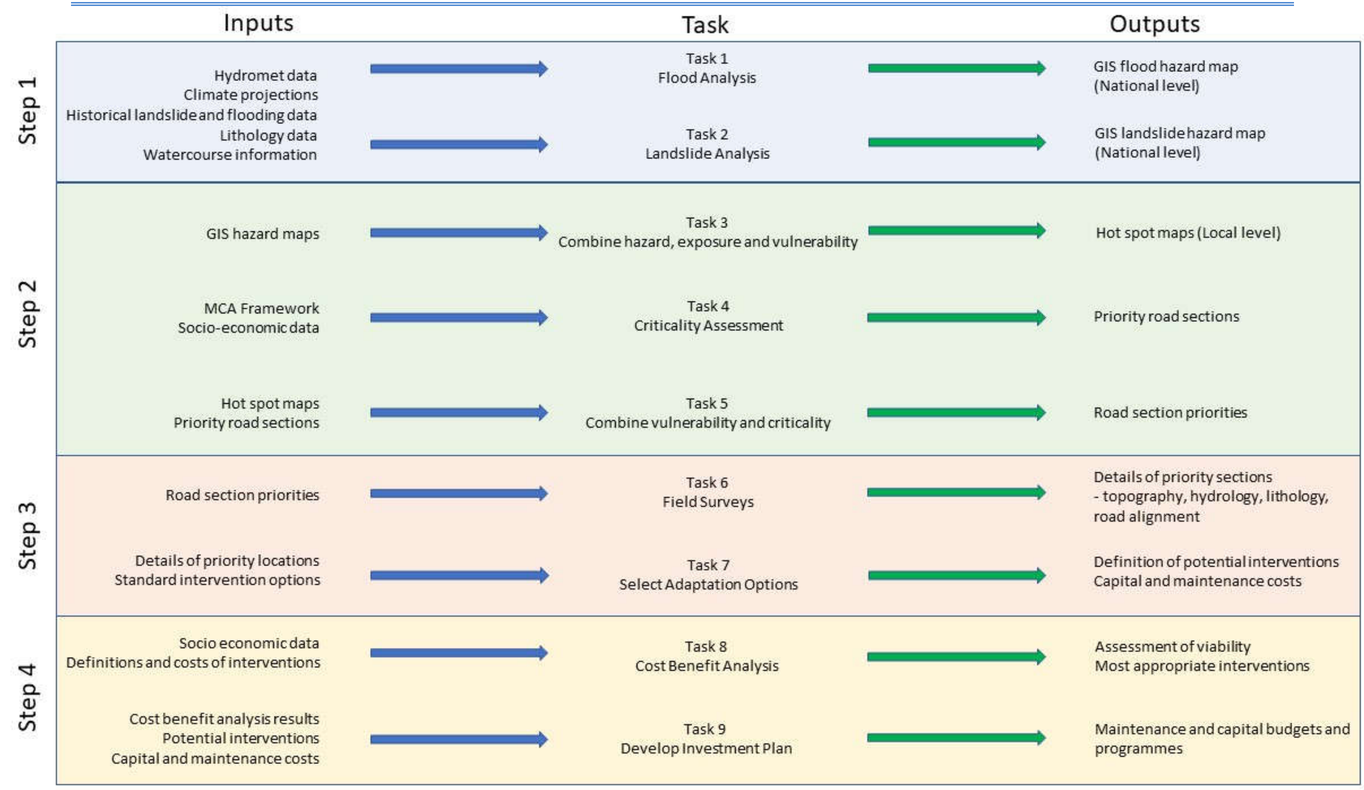


Figure 5 Summary of Key Steps and Tasks

The methodology for flood and landslide hazard and risk assessment will integrate into current approaches for the design of new roads, which already includes slope stability calculations and results from previous design stages and utilises detailed hydrological and hydraulic modelling. However, using the CVRA to inform selection and design of resilience measures will mean that instead of using historical precipitation models (both cumulative and intensive), future climate projections of precipitation will give different (generally increased) flood and landslide risks. In addition, the choice of algorithms (the way in which the different hazards are assessed together and linked to exposure and vulnerability aspects) can be varied as a sensitivity analysis.

2.5.1 Data requirements

The acquisition and management of data for the risk assessment is required throughout the assessment process. There are three sources of data used in this process:

- **Primary Data**, which is acquired as part of field surveys and data collection;
- **Secondary Data**, which is obtained from existing sources, such as those available from various government institutions; and
- **Derived Data**, which is developed using the above types of data, from various analysis, analytical processes, assumptions and estimates, in order to interpret where some data is missing.

Sufficient data quality is vital to any risk assessment and its outputs. Data acquisition is usually time consuming and expensive, so before starting this analysis, it is necessary to identify the relevant data types available and their appropriate sources. Some data is easy to obtain as end-user products or through open access sources, whilst other data can be derived using different freely available data sets. Some data, however, may need to be collected or updated through extensive field investigations or surveys.

The scale of the baseline hazard assessment (i.e. national, regional, local/detailed level), the extent of the area to be covered (because natural hazards have spatial distribution), as well as the outputs from assessment, are all crucial in deciding what kinds of data are needed.

Baseline climate data is crucial in describing and forecasting the current climate most likely to be experienced at a given location. It also serves as a benchmark against which recent or current observations can be compared, including providing a basis for many anomaly-based climate datasets (e.g. global mean temperatures). It is based on historical records, with mean values for successive 30 years periods being the most frequently used statistical normal parameter and a requirement of the United Nation's World Meteorological Organization (WMO). In Macedonia, the National Hydrometeorological Service holds long-term daily and monthly records.

For basic climate elements (annual rainfall amounts, maximum and minimum air temperatures and others), series of data from 1961-2015 were used. The data from the national water strategy were used as source. For the maximum 24 hours of precipitation, series data from 1961-2017 for 13 stations were

used. For torrential rains and different return period, the latest HMS data was used. Innovation of the IDF curves was carried out by HMS for six main meteorological stations.

Therefore, in any of the tasks, the initial critical action is to perform a thorough diagnostic of data availability and additional effort needed to collect/screen/estimate any key missing data. The requirements on data detail (which primarily depends on the adopted scale of analysis) and critical parameters defined herein will guide the depth of the approach and resources needed. Since the scope of analyses and the respective data definitions are set herein, this task is an integral part of the Data Layer.

More details on data requirements in each step is in Part B of the Guidelines.

2.5.2 **Step 1.** Climate modelling and hazard analysis to create layers at a national scale for input into GIS, to inform the identification of hot spot areas

The end purpose of this step is to identify areas of the country which present climate related resilience concerns, based upon analysis of the overall environment and the specific aspects of the areas identified.

The main activities within this task is creating the baseline hazard (flood and landslide) GIS maps and overlaying these GIS hazard analysis maps with the road network, to develop GIS exposure maps that show the hot spots within the network.

a) Climate modelling and hazard analysis - baseline climate characteristics for Macedonia

Where existing hazard data sets, uplifted for relevant (and up to date) climate scenarios have been produced these can be directly imported (for example, information from landslide analysis at a national level which has been previously undertaken[7]). Where these don't already exist, they are required to be created as an additional task. These guidelines describe the creation of two series of datasets:

- Flood risk datasets; and
- Landslide risk datasets.

For the purposes of these Guidelines, current climate and future climate change baseline maps in GIS have been prepared. These are to be used as the initial guidance on identifying the current and potential future hazard (flood and landslide) hotspots in R. North Macedonia. These are incorporated in PESR RAMS database.

Rainfall baseline: The maps are created by Inverse Distance Interpolation of National Hydrometeorological Service weather station data and overlapped with PESR road network. These give initial assessment of the areas where the PESR road network is exposed to weather hazards.

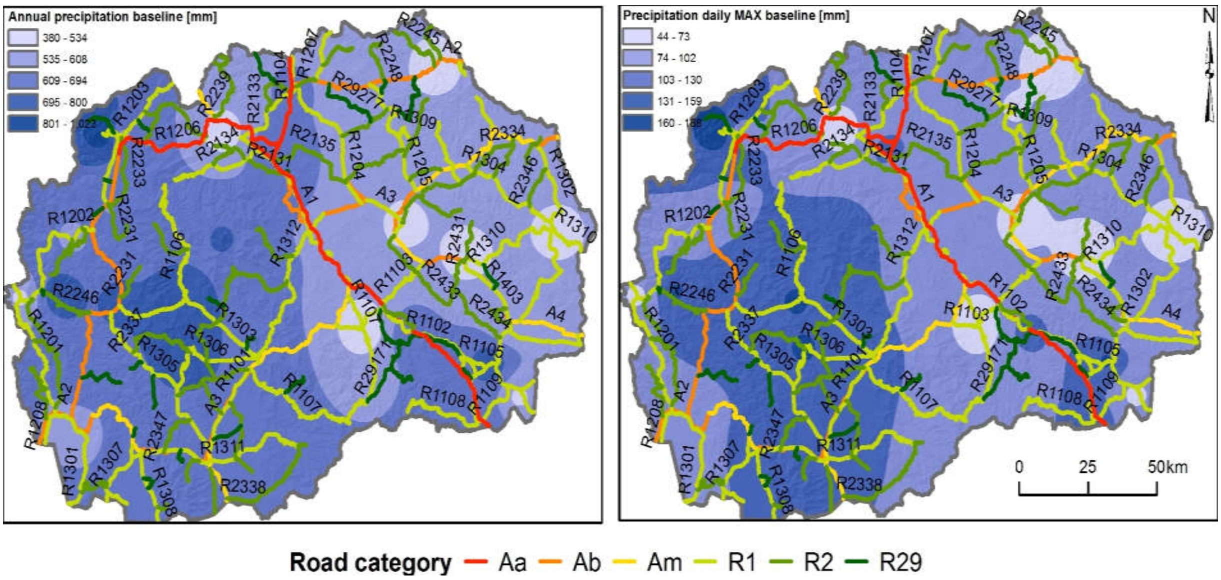


Figure 6 **Current rainfall baseline map**

[7] Prof Ivica Milevski, University of St Cyril and Methodius, Faculty of Natural Sciences and Mathematics (in press)

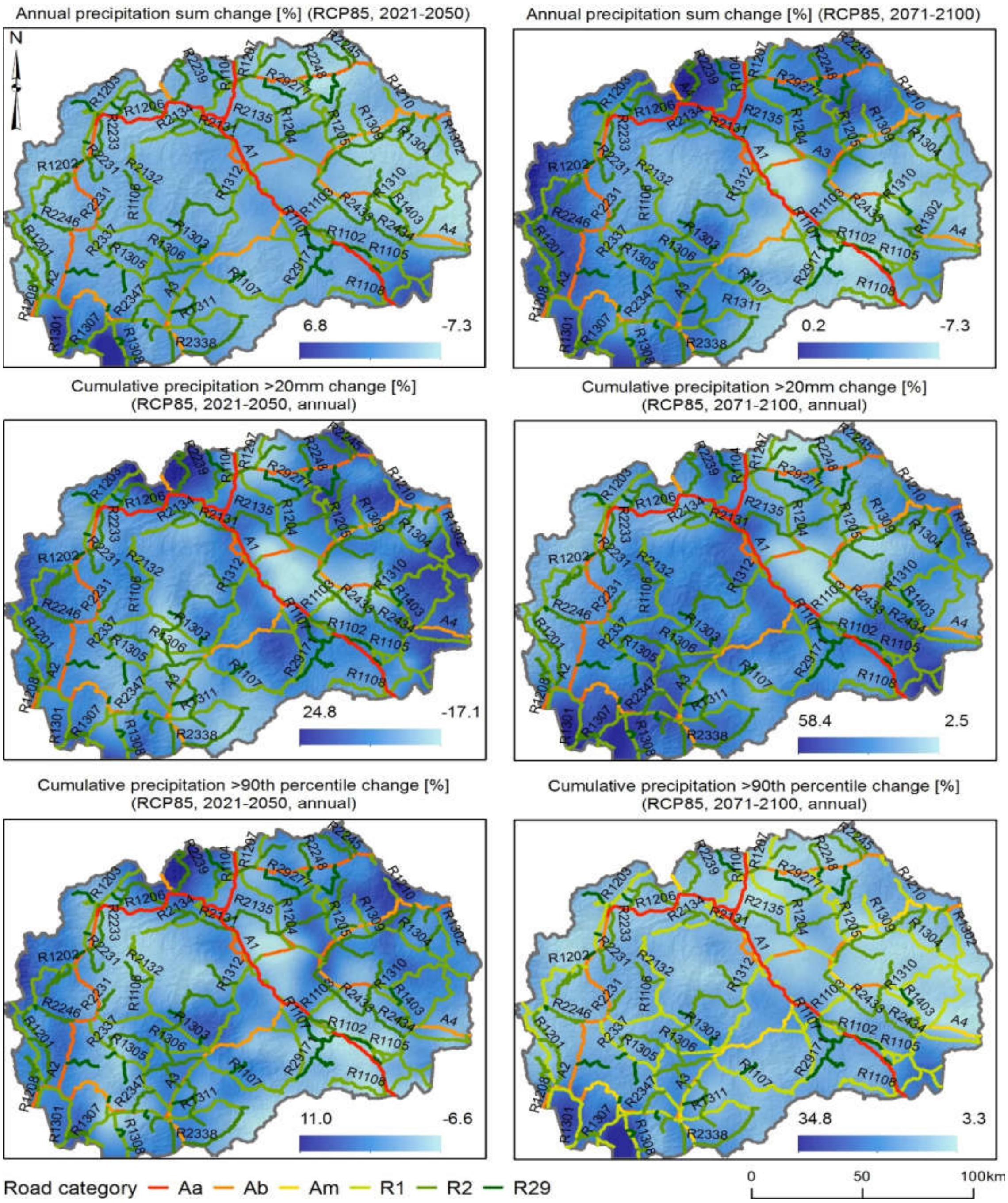


Figure 7 **Rainfall projection maps**

Similarly, the temperature baseline and projection maps have been produced as entry information for the further analysis for both Flood and Landslide Hazard assessment of these Guidelines.

b) **Flood analysis, GIS flood hazard map at national level:** The outcome of this methodology is to show the spatial distribution of flood hazard along with its intensity level, ranging from very high to very low. The Multi criteria decision method for assessing criterion weights: entropy, ranking, rating, trade-off analysis, and pairwise comparison, among others is the Analytic Hierarchy Process (AHP) (Saaty) that is applied to solve decision-making problems related to water resources. This GIS-based multi-criteria mapping approach is used for flood risk assessment to present more simplified and visual models for flood hazard assessment. In contrast, the proposed approach only requires the spatial layers of the parameters that contribute to the flood hazard. The main advantage of this methodology is the possibility of obtaining a reliable flood hazard map at a relatively low cost and time to identify only areas that need further detailed assessment. Also, it is simple to update, and is flexible in terms of which criteria is included. The methodology consists of the following steps:

1. Defining the Problem
2. Identification of key experts and stakeholders in the decision-making process and the definition of criteria for assessing susceptibility to floods
3. Collection and preparation of data (statistical analysis, etc.) and creation of raster data for each factor
4. Classification of data sets and forming the suitability map for each factor
5. Establish a matrix of criteria for decision making and evaluation
6. Calculation of weighted factors of the criteria
7. Weighting of maps and their summing up in the map of vulnerability

To each of the criteria different score (rank) on a scale of 1 (not susceptible to floods) to 5 (Most prone to floods) was assigned in accordance with the limitations, the experts opinion involved in the evaluation and international literature.

Table 2 Criteria scoring

Criteria	Distance to streams (m)					Height above river (m)					Terrain Slope (°)					Rainfall (mm) annual					Curve Number (CN)				
Description	0-100	100-300	300-500	500-1000	>1000	<2	02-May	05-Aug	08-Oct	>10	0-10	Oct-20	20-30	30-50	>50	<500	500-750	750-850	850-900	>900	<40	40-50	50-70	70-90	>90
Grade	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	1	2	3	4	5	1	2	3	4	5

GIS based analysis produces maps for each of the criteria above, which with overlaying of the hazard maps and the road network produces the exposure map below. The selected five factors have been weighted to be used in Flood hazard evaluation (distance to stream, height above river, slope, rainfall and curve number). The flood hazard map based on AHP produced in GIS environment shows a pattern of flood influenced strongly by rainfall intensity parameters due to high weight assigned during the MCA procedure of AHP, as shown in Figure 8 below. The spatial pattern of the flood hazard map has been categorized in five levels of hazard classes namely very low, low, medium, high and very high flood hazard.

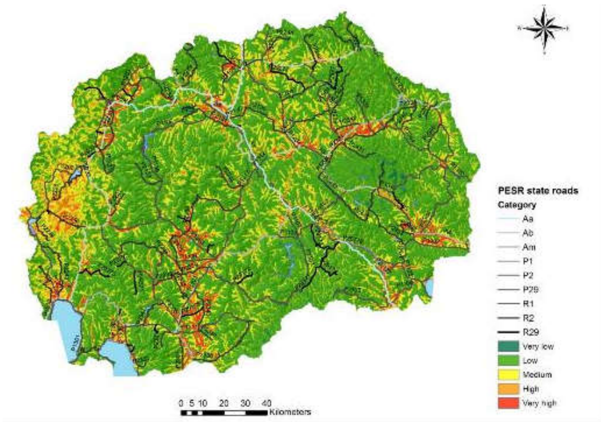


Figure 8 Flood Hazard Map

Verification of the resulting flood hazard map was completed using several past flood information where infrastructural damage was evident (from 2015). The results below shows those almost all past flood events were located in hazard classes' medium to very high.

Table 3 Classes of flood hazard and number of historical flood events

FLOOD HAZARD	NUMBER OF EVENTS
VERY LOW AND LOW	6
MEDIUM	12
HIGH	9
VERY HIGH	13

Furthermore a visual inspection and an assessment of the obtained hazard map was performed by comparing it to a flood zone map developed on national level. Satisfying matching between the two maps was observed even though the flood zones map is fairly coarse and on small scale (1:200,000) and has the shortcoming that is developed only for alluvial lowlands of the major rivers (minor tributaries and torrents are not included). Results are shown in

Figure 9 below.

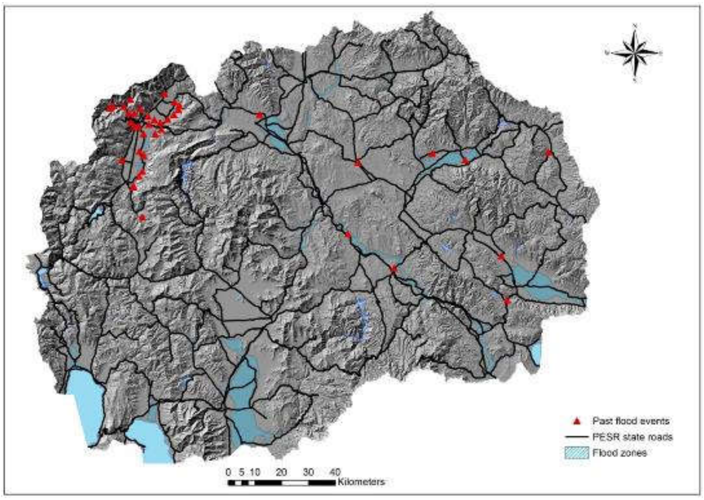
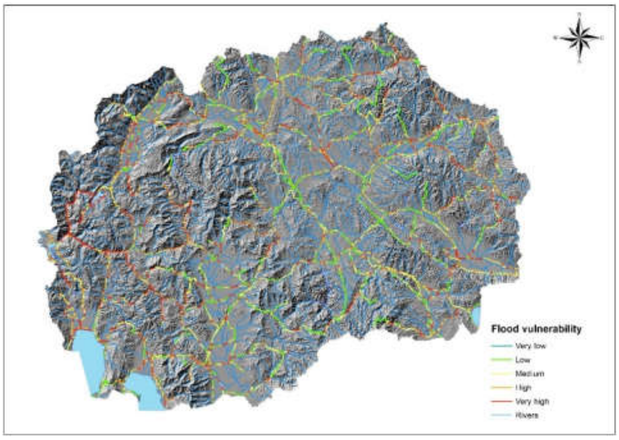


Figure 9 Flood Zones and Past Flood Events

Additionally an analysis of affected PESR state roads was performed, as cumulative length per hazard class for current (table 4) and future scenarios in the figure to the right.

Table 4 Classes of flood hazard and total length of PESR state roads

FLOOD HAZARD	LENGTH KM BASELINE	LENGTH KM CUMULATIVE >90TH PERCENTILE CHANGE 2071-2100
VERY LOW	11	7
LOW	1681	1418
MEDIUM	1708	1642
HIGH	734	923
VERY HIGH	507	652



c) **Landslide Hazard Analysis, GIS hazard map at national level:** The landslide susceptibility at a national scale is performed by a model based on Analytical Hierarchy Process (AHP) obtained from Prof Dr. Milevski et al. (in press), wherein, typical geological, morphometric and environmental parameters were combined. The climate scenarios and road network parameters are incorporated in the model and each parameter is represented as a raster model that was subjected to a typical GIS raster processing. This included their reclassification into appropriate intervals, weighting of the importance of each class, and finally, addition of each raster into a final Landslide susceptibility model. Details on this procedure are given in detail in the Part B and the annex. The susceptibility model represents a distribution of the natural potential to develop landslides, depicted by very high to very low susceptibility classes (upper left). According to the adopted procedure (see Part B/annex), quasi-hazard can be simulated by substituting temporal dynamics of the landsliding process by the temporal dynamics of its trigger, in this case, the rainfall factor. Obtained factor is within 0-1 range and highlights areas that have both, heavy rainfall extremes (daily) and high total rainfall throughout the year, i.e., the saturated areas. It was finally used to multiply previously created (AHP) landslide susceptibility raster to overlap these saturated areas with zones of high landslide potential. Such procedure allows relative hazard estimation, suitable for splitting hazard into very high to very low classes, indicated by the red-green colour ramp by using the Natural Breaks interval splitting method.

Short and long-term projections of landslide hazard are generated by using the baseline hazard map and multiplying it with projected rainfall factor, i.e., a 1 + the product between according (short/long-term) annual sum change and cumulative 90th percentile change, which are considered as rainfall parameters that best reflect those used for the baseline hazard.

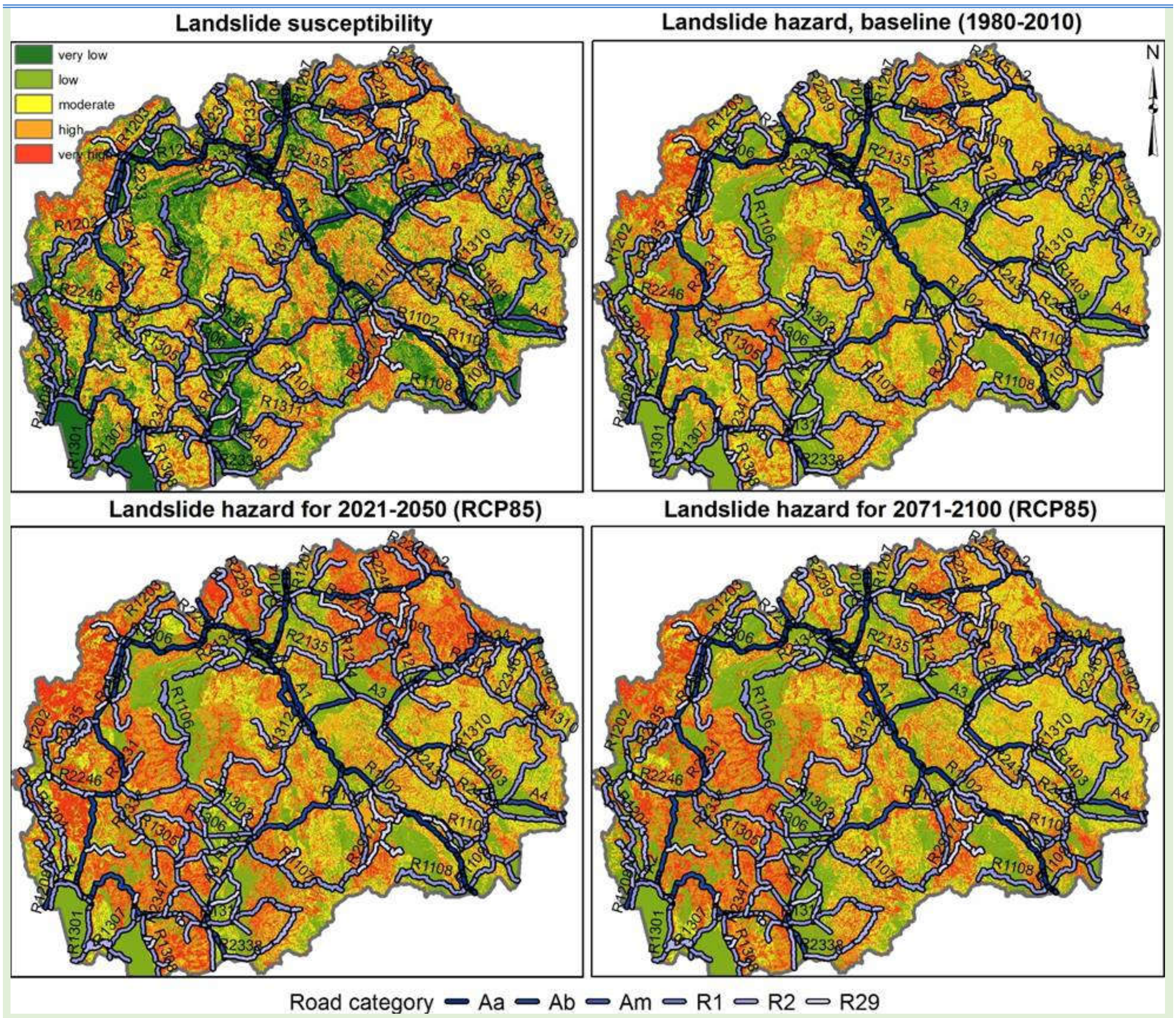


Figure 10 Baseline Landslide Susceptibility and hazard maps

The resulting baseline landslide hazard map (upper right) reveals that western and southernmost parts have very high landslide hazard, as well as the NE, and some smaller clusters within the central parts. The A2 road is heavily exposed, together with some R1 and R2 roads. However, the most severely affected areas are mainly away from the main state roads.

The change is dramatic for the short-term hazard projection, where most of the moderate to high hazard classes from the baseline shift towards high to very high, i.e., for an entire class. Most of the A2 and A3 routes are highly exposed, while A1 is moderately exposed especially in the hilly areas. Most of the R1 and R2 roads along the western side of the country also fall within high to very high hazard. Given that the rainfall trends for short-term projection are clustered all around the country, as previously discussed, such generic increase of landslide hazard is anticipated.

Long-term projection is more optimistic, as the landslide hazard is only somewhat more pronounced in comparison to the baseline. The main change is within the moderate class which tends to increase to high hazard, thereby increasing the exposure along the A2 route and associated R1/R2 roads in the western section. The strongest changes are around Ohrid area and Demir Kapija, which is in compliance with previously discussed anticipated changes of the extreme rainfall pattern for long-term rainfall projection.

2.5.3 **Step 2.** Create CVRA model in GIS environment to produce hotspot maps to identify priority road sections for further study and interventions

The end result of this step is a list of priority road sections that have been identified as being vulnerable to flooding and/or landslide risks and are considered to be critical links in the network. These priority road sections will then be further studied in more detail.

This step involves three distinct tasks:

- Firstly, analysing GIS exposure maps that show the hot spots within the network to continue with the flood and landslide risk analysis on detailed scale – local level
- Secondly, the completion of a multi-criteria analysis (MCA), incorporating key socio-economic factors to identify the most important (critical) road sections; and
- Thirdly, combining these three analyses to identify priority road sections across the studied network.

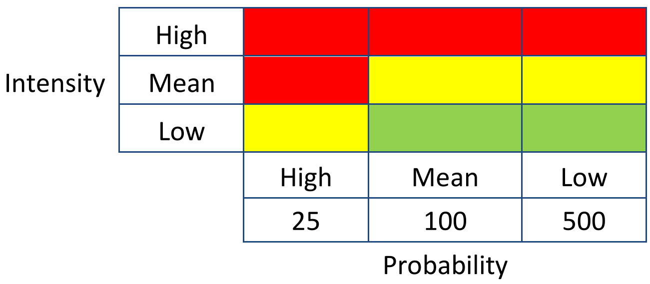
a) Modelling for flood hazard and risk assessment at detailed scale

Flood risk maps shows areas at risk of flooding with low, medium and high probability, combined with: type of flood, the flood extent; water depths or water level where appropriate or flow velocity. This is used for preparing maps to identify areas more suitable for development. Maps are essential for previewing and planning of land occupation extension, aiming to reduce damage and losses for the population and public authorities as a result of natural disasters. In cases where the areas are already occupied, e.g., the result could be useful for defining the necessary measures to address potentially damaging events.

Flood risk map is produced for return period of 100 years. By combining the probability and the intensity (magnitude), the latter expressed as flow velocity or depth, the flood risks class is obtained as indicated in the following table;

Table 5 Flood risk class and criteria for classification

Process	Low intensity	Mean intensity	High intensity
Flooding (Torrents)	h > 0.5 m	0.5 m < h < 1.5 m	h > 1.5 m
Flooding (Lowland river)	h < 0.5 m	0.5 < h < 2 m	h > 2 m



High risk zone mainly designates a prohibition domain (area where development is prohibited).

Moderate risk zone is mostly a regulation domain, in which severe damage can be reduced by means of appropriate protective measures (area with restrictive regulations). Low risk zone is mainly an alerting domain (area where people are notified at possible risk).

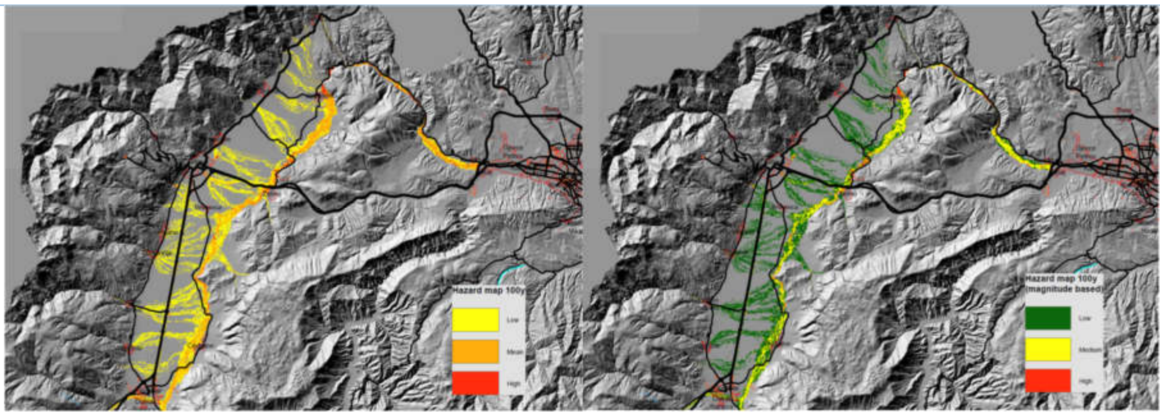


Figure 11 Flood risk maps Upper Vardar (100year)[8]

This overplayed with the road network, indicates the exposure of the road network that is at risk of flooding. * Note, Empirical methods for the determination of hydrological parameters using new parameters has been developed in Part B of the Guideline, section 2.2.1.6.

b) Landslide analysis to create GIS landslide hazard maps:

The overall objective of this task is to identify the relative levels of susceptibility, hazard, exposure, vulnerability/risk to landslides that road network experiences under current climate condition and will experience in future climate scenarios. The output from the task is a series of according maps covering a road section, as example given through the case study area in the Polog region. These relative levels need to be standardised into a normalized scale, typically ranging from 0 to 1. This task also needs to use climate change models to estimate how current levels are expected to change in the future. Using existing climate change projections, the output from the task should include three series of maps, one for each climate projection.

According to the available insight into the stakeholder's road network database, the smallest road element is a road link, and all preceding models are to be reflected along road links. This means that road exposure, vulnerability and risk will be unique values along a link, albeit 10 m or 10 km long. Alternatively, these can be further split into regularly spaced segments (e.g. 500 m) to reflect the final risk output somewhat better, location-wise. Thus, there are two approaches at the very beginning of risk estimation (a) link-level, and (b) segment-level.

The exposure to landslide hazard is calculated per each road link (predefined geometry). The baseline hazard values are projected onto the network, and maximal value picked up along the link is assigned for the entire link. The Vulnerability is intrinsic road property, and is based on its condition and setting. The criteria for estimating road Vulnerability includes road category (in the example, it is the same category along the road, so no influence), International Roughness Index (IRI, taken from RAMS portal visually), and road link length (node-to-node) as important factor of potential rerouting in case of emergency. These factors are collected along a road and normalized, to relative range (e.g. 0-1. The final Vulnerability is obtained by multiplying individual factors. The road risk is expressed on a relative 0-1 scale, as a product

[8] UNDP, "Reducing Flood Risk in the Polog Region."

of Exposure and Vulnerability, and can further serve as a tool for deciding priorities and revealing the most critical parts of the road requiring attention.

The results expressed in GIS map are presented in Figure 12 below.

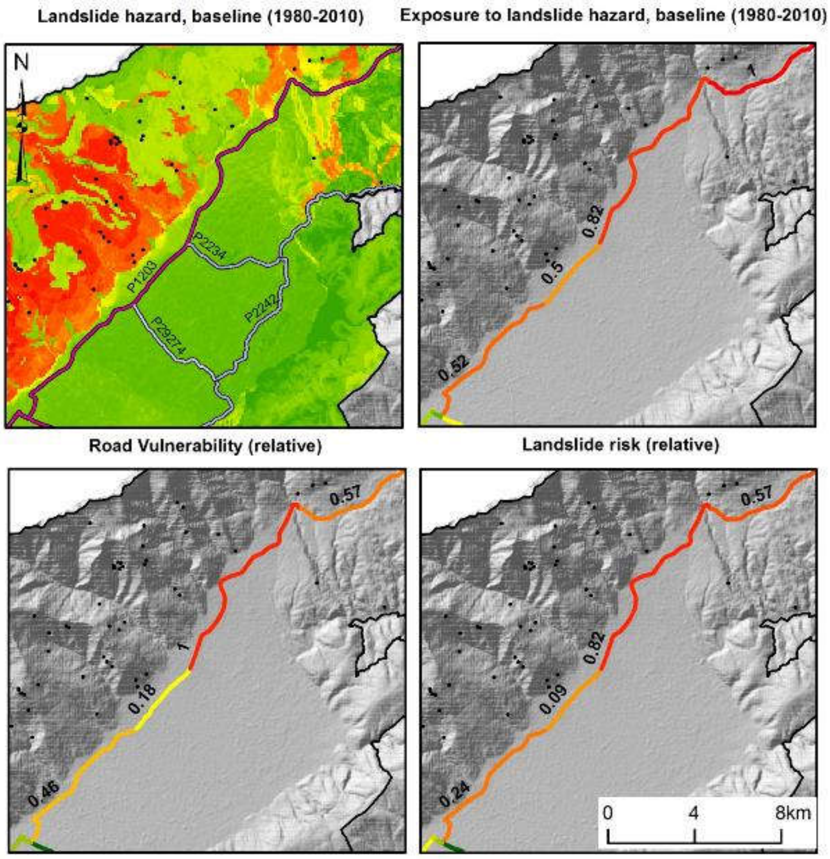


Figure 12 **Example of calculation of road exposure, vulnerability and risk**

c) Criticality Analysis:

In order to determine if the road under risk is important to PESR, Criticality Analysis need to be conducted. This is conducted following the determination that a road section is in a hot spot area and parts of the section are under high risk. The analysis of criticality is based upon a multi-criteria analysis framework, which incorporates a series of socio-economic factors. These factors are weighted, against agreed criteria and scoring systems to provide a measure of the relative importance of each road section. These calculations are completed within the GIS, utilising data from both PESR's own RAMS and external data sources. The criteria included in the MCA framework are summarised below. These criteria were carefully chosen to reflect policy objectives in North Macedonia, as well as key aspects that should be considered when assessing the value of road access to an area. Criteria included in the MCA include:

- Traffic intensity
- Population
- Road network density
- Locations of schools and hospitals

- Locations of other key infrastructure (electricity and water stations, municipal buildings, religious buildings etc)

These scores are then mapped, using the GIS, to highlight the most critical road sections. An example of this mapping is shown in Figure 13 below. These resulting GIS maps are incorporated in PESR Road Asset Management System.

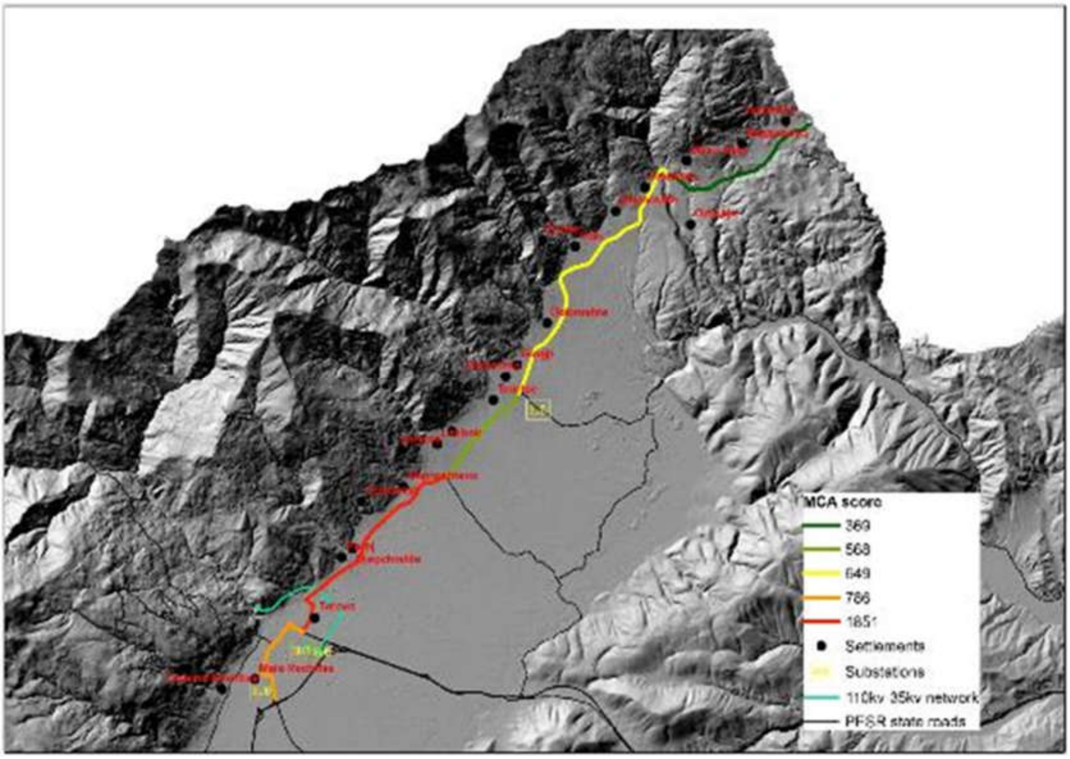


Figure 13 MCA Score represented on GIS

d) Combining Criticality and Vulnerability:

Finally, these three analyses are combined to identify the priority road sections. This process produces a single index that can be used to highlight priorities for further study. In using the unified index it is important to note that the two aspects (vulnerability and criticality) can be weighted in different ways, to reflect alternative policy objectives. For the pilot studies, the two aspects were weighted equally.

The purpose of these assessments is to identify those road sections that are both vulnerable and critical, as these should become the highest priorities for intervention to improve resilience. This combination of aspects is shown in Figure 14 below, noting that the aim should always be to identify the road sections that would lie in the bottom right hand corner of this matrix.

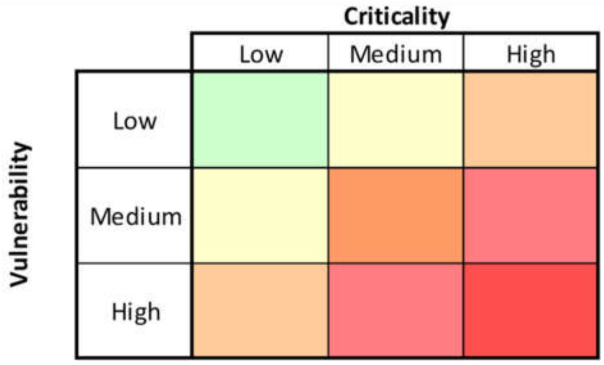


Figure 14 Combining Vulnerability and Criticality

The presentation of these results should be done via the GIS system, showing the result for each section within the road network. An example of this is shown in Figure 15 below. This shows how it is possible to differentiate between contiguous sections which have different characteristics and levels of criticality.

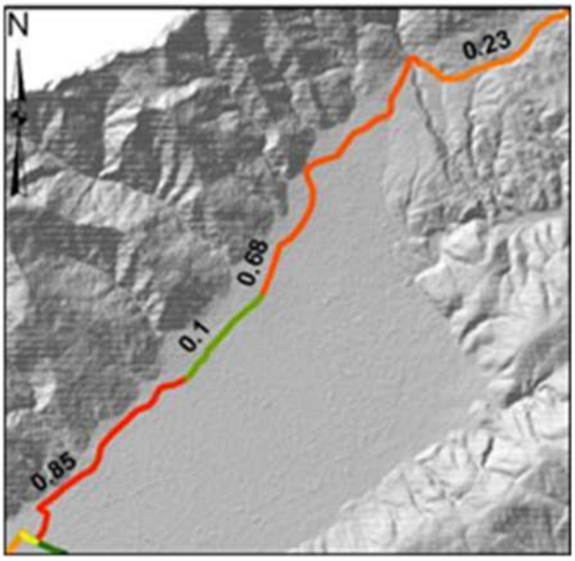


Figure 15 Example of Presentation of the Unified Index Results

2.5.4 **Step 3** - Use CVRA output and field studies to select engineering and non-engineering interventions

The end result of this step will be a list of priority road sections, with appropriate intervention options in each case, based upon field studies and engineering analysis. These options will then be further assessed through cost benefit analysis, to identify a robust, viable investment plan.

Under this step, the engineering team should undertake appropriate field visits together with other experts depending on the hazard at the hot spot locations (geologist, hydrologist, roads engineer etc). Site visits are required to both fill in any data gaps and validate the model, and then assess the residual resilience at these locations. Just as the inputs to the GIS model require different expertise areas, the site assessment and design of resilience improvements requires different disciplines to work together. This will entail further site-specific survey (to inform design) and physical assessment of the design, condition and other criteria of selected infrastructure elements at risk. The data collected during field visits, should be recorded and analysed using the standard data collection forms included in the Annex 1 of the Guidelines.

The site visit team should propose the list of interventions for the road section under risk of particular natural hazard(s), indicate expected effects of each intervention (long or short term), classify the type of intervention (maintenance, rehabilitation, etc.) and roughly estimate the budget. These interventions could typically include:

- **Physical interventions outside of the road corridor** to reduce the exposure of the transport infrastructure (e.g. to reduce landslide risk on adjoining land, to reduce flood risk through upstream measures in water catchment).
- **Engineering interventions to the transport infrastructure within the road corridors.** For example, this could be to strengthen an infrastructure element (e.g. larger, stronger), change it (e.g. replace culvert with spillway or bridge structure) or better protect it (e.g. slope protection, river training works).
- **Non-engineering measures**, such as to adopt performance standards, introducing early warning systems etc. – which be location specific or apply more widely.

Interventions will generally involve a combination of all three of these aspects on different type of road assets. The potential options for interventions are summarised in Part C of these guidelines, together with standard forms for recording analyses and results. An example of the summary table created for this study is shown in figure 16

Road id	GPS coordinates		Hazard		Recommendations Measures			Cost in Euros	
Location	**From**	**To**	**Hazard**	**Findings**	**Short Term measure**	**Long Term measure**	**Maintenance**	**Cost**	**Comments**
A3 Locn No 2. West side 3.4km south of Makedonska Kamenitsa	42° 0'18.93"N 22°35'4.48"E	42° 0'22.28"N 22°35'7.73"E	Rock fall	Road passes through a cutting. The rock faces are a problem area on both sides of the road are shedding small rocks and debris down their faces onto the road edge. The high west side face (11m approx) is a particular problem. Much debris are being washed down from the top slope edge to slide down onto the road. The continual loss of material may result in larger rocks being loosened to fall onto the road.	Clean high slope face, and set back toe to install low catch wall (NJB) or alternatively a concrete lined catch ditch. Construct a ditch or earth dam above the slope to direct water away to the side valleys at either end of the cutting. Inspect and clear/strengthen the ditch / dam before snow melt and storm seasons.	Set back rock face with catch ditch or catch wall to base and 2m berm at 5m height. Construct a ditch or earth dam above the slope to direct water away to the side valleys at either end of the cutting. Protect face with standard weight rock fall gravity mesh. Inspect and clear/strengthen the ditch / dam before snow melt and storm seasons.	Increase frequency of inspection of the location and removal of fallen material. Record all rockfall events. Implement a messaging system and dedicated phone line to enable road users to report rockfalls direct to PESR/Maintenance company. Advertise the system locally to residents and road users, and provide advisory signs along the route giving the contact details	Clean high face+low catch wall at toe and ditch above slope. Approximated around 27.000 Euros Catch wall at toe, berm at 5.0m and ditch above slope + protect face with mesh. Approximated around 55.000 Euros, it may require expropriation and we don't have info	This location is a typical problem of the many cut slopes that exist on the approach to MK form the north and the south. Rockfall interventions may be as frequent as 6 p.a.

Figure 16 Example Summary Table of Intervention Options

2.5.5 Climate impact and adaptation options - Road standards – adaptation

Climate and increased natural hazard resilience aspects should be reflected in road design standards.

The most important factors are the road levels (such as in flood plains), the surface and cross drainage of the road and erosion protection of the road and associated assets (e.g. culverts and bridges). These aspects are discussed further as follows:

- **The expected flood levels and flowrates** used to design road assets (e.g. river crossings and surface drainage) in any given location should include an appropriate uplift due to the projected climate effects (increased storm intensity).
- **Road elevations** must be designed at a safe level above the flood elevations. To our understanding, Macedonian standards require for the subgrade level to be at 0.3-0.5 m above the expected flood level. This is in order not to risk having the sub-grade saturated in water and hence weakened. This safety level will result in road elevations approximately one meter (as a minimum) above flood levels. Climate projections should be used to review whether current road elevations are sufficient at each particular location.
- The **cross drainage** of the road should be properly designed and sufficient for the predicted water after the climate change effects on peak precipitation (e.g. the likely return period for the maximum rainfall intensity for a given storm period – such as one hour) has been considered. Where a new road is planned, or major rehabilitation is planned for a road, the flow of water in the drainage system alongside the road should be fully investigated. The hydraulic capacity of existing structures should be determined. The type and size of cross drainage should be reviewed, with increased capacity, or alternative engineered or non-engineered solutions such as improved slope protection.
- **Erosion protection** should be constructed so that it is able to cope with accelerated and increased flows. It is especially important at the outlet of cross drainage structures and where there is expected to be major flow of water along embankments. Scour erosion can undermine a road very quickly. Equally, it can affect the stability of the toe of embankments (such as where a river runs close to the base of road embankment) or bridge abutments or river protection works. Similarly, flash flooding can increase the risk of landslides as it adversely affects slope stability. Slope protection could include bio-engineering and/or engineered solutions such as retaining walls or improved drainage), both within and beyond the road corridor.

The climate resilience measures to address landslide and flood risks are shown in the Error! Reference source not found. below, along with an indication as to which of the projected climate change effects in North Macedonia they are most useful to combat. The details of each measure, its application and the corresponding non-engineering measures at project level are detailed in Part C of the Guidelines.

Table 6 Overview of Potential Resilience Measures

	Category/Resilience Measure	Flooding	Flash flood	Landslide
1	**Outside of Road Corridor**			
1.1	Realignment (vertical or horizontal)	X	X	X
1.2	Watershed/catchment management	X	X	
2	**Cross-drainage/structures**			
2.1	Culverts and box culverts improvements	X	X	
2.2	Roadway Swale	X	X	
2.3	Permeable embankment	X	X	
2.4	Debris stopper	X	X	X

2.5	Bridges	X	X	
3	**Road Drainage**			
3.1	Road pavement drainage	X	X	
3.2	Longitudinal road drainage	X	X	
3.3	Scour checks	X	X	
3.4	Cascade/spillways	X	X	X
4	**Erosion Protection**			
4.1	Retaining and façade walls	X	X	X
4.2	Gabion mattresses and boxes	X	X	X
4.3	Rock protection		X	X
4.4	Bioengineering measures	X	X	X
5	**Slope Stabilisation**			
5.1	Cut off drains		X	X
5.2	Slope protection vegetation and drainage			X
5.3	Soil reinforcement and geotextiles	X	X	X
5.5	Rockface scaling			X
5.5	Debris and rockfall netting			X
5.6	Catch ditches and fencing/walls			X
5.7	Reinforced sprayed concrete			X
5.8	Ground Anchors and Rock Bolts			X
5.9	Warning systems			X
5.10	Reprofile slope (non-Rock material)			X
5.11	Rock Shelters			X

2.5.6 **Step 4** - Prioritise measures on an economic basis and develop an investment plan

The end result of this step will be a fully justified programme of interventions that will be available to inform and influence the future investment decisions of PESR.

Based on the list of possible interventions, their effects, expenditure category and cost, PESR should prioritize interventions and include them in the annual or multiannual budget planning framework. This process will need to reflect the analyses undertaken, plus more detailed assessment of the options identified at a given location.

To ensure that the most effective and efficient interventions are implemented, further detailed economic appraisal should be undertaken, where appropriate. It is likely that potential interventions will fall into one of three categories, which determine the need for a CBA:

- Small investments, which can easily be incorporated into a maintenance programme, or where the cost of completing the CBA cannot be justified, where cost benefit analysis is not required
- Investments on roads which are deemed to be of the highest criticality and where the vulnerability is extreme, where action is essential and therefore cost benefit analysis is not required
- All other investments, where cost benefit analysis should always be undertaken.

For interventions that fall into the third category, Cost Benefit Analysis (CBA) should be undertaken once intervention options have been identified. Often, a series of measures can be applied at each location and it is necessary to compare these with one another and with interventions at other locations. CBA compares the costs associated with the current, or Do Nothing situation, against one or more Do Something scenarios. Typically, each scenario will involve investing in the short term, to achieve longer term benefits and CBA provides the framework to assess these. These guidelines set out an approach to the completion of a climate resilience investment CBA. They should however, be read in conjunction with the published guidance from IFI's where this source of funding is being sought, as any CBA will need to also be consistent with the IFI guidelines.

For the CBA, the following sources of benefit have been identified and are required to be estimated. The largest element of benefits relate to likely damage to the infrastructure that would result without the investment. Other areas of benefit, include reductions in additional transport costs that would be incurred during periods when a road is closed and drivers must use an alternative route, and losses to local businesses due to them not being able to send or receive orders.

These guidelines describe a standalone CBA, but it is important in the medium term that the CBA process in incorporated into the Road Asset Management System (RAMS) and general Investment Planning. The existing RAMS system already incorporates much of the climate data needed to assist the decision making process on the priority investment. It will be important to further develop this methodology so that a more automated CBA process can be included in annual budgeting, alongside the more traditional pavement management system, used to determine priorities for other maintenance and investment.

3 North Macedonia: country context and its road network, landslide and flood risk, baseline and future climate scenarios.

3.1 Overview

An overview and comprehensive summary of the physical context of North Macedonia, its road network and PESR, and its current climatic baseline, landslide and flood risk, together with future climate projections are presented in Part B of these guidelines. This includes:

- An introduction to the Republic of North Macedonia, summarising its economy, geography and administrative structures;
- An introduction to the road network (its extent and breakdown by classification and region), its strategic links to surrounding countries and the roles of the Ministry of Transport and Communications and PESR;
- Details of the current climatic conditions, including the various climatic regions across the country and their relation to road classification, and the temperature and precipitation baselines across the country;
- Details of the range of natural hazards affecting the country, and more details of the two most significant impacts which form the focus of these guidelines: flooding and landslides.
  - Flood risk is introduced with a presentation of the main watershed catchments and critical flood areas before providing an overview of the extent of recent flood damage (focusing on the 2014 and 2016 floods) and their damages across different sectors and to roads and bridges.
  - The current regulatory framework for flood risk management is then set out. This focuses on the Law on Waters and the Law on Protection and Rescue before providing a summary of the timetable and actions required to implement the EU Flood Directive.
  - Landslide risk is introduced drawing on key findings on recent research on the prevalence of landslides (Peshevski et al 2013) before considering the scale and type of impacts of landslides on communities and the road network.
  - The current landslide risk management practice in relation to PESR roads is set out. This includes both the regular procedure (detection, inspection, design, response, implementation, procurement and completion) and the emergency response for urgent works. This highlights the need for new legal recommendations to give PESR the powers needed to carry out works to address landslides that extend beyond the road corridor;
- The modelled future climate projections for the country are then described. This describes how climate change leads to higher temperatures, which in turn impact upon the uncertainty (including seasonality), severity and frequency of future rainfall patterns. This section sets out how the climate projections are used and sets out the latest findings for the RCP8.5 climate scenario. This includes the projected change in temperature and changes in extreme rainfall across the country, overlaid over the road network. The predicted future precipitation changes across the road network include a high degree of uncertainty but generally: significant change to long-term rainfall with dry areas becoming drier and wetter areas becoming wetter and significant increase in both moderate extreme rainfall events (+60%) and events where there is continued extreme precipitation over several days (+30%). The road sections that are already identified as vulnerable to floods based on historic data, are even more affected mainly with spreading of areas with high to very high class of vulnerability. This is particularly obvious if we take into account the total length of affected roads per vulnerability class for long-term projection 2071-2100

These rainfall projections form the basis for the methodology for the guidelines set out Part B of this report, firstly to calculate how flood risks are changed spatially and then how this affects the risk of flood-related landslides. These hazards are then explored together in the GIS environment to highlight the locations where the most significant and critical impacts on the road transport network are likely to occur.

3.2 Introducing the Resilience of Road Transport Infrastructure

3.2.1 What is Resilience?

Before considering how climate change impacts on resilience, and exploring the CVRA process itself, it is useful to provide a brief introduction into the concept of 'resilience' and how it relates to the road transport sector. This draws on the framework created in the World Bank guidelines titled Disaster Risk Management in the Transport Sector[9].

The resilience of transport infrastructure is multi-dimensional and applies at different scales: from the properties and exposure of individual infrastructure elements and how these together create a transport corridor, to how these combine to form infrastructure systems, and how these are operated, maintained and interact with wider society and the environment. This is summarised in

Figure 17 below.

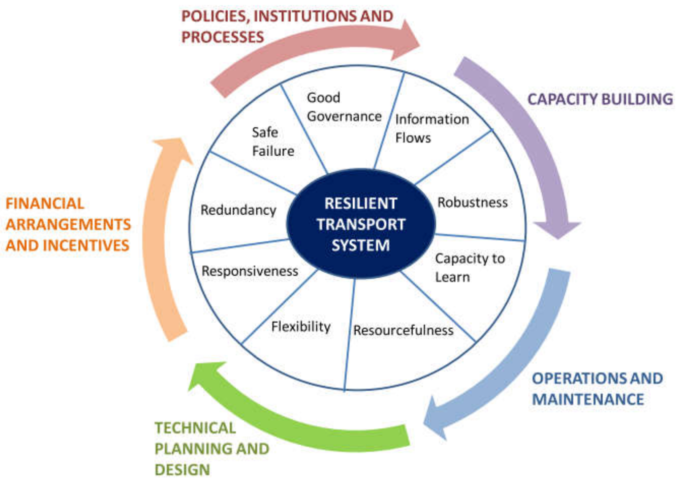


Figure 17 Different Aspects of Resilience in Transport Infrastructure

Source: Toolkit produced in Disaster Risk Management in the Transport Sector, 2015, World Bank

This highlights that resilience is not just a property 'of' something, but a function of how it relates to wider systems (purpose) and context (environment): what it is 'for'. For example, consider an individual infrastructure element, such as a bridge. We could think about the resilience of the bridge itself, as well as how the bridge improves the resilience of the wider transport system (both reducing flood risk compared to a culvert or spillway at that location), and in doing so connecting the road networks on different sides of a water course together.

[9] Nakat Z., Moor R., Boardbent M., Essex J., Fitzmaurice S., Hamza M., Pakeer K., Steele A., Stiff T., and White J. (2015) Disaster Risk Management in the Transport Sector: A Review of Concepts and International Case Studies. Published by GfDRR, World Bank, New York, USA.

At the other extreme consider the resilience of the overall transport system. To be resilient a transport system generally needs to have redundancy (different routes you can choose if one is closed for some reason). Also, the resilience of a transport system could be considered in terms of its performance in sustaining access to different things. Typically, this includes both access to social infrastructure (i.e. schools, hospitals etc) and how it provides economic mobility as a piece of critical infrastructure. Deciding how to improve resilience will necessitate balancing these priorities as to what a transport system is for: providing both accessibility, generally to more local social infrastructure, whilst sustaining the economic value of the transport system's critical links. When we prioritise how we wish to enhance infrastructure resilience we need to balance the resilience of different infrastructure elements and systems, with how this infrastructure leads to more resilient communities and society.

3.2.2 Current Issues on North Macedonia's road network

The current issues highlighted on the road network in North Macedonia where explored in a site visit to a number of locations, as highlighted in Box 2 below.

Box 2 Exploration of key resilience issues to be addressed on the road network

The roads were driven through and video recordings and photos taken at along some road sections. The problems identified were as follows and confirm our initial review of the situation in the R. North Macedonia:

- In the steeper terrain in the R. North Macedonia the natural hillside slopes tend to be unstable due to the difficult and variable geology and erosion by rainfall and water flows.
- Rock faces are fractured and prone to spalling or larger slippage especially where weaker zones exist in more stable rock.
- Road cuttings have slopes that are considered too steep for the geology encountered. This relates to historical roads and to roads currently under construction.
- It is not uncommon to see slopes that are at a slope of > 1 in 2. Such steep slopes are not considered to be a stable in material that is fragmented (Schists), especially over the longer term.
- Maintenance of drainage both roadside drains and channels to drainage structures, is generally inadequate. Given this fact, it is possible that drainage provide above or on side slopes will be similarly poorly maintained.
- Roads away from the mountain areas commonly then cross flood plains on low embankments. Flood risk maps have not been prepared for all such locations.

Previous discussions have identified that due to budget restraints, insufficient investigation of the soil and geological conditions are carried out during the feasibility (if conducted) and preliminary design stage of a new road project. Although the cost of such investigations may seem expensive, for no physical output, their cost can be recouped many times over by savings in claims by the construction contract.

Source: Drive through visits conducted on 21st and 22nd November 2018 of the following roads: 1. Regional road, section Kochani - Makedonska Kamenica; 2. Highway, section Demir Kapija – Smokvica; and 3. Regional road, section Mavrovo – Debar, landslides and rock fall problems. Field inspection visit 12-13 June 2019

4 Institutional Assessment and Non-Engineering Measures

PESR's response to climate change will need to be multi-faceted and incorporate changes to its processes and procedures, but also will require investment in a range of interventions. It will also be necessary to invest to develop its internal capacity and the capacity of organisations that it relies upon. Below is a list of the non-engineering measures that are recommended for implementation by PESR.

Further details are provided in a separate institutional assessment report.

Data and monitoring				
	Adaptation measure	Short-term (1 year)	Mid-term (3 to 5 years)	Long-term (5 and more years)
1	Expand asset inventory with climate resilience relevant data and information			
	Integrate the landslide and flood susceptibility maps with all the data included in them, update the data with the field surveys as per the workshop under this TA			
2	Expand asset inventory with elements of roads, bridges and tunnels (eg. culverts)			
	This is especially important for the identified hotspots based on the CVRA methodology			
3	Integrate climate scenarios module into existing RAMS			
	The output from the climate vulnerability and risk assessment will be identification of priority needs and locations within the road network. This needs to be brought into the RAMS to be used as prioritization and planning tool			
4	Hydrological-Meteorological monitoring			
	Request the improvement of the existing meteorological monitoring system:. • Installing new automatic meteorological stations • Installing new automatic rain stations			
5	Develop and track performance metrics related to extreme weather (i.e. number/duration of weather-related road closure)			
	Weather and climate are key influences on the triggering of landslides and of course floods and climate change models indicate the potential for such events to become more frequent and/or more severe.			
6	Create after-event reports with clear recommendations for improvement following extreme events			
	Build capabilities of the road sub-sector organizations to better assess options for enhancing resilience both in the long-term perspectives assessing the efficacy of design standards and engineering measures and in the processes of preparation for disasters. Build database of these recommendations.			
7	Implement Early Warning System			
	Expand both coverage and quality of fixed and mobile monitoring capabilities within PESR. Use all available sources of data to obtain accurate and current information concerning hot spots. The system should allow the "real-time" capture and analysis of appropriate water level rainfall data, including forecast rainfall data.			
8	Use remote sensing technologies for monitoring			
	Some of the monitoring data could be obtained by remote sensing technologies using free access data. Free access to those data and continuous screening of the land surface with climate data could help in analysis of triggers and occurrence defining thresholds for climate related road hazard.			
9	Build appropriate relations, common plans and programmes with stakeholders and other public entities			

	Initiate a strategy for dealing with land management issues in the light of debris flow potential should be considered in consultation with i.e. Ministry of Agriculture, Forestry and Water Economy. Dialogue with this Ministry will be required also in terms of forestry practices which can have a significant impact on the stability of hillsides.			
10	The GIS-based assessment			
	The GIS-based assessment should be completed on all hotspots identified from the National Scale Hazard Assessment Maps.			
11	Incorporating MCA Criticality in RAMS			
	Socio-economic criticality: similarly the database on socio-economic criticality should be added to the RAMS.			
	Maintenance practice			
	Adaptation measure	**Short-term (up to 1 year)**	**Mid-term (3 to 5 years)**	**Long-term (5 and more years)**
12	Define maintenance catalogue with the technical standards for hot-spots routine maintenance			
	Decide about output and/or outcomes which must be provided by the maintenance company(ies) within their routine maintenance practices on the road.			
13	Initiate the strategy for building capabilities of maintenance company			
	Define the limited types of works which will be in the responsibility of Makedonia PAT. The rest should be contracted within comprehensive maintenance contracts First contracts are to be input-based where actions, treatment and its frequency may be detailed.			
14	Stockpile materials and equipment and store them in strategic areas prior to events			
	Apart from technical standards concerning relevant roads' elements (eg. culverts) put clear requirement for the maintenance company(ies) to have all appropriate equipment and material collected close to the hot spots to ease the response to extreme weather events.			
15	Implementation of mixed maintenance strategy (proactive, predictive, preventive, reactive)			
	Carry out scenario analysis on the best maintenance strategies for the assets under PESR supervision to examine long-term consequences of focusing on rehabilitation of deteriorated sections only.			
16	Expand technical condition indicators			
	Apart from roughness implement other technical factors for the network condition assessment of climate related infrastructure			
	Resources and funding			
	Adaptation measure	**Short-term (up to 1 year)**	**Mid-term (3 to 5 years)**	**Long-term (5 and more years)**
17	Improve of tracking of maintenance expenses and operational disruptions including their cause and severity and incorporate that information into budgeting processes over time			
	Require from maintenance company(ies) and from engineers supervising these companies to report to the PESR about the costs incurred for responses to extreme weather events. Build database of these costs related to types of events, assets and road section/region			
18	Implement climate-related data for budget setting			
	After integration of climate impact indicators and parameters into RAMS, supplement the report for the Ministry of Transport presenting the realistic funding requirements for planned maintenance and additional costs related to climate impact mitigation measures.			

19	The Field inspection as form of site-specific inspection programme should be extended through 2019 and subsequent years. A programme for 2020 should be in place by the end of 2019			
20	Introduce emergency fund in the maintenance budget forecast to account for dealing with potential extreme weather related damages of the road network			
	It is estimated that around 15% of the allocated maintenance budget is currently used for emergency maintenance as a result , in any given year. This should be a separate line in the Maintenance Budget.			
In-house and outsourced workforce				
	Adaptation measure	**Short-term (up to 1 year)**	**Mid-term (3 to 5 years)**	**Long-term (5 and more years)**
21	Establish framework contracts for emergency maintenance			
	Prepare contracts for: emergency clear up and response; emergency repairs and maintenance; consulting engineering support for specification, supervision and certification of works			
22	Train existing personnel on the potential impacts of climate change and how this may affect their roles and responsibilities			
23	Determine the right level of workforce requirements and capabilities (especially for hot-spots) for all types of maintenance			
	Clarify the requirements for the maintenance company(ies) - as with the stockpile of equipment, materials and technical standards – to allocate appropriate quantity of employees in case of threat of extreme events			
24	A strategy for dealing with land management			
	A strategy for dealing with land management issues in the light of debris flow potential should be considered by PESR in consultation with other stakeholders.			

5 Legal Assessment

A key part of this work was a detailed review of the existing statutory framework within which PESR operates, with particular attention to aspects that impact upon PESR's ability to respond to climate related events, or provide mitigating measures to reduce the likelihood of future events.

5.1 Relevant Laws

Even though several legal acts regulate different aspects of the landslide, there is no specific law (or bylaw) dealing with landslide management in an overall and comprehensive way, including assessment and modeling of the areas susceptible to landslides, as well as planning and carrying out measures and activities for prevention of damages and losses on transport and related infrastructure, especially in cases of long precipitation and snow melting.

The list of laws and bylaws considered relevant for road designing and network resilience, taken in due analysis are:

1) Law on Public Roads (Official Gazette of RM n.84/2008; 52/2009; 114/2009; 29/2010, 124/2010; 23/2011; 53/2011; 44/2012, 168/2012, 163/2013, 187/2013, 39/2014, 42/2014, 166/2014, 44/2015, 116/2015, 150/2015, 31/2016, 71/2016 and 163/2016) and the subsequent bylaws:
    - Rulebook on measures for road maintenance, the manner and timeframe for their implementation, as well as the type and manner of carrying out regular, winter, periodic and emergency maintenance**.** (Official Gazette of RM No.152
    - Rulebook on the technical elements for the construction and reconstruction of public roads and objects along the roads (Official Gazette of RM n.110/2009, 163/2009; 26/20210; 1603/10; 9420/11; 146/2011 and 9/2017).
2) Law on Construction (Official Gazette of RM n.130/2009, 124/2010, 18/2011, 36/2011, 49/2011, 54/2011, 13/2012, 144/2012, 25/2013, 79/2013, 137/2013, 163/2013, 27/2014, 28/2014, 42/2014, 115/2014, 149/2014, 187/2014, 44/2015, 129/2015, 217/2015, 226/2015, 30/2016, 31/2016, 39/2016, 71/2016, 103/2016,132/2016, 35/2018, 64/2018 and 168/2018) and the subsequent bylaws:
    - Rulebook on the content of the projects, the designation of the project, the manner of verification of the project by the responsible persons and the manner of the use of electronic records (Official Gazette of RM n.24/201, 68/2013, 81/2013, 219/2015 and 52/2016)
    - Rulebook on standards and norms for design (Official Gazette of RM n.60/2012, 29/2015, 32/2016 and 114/2016).
3) Law on Public Procurement (Official Gazette of RM No. 24/19)
4) Law on Expropriation (Official Gazette of RM No. 95/2012, 131/2012, 24/2013)
5) Law on Spatial and Urban Planning (Official Gazette of RM n.199/2014, 44/2015, 193/2015, 31/2016, 163/2016, 90/2017, 64/2018 and 168/2018)

5.2 Recommendations

The following recommendations are issued upon the above analysis with respect to further regulating and/or amending existing legislation closely related to road transport sector, and road construction, respectively:

1. The definition of emergency maintenance (interventions) should be made more precise in order to determine if landslide remediation could be treated also as an emergency intervention, and in general the procedure and actions in the cases of extraordinary events could be elaborated in a clearer and more precise fashion.

The following could be considered:

- Article 36 from the Law on Public Roads should remain as it currently reads:

  (1) "The works for regular maintenance are all activities for continuously enabling functional road conditions and safe traffic

  (2) The works for winter maintenance are all activities carried out for ensuring traffic in winter conditions

  (3) The works for periodic maintenance are all activities undertaken occasionally for extension of the life cycle of the road infrastructure

  (4) The works for emergency maintenance of roads are activities undertaken for removing the damages caused by unforeseen occurrences and for enabling uninterrupted and safe traffic

  (5) The type of the activities for the works from the paragraphs (1), (2), (3) and (4) of this article and the manner of performance are prescribed by the minister of transport and communications."

- A new paragraph (6) and (7) to be added to Article 36 reads:

  (6) "For the works for emergency maintenance of roads from the paragraph (4) of this article, a special reserve fund is earmarked within the Annual Programme for construction, reconstruction, rehabilitation and maintenance of the state roads adopted by the Public Enterprise "State Roads" (PESR) in accordance to Article 4."

  (7) "For the purposes of effective disaster management, the funds for emergency interventions from paragraph (6) of this article, are immediately deployed upon an emergency event through framework contracts of PESR concluded with legal entities registered for carrying out works for maintenance of roads in accordance to the article 34, paragraph 2 and the Law on Public Procurement".

- Article 18, paragraph 1, item 5 from the Rulebook on measures for road maintenance, the manner and timeframe for their implementation, as well as the type and manner of carrying out regular, winter, periodic and emergency maintenance should be amended and read:

  "- protection from erosion of embankments, ***landslide*****s** and rocks downfall, and placing appropriate systems for protection"

- A new paragraph (2) to article 18 should be added and reads:

  "Due to the nature of the activities foreseen in paragraph 1, item 5, which are undertaken as to prevent immediate dangerous impact on the road users, they shall be considered and treated as priority interventions for periodic maintenance in accordance to the Law on Construction.

2. There needs to be a clear provision that allows for the rehabilitations including the landslide constructions to be carried out without construction permit and infrastructure project. This is important for an efficient and fast track procedure for concluding these constructions.

   - Under the heading 9. *Constructions for which construction approval is not necessary* from the Law on Construction, in article 73 , paragraph (1), after the words "supporting walls", the words "and other elements of landslides remediation" are added.
   - Article 45, paragraph (1) from the Law on Construction to be amended and reads:

     "Infrastructure project shall be prepared for linear infrastructure constructions, with exception for constructions related to landslide remediation. The project shall contain a technical solution for the infrastructure with all of its elements containing text and graphic parts and shall show the track of the infrastructure."

3. A correct categorization of the landslide constructions will enable correct provisions to be applied with regards to the services for designing, audit and supervision, for appropriate inspection, issuing corresponding company licenses etc.

   - In the Article 57 from the Law on Construction, in paragraph (1) related to first category constructions, after the words "state roads", to add the words "constructions intended to remediation of landslides".

4. A distinction is proposed in the Law on expropriation with regards to the procedure for expropriation in cases where the land is privately owned, so that this process does not withhold the road intervention upon landslide occurrences

   - In the Article 26, paragraph 1: "Along with the proposal for expropriation, the following is submitted:", the item 1) "excerpt from the act for physical planning or approved Infrastructure project" to be deleted.

5. The legislator could allow for greater level of flexibility when it comes to the changes of the framework contracts with the economic operators (in this case of PESR with its Contractors), as well as a better usage of the existing framework contracts in line with FIDIC rules.

   - The Article 119, paragraph 2 from the Law on Public Procurement, should be changed and reads:

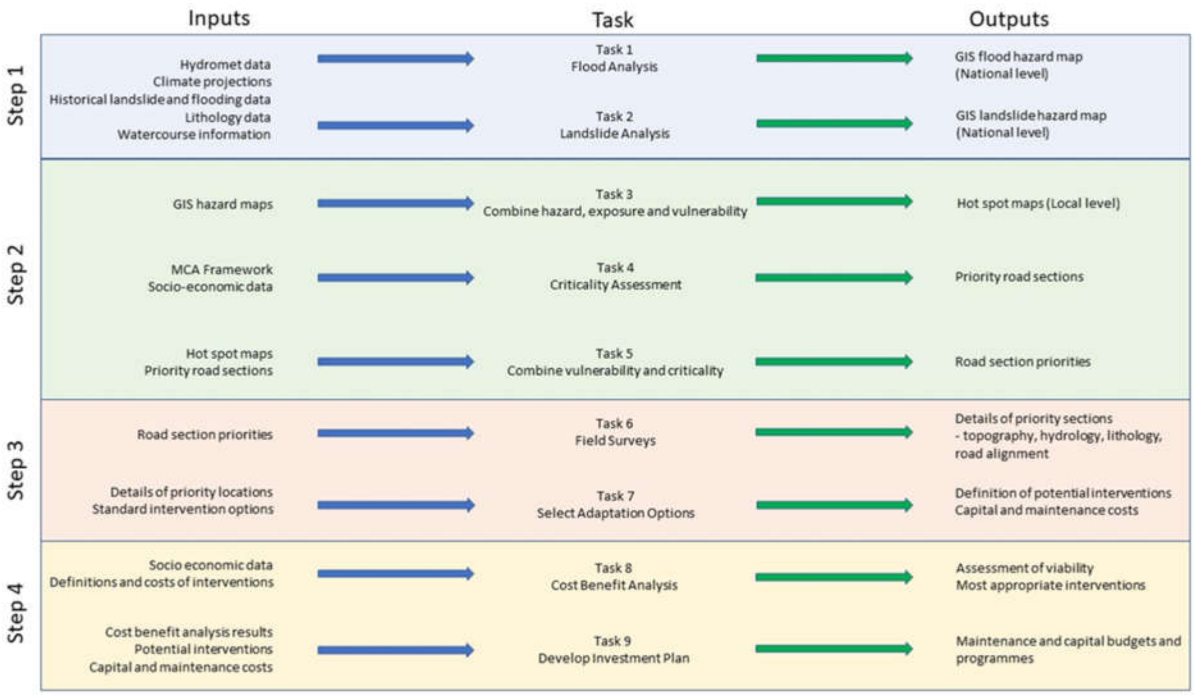
     "…the total amount of the changes in the contract or the framework agreement is not allowed to go above 30% of the value of the original contract or framework agreement…"

A special law on soils to enable permanent monitoring, i.e. systematized measurement, monitoring and control of the state, quality and changes in soil as an environmental medium in North Macedonia has been recognized.

6 CONCLUSION

Recent events in North Macedonia in 2014 showed the potential impact that climate change is likely to have on the country's road network. To limit future economic and financial damage to North Macedonia, it is important that PESR actively identifies ways in which it can effectively and efficiently strengthen the road network infrastructure to reduce the likelihood of damage and road closures.

These guidelines have been produced to offer a means by which PESR can strengthen its internal processes, to better understand and react to the known and predicted risks associated with climate change. The guidelines aim to provide a process that is both free-standing and can be implemented within PESR's existing asset management system. In addition to the technical aspects of producing the guidelines, we have completed institutional and legal reviews, to identify recommended actions to assist PESR in its role. The figure below summarises the process into 4 steps and 9 tasks.



As part of the work to develop these guidelines, we have completed Step 1, which identifies the areas of North Macedonia that are susceptible to either landslides or flooding. This work has resulted in GIS based maps showing which road sections lie within 'hot spot' areas and should therefore be studied in more detail. The data used to develop these maps and the resulting maps have both been incorporated into PESR's asset management system.

Using the Polog Region as a case study, we have then completed all the other steps, to show the process and provide examples of the outputs from different stages. Using the road section between Gostivar and Jazhince as an example, we have completed the steps to identify and study detailed hotspots, undertake multi-criteria analysis, completed necessary field visits, developed appropriate interventions, and completed cost benefit analysis. At all stages, PESR engineers have been involved in this process.