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PANOPTIS

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Development of a Decision Support System for increasing the Resilience of Road Infrastructure based on combined use of terrestrial and airborne sensors and advanced modelling tools-

Grant Agreement Number: 769129

D2.1: End-user needs and practices report

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Table of Contents

TABLE OF CONTENTS 2

LIST OF TABLES 3

LIST OF FIGURES **4**

ABBREVIATION LIST **5**

EXECUTIVE SUMMARY **9**

1. INTRODUCTION **11**

1.1 PURPOSE OF THE DOCUMENT 11

1.2 INTENDED AUDIENCE 12

1.3 INTERRELATIONS 12

PART I: SETTING THE SCENE AND PRESENT PRACTICES **1**

2. OVERVIEW OF THE TRENDS AND CHALLENGES OF EUROPEAN ROAD SECTOR **1**

2.1 OVERVIEW OF THE CHALLENGES OF THE EUROPEAN ROAD TRANSPORT 1

2.1.1 Impact of climate change on road infrastructure[3] 2

2.2 A ROAD TRANSPORT STRATEGY FOR EUROPE 7

2.2.1 Europe on the move 7

2.2.2 The Trans-European Transport Network (TEN-T) 8

2.3 RESEARCH NEEDS: FEHRL'S STRATEGIC EUROPEAN ROAD RESEARCH PROGRAMME 9

2.3.1 The fifth generation road: The resilient road[3] 12

3. REGULATORY AND POLICY FRAMEWORK **15**

3.1 RISK MANAGEMENT 15

3.1.1 EU Policies contributing to Disaster Risk Management 15

3.1.2 EU Civil Protection Mechanism (UCPM) 20

3.1.3 Overview of Natural and Man-made Disaster Risks the European Union may face. 20

3.2 THE EUROPEAN PROGRAMME FOR CRITICAL INFRASTRUCTURE PROTECTION 32

3.3 EU CLIMATE ADAPTATION STRATEGY 34

3.3.1 Adapting infrastructure to climate change 35

3.3.2 EU policy mainstreaming in Climate Adaptation 35

3.4 EU INTERNAL SECURITY STRATEGY 37

3.5 INTELLIGENT TRANSPORT SYSTEMS 38

3.5.1 Directive 2010/40/EU deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport 38

3.5.2 Telematics: deployment of road telematics 39

3.6 NAVIGATION BY SATELLITE 41

3.6.1 Europe's 2 satellite navigation systems moving forward 41

3.6.2 Satellite navigation applications 42

3.7 COPERNICUS: THE EUROPEAN EARTH OBSERVATION PROGRAMME 42

3.8 INFRASTRUCTURE FOR SPATIAL INFORMATION IN THE EUROPEAN COMMUNITY (INSPIRE) 44

3.9 DRONES (UNMANNED AIRCRAFT) REGULATORY FRAMEWORK 45

3.9.1 PANOPTIS demo sites 46

4. GOOD PRACTICES ANALYSIS 49

4.1 DATA, SCIENTIFIC MODELS & TOOLS OF DIFFERENT HAZARDS AFFECTING ROADS INFRASTRUCTURE 49

4.2 USE OF INTELLIGENT TRANSPORTATION SYSTEMS (ITS) IN EUROPEAN ROAD NETWORK 60

4.3 MOBILE DAMAGE MAPPING TECHNOLOGIES FOR ROADS MAINTENANCE 62

4.3.1 Vehicles based-mapping 62

4.3.2 UAV's based (drones) - mapping 63

4.4 SATELLITE IMAGERY 65

4.5 USE OF MANAGEMENT SYSTEMS (MS) AND DECISION SUPPORT SYSTEM (DSS) IN ROAD INFRASTRUCTURE 66

4.5.1 Management systems used in Spanish demo site 71

4.5.2 Management sytems used in Greek demosite 73

PART II: USER NEEDS AND MODUS OPERANDI 75

5. END USERS' NEEDS (UN) AND HIGH LEVEL REQUIREMENTS (UHLR) 75

5.1. ACCIONA NEEDS AND HIGH LEVEL REQUIREMENTS 76

5.2. EGNATIA ODOS NEEDS AND HIGH LEVEL REQUIREMENTS 86

5.3 COMPARISON OF ACCIONA AND EGNATIA ODOS NEEDS 92

5.4 COMPLEMENTARY NEEDS PROVIDED BY EXTERNAL ORGANIZATIONS TO PANOPTIS PROJECT 93

5.4.1 Rijkswaterstaat' needs and high level requirements 95

5.4.2 French road police (Gendarmerie) needs and high level requirements 97

6 CONCLUSIONS 98

7 REFERENCES 101

List of Tables

Table 1 Length of total motorways networks in Europe, (kilometres, 2015)..... 1

Table 2 Climate risk and impacts on transport infrastructure (Annex I from Adapting infrastructure to climate change accompanying the document An EU Strategy on adaptation to climate change) 4

Table 3 A range of adaptation option. Source ADB 6

Table 4 Targets by priority area set on the FREHRL Strategic plan for 2017-2020[14] ... 10

Table 5 EU Policies contributing to Disaster Risk Management concerning PANOPTIS. 16

Table 6 Flooding risk in National Risk Assessments (DG ECHO)..... 22

Table 7 Extreme weather risk in National Risk Assessments (DG ECHO)..... 24

Table 8 Earthquake risk in National Risk Assessments (DG ECHO)..... 27

Table 9: Critical infrastructure disruption risk in National Risk Assessments (DG ECHO) 30

Table 10 List of European critical infrastructure sectors based on Directive 2008/114/EC (EC, 2008) 33

Table 11 34 spatial data themes of INSPIRE Directive 44
Table 15 Road Structural Safety DSS 59
Table 16. Road Safety DSS Worldwide 60
Table 17 ACCIONA needs and high level requirements to PANOPTIS system. 76
Table 18 Egnatia Odos needs and high-level requirements to PANOPTIS system. 86
Table 19 Rijkswaterstaat needs and high level requirements to PANOPTIS system. ... 95
Table 20 French road police (Gendarmerie) needs and high-level requirements to PANOPTIS system. 97

List of Figures

Figure 1 Change in mean annual temperature (left) and mean annual precipitation (right) by the end of this century 3
Figure 2 Nature of adaptation options in the transport sector. Source: ADB 6
Figure 3 The Core Network Corridors 9
Figure 4 Priorities of FEHRL Strategic European Road and cross-modal Research and implementation Plan 2017-2020[14] 10
Figure 5 Outline Milestones for Climate Change Resilient Transport 15
Figure 6. Mapping of flood events in Europe. UCPM activations from 2006 to 2016. DG ECHO/JRC 23
Figure 7 Distance restrictions applying drone operation in Greece. 48
Figure 8 Free-flying zones for drones in Greece 49
Figure 9 Overview of EFAS flood probability maps several days before the devastating Central European floods in May/June 2010. 50
Figure 10 Overview of EFFIS viewer showing near real time information of fire danger. 51
Figure 11 DO map Situation of Combined Drought Indicator in Europe - 2nd ten-day period of August 2018 52
Figure 12 Example France Severe Weather map on 28.08.2018. 52
Figure 13 ESWD map featuring severe weather events 53
Figure 14 Static fores fire risk map, in summer (left) and Winter (right). Soruce: Italian Department of Civil Protection 2015 54
Figure 15 Vulnerability matrices, for: different types of buildings (A to E); for two intensities (VII and VIII). The degree of damage goes from light damage (G1) to collapse (G5) (Spain, Ministry of Interior, 2015) 55
Figure 16 Vulnerability functions for bridge type 332 for 4 limit states and the equivalent vulnerability functions in terms of damage %. Transverse direction 56
Figure 17 Egnatia Motorway sections most at seismic risk 56
Figure 18 “Loss risk” map (left) and “life risk” map (right), 100 year return period (Italian Department of Civil Protection, 2015) 57
Figure 19 Cross border area of the DACEA project, with the seismic stations. Source: DACEA, 2013. (http://www.quakeinfo.eu/en) 57
Figure 20 Smart Roads applications. Source: swarco group 61
Figure 21 C-Roads Road pilot sites 62
Figure 22 Benefits of drone-technology for roads surveying and mapping. 63

Figure 23 SAR “interferometric” image showing surface deformation of a landslide in the municipality of Kåfjord (Norway) 66
Figure 24 Sitraffic Conduct+: Modular system architecture 67
Figure 25 Sources of Datasets integrated in Esri Roads and Highways software. 68
Figure 26 MARWIS mobile road weather information sensor by Lufft. 69
Figure 27 RoadMaster tool by MeteoGroup. 70
Figure 28 ITERNOVA Management system used in Spanish demo site 72

Abbreviation List

Abbreviation	Definition
AWS	Automated Warning Systems
CAPEX	Capital Expenditure
CC	Climate Change
CCTV	Closed Circuit Television
CEF	Connecting Europe Facility
CEN	European Committee for Standardisation
CIP	Critical Infrastructure Protection
CIWIN	Critical Infrastructure Warning Information Network
CMF	Crash Modification Factor
COM	Communication from the Commission
COP	Common Operational Picture
CTR	Controlled Traffic Region
DRR	Disaster Risk Reduction
DSS	Decision Support System
EC	European Commission
ECI	European Critical Infrastructure
EDO	European Drought Observatory
EEAS	European External Action Service
EFAS	European Flood Awareness System
EFFIS	European Forest Fire Information System
EMS	Emergency Management Service
EN	European Standards

Abbreviation	Definition
EP	Emergency Plan
EPCIP	European Programme for Critical Infrastructure Protection
ERCC	Emergency Response Coordination Centre
ERDF	European Regional Development Fund
ERN-CIP	European Reference Network for Critical Infrastructure Protection
ERTMS	European Rail Traffic Management System
ESS	Environmental Sensor Stations
ESWD	European Severe Weather database
EU	European Union
EURO-CORDEX	Coordinated Downscaling Experiment-European Domain
FEHRL	Forum of European Highway Research Laboratories
FOR	Forever Open Road
GDO	Globe Drought Observatory
GNSS	Global Navigation Satellite System
GSA	European GNSS Agency
HR	High Resolution
HRAP	Holistic Resilience Assessment Platform
ICT	Information and Communication Technologies
IMS	Incident Management System
IRs	Implementing Rules
IRI	International Roughness Index
ISS	Internal Security Strategy
ITS	Intelligent Transport Systems
KSIs	Killed or Seriously Injured
KPI	Key Performance Indicators
LIDAR	Light Detection and Ranging or Laser Imaging Detection and Ranging
MEPs	Members of the European Parliment
ML	Machine Learning
MS	Management systems

Abbreviation	Definition
MTOM	Maximum take-off mass
NAS	National Adaptation Strategy
Natech	Natural Hazard Triggering Technological Disasters
NHTSA	National Highway Traffic Safety Administration
NRA	National Risk Assessments
O&M	Operation and Maintenance
OHVD	Over Height Vehicle Detection
OPEX	Operational Expenditure
OSP	Operator Security Plan
PFRA	Preliminary Flood Risk Assessment
RCM	Regional Climate Model
RDS-TMC	Radio Data System / Traffic Message Channel
RI	Road Infrastructure
RT	Road Telematics
RWIS	Road Weather Information System
SAR	Synthetic Aperture Radar
SERRP	Strategic European Road Research Programme
SGSA	Geotechnical and Structural Simulation Tool
SHM	Structural Health Monitoring
SWD	Staff Working Document
TEN-T	Trans-European Transport Network
TCC	Traffic Control Center
TI	Transport Infrastructure
TMCs	Traffic Management Centres
TMS	Traffic Management Systems
UAV	Unmanned Aerial Vehicles
UCPM	Union Civil Protection Mechanism
UHLR	User High Level Requirements
UN	User Needs
UNFCCC	United Nations Framework Convention on Climate Change

Abbreviation	Definition
UNISDR	United Nations Office for Disaster Risk Reduction
VMS	Variable Message Signs
VSLS	Variable Speed Limit Signs
WRCP	World Climate Research Program

Executive Summary

PANOPTIS aims to improve the resiliency[i] of transport infrastructure in adverse climate conditions, such as extreme weather phenomena, and other disaster events, such as earthquakes or landslides. The project's main goal is to combine small-scale climate change scenarios (applied to infrastructure) with structural and geotechnical simulation tools and actual data (from existing and novel sensors), so as to provide transport infrastructure managers with an integrated decision tool capable of improving transport infrastructure management in the planning, maintenance and operation stages. Towards this, PANONPTIS relies on the following developments:

- Reliable quantification of climatic, hydrological and atmospheric stressors
- Multi-Hazard vulnerability modules and assessment toolkit.
- Development of a forecasting module to provide high-resolution tailored weather and precipitation forecasts
- Improved prediction of structural and geotechnical safety risk through the use of Geotechnical and Structural Simulation Tool (SGSA)
- Improved multi-temporal, multi-sensor observations with robust spectral analysis, computer vision and Machine Learning (ML) damage diagnostic for diverse Road Infrastructure (RI)
- Detailed and wide area transport asset mapping, integrating state-of-the-art mobile mapping and making use of Unmanned Aerial Vehicles (UAV) technology
- Design of a Holistic Resilience Assessment Platform (HRAP)
- Design of a Common Operational Picture (COP) including a Decision Support System (DSS), an enhanced visualization interface and an Incident Management System (IMS) that can be shared between all the organisations involved in the Road Infrastructure operation and management

The PANOPTIS integrated platform (and its sub-modules) will be validated in two highway sections in the Greek and Spanish primary road network. The cost, benefit and the time of the proposed system and incurred procedures will be compared to the manual or non-automated and non-integrated procedures and means of the motorway operation (up to the time of the project initiation).

The present document, deliverable D.2.1"*End-user needs and practices report"* is a deliverable of the PANOPTIS project, and it aims to provide an analysis of current practices, needs and expectations from infrastructure end-users, focusing on road operators. D.2.1 aims to stablish dialogue with road operators to understand their needs and translate into requirements to the PANOPTIS tool. So that, the user needs collected

[i] The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions". (UNISDR, 2009)

in D.2.1 will serve as initial terms of reference for the design, development and realization of the technical components of the PANOPTIS System.

In addition, D.2.1 also provides a deep analysis of all technical, regulatory and financial aspects that shall be considered for the development of PANOPTIS integrated system.

D2.1 consists of two main parts:

- **Part I: From Chapter 2 to Chapter 4**
  Part I aims to set the scene of the project, in terms of strategic and regulatory context, and to provide the state of the art practices and technologies to be considered for the development of the integrated PANOPTIS tool. A brief description of each chapter is provided below:
  - ✓ Chapter 2 provides a general introduction of the European road sector, delving into challenges (such as climate change), Strategic Plans, and research needs.
  - ✓ Chapter 3 refers to all relevant regulations, guidelines, and standards to be taken into consideration in order to define WP2 methodological approach,
  - ✓ Chapter 4 collects a set of good practices, models and tools already available for RI stakeholders, with regard to risk prediction and assessment, operational and strategic management and decision support

- **Part II Chapters 5 and 6.**
  Part II focus on the definition of the end-user needs, parting from the review of the current modus operandi.
  - ✓ Chapters 5 provides the infrastructure owners' needs and expectations that will be used as baseline for the development of PANOPTIS integrated system,
  - ✓ Chapter 6 draws the main conclusions,

To complete the structure of the document, Chapter 1 provides the Introduction and Chapter 7 the References.

1. Introduction

1.1 Purpose of the document

The objective of *D.2.1"End-user needs and practices report",* is to gather the current practices, needs and expectations from infrastructure stakeholders, focusing on road operators.

D.2.1 is the first deliverable of WP2 *End-user requirements and Platform design,* aimed at producing an architectural specification of the PANOPTIS integrated platform, which will be the basis for the technical developments in WPs 3-6, as well as for the integration and piloting activities in WP7. The strategy of WP2 is to start with the analysis of the end users' current practices and needs (*in Task 2.1*), followed by the specification of system requirements and use cases *(in Task 2.2)*, and finalized with the specification of the architecture itself *(in Task 2.3)*.

The present document D.2.1 specifically reports the work done in Task 2.1. "*End-user needs and good practices analysis"*. D.2.1 focuses on collecting the end-users stories, to feed Task 2.2 *Specification of system requirements, use cases, scenarios definition, and KPIs),* aimed at converting these end-user stories into a detailed specification of functional and non-functional requirements of PANOPTIS system.

The PANOPTIS project aims to keep solutions end-user-centric, and avoid the pitfalls of a technology disassociated from the Market. Accordingly, D.2.1 has collected a comprehensive list of end-users' needs, sufficiently complete to set up the requirements for each one of the technologies forming the PANOPTIS system. The approach followed by the consortium has been to identify the needs and concerns from the two end-users of project (Egnatia Odos and ACCIONA), based on their deep knowledge and long experience in managing contracts of Roads Infrastructure. Egnatia Odos and ACCIONA have also been able to provide high-level requirements, since they are aware of the project's technologies as well as of the features of the demo premises. Complementarily, some relevant RI stakeholders external to the project, such as the French road police (Gendarmerie) and the Dutch Infrastructure operator Rijkswaterstaat have added some extra-needs and desired requirements to the list. As the PANOPTIS project applies "agile" methodologies, the end-users needs' log presented in this document, will keep active throughout the project, allowing new additions and updating, in order to guarantee that the PANOPTIS system includes all relevant inputs (also coming from stakeholders external to the project), and adapts to the future work and findings of the project.

In addition to the collection of inputs from the end-users, this task provides a deep analysis of all technical, regulatory and financial aspects that shall be considered for the development of PANOPTIS integrated system. This includes the analysis of EU and national relevant regulations and recommendations, and the compilation of most widespread current standards, practices, and solutions/tools related to operational and strategic management, risk analysis and decision-making for more resilient RI/ TI.

1.2 Intended audience

D.2.1 is a public document, and thus will be reachable by all the stakeholders in the Transport/Road community. It is particularly interesting for end users, meaning road agencies involved in the management and operation of the road infrastructure in order to learn from the PANOPTIS system and provide additional needs. It is also worthwhile for the ITS Industry to identify the current practices and needs from infrastructure managers, and adapt ITS products to these needs.

1.3 Interrelations

WP2 applies a bottom up strategy to design the PANOPTIS Platform according to end-user needs.

- First, D.2.1 identifies the current needs and expectations of RI end-users,
- Second, D.2.2 builds over these needs to define PANOPTIS functional and non-functional requirements
- Third, D.2.3 finally come up with the architectural specification of the system that better matches with the requirements defined in D.2.2. The architectural specification will be the basis for the technical developments in WPs 3-6, as well as for the integration and piloting activities in WP7.

Therefore, the present document represents the foundations for the design of the PANOPTIS integrated system in the technical WPs (from WP3 to WP6). Furthermore, since D.2.1 is guided by PANOPTIS end-users (ACCIONA and Egnatia Odos), it is the main source of information to define the specific pilot cases of the demonstration WP (WP7).

It is important to remark that, given the importance of the end-user needs' log reported in D.2.1 for the development of the PANOPTIS project, and because of its young nature (it is only produced in Month 4 of the project), the consortium will monitor, complete and update this log along the duration of the project according to the future work and findings in other WPs. The end-users will be invited to the components reviews and the integration sessions, which will enable them to express additional or more detailed needs.

PART I: SETTING THE SCENE AND PRESENT PRACTICES

2. Overview of the Trends and challenges of European Road sector

Chapter 2 gives an introduction of the main challenges faced by the European Road sector nowadays, delving into climate change, as well as a review of the strategies adopted by the sector towards the modernization of the road infrastructure. It includes some key policies, funding schemes, and research roadmaps established by the EU to achieve the next generation of resilient roads.

2.1 Overview of the challenges of the European Road Transport

Road transport is vital for the EU's economy: with more than 75,000 kms of motorways, it carries more freight and more passengers than all other modes combined[1].

It is estimated that Road transport related industries provide employment to more than 14 Million people in Europe and directly contribute by 11% to the European Gross National Product[2].

Table 1 Length of total motorways networks in Europe, (kilometres, 2015).

Length of Motorways							
EU28	**s 75,820**	Estonia	147	Latvia	//	Slovakia	463
Austria	1,719	Finland	881	Lithuania	309	Slovenia	773
Belgium	s 1,763	France	**11,599**	Luxembourg	161	Spain	**15,336**
Bulgaria	734	Germany	**12,993**	Malta	//	Sweden	2,119
Croatia	1,310	Greece	1,589	Netherlands	2,756	United Kingdom	s 3,769
Cyprus	272	Hungary	1,884	Poland	1,559	Iceland	s 11
Czech Republic	776	Ireland	916	Portugal	3,065	Norway	392
Denmark	1,237	Italy	6,943	Romania	747	Switzerland	1,440

s = estimated value
Data Sources: Eurostat | International Organisations | National Entities | European Commission - Transport in Figures Statistical pocketbook
Source: PORDATA
Last updated: 2017-09-18

The development of road infrastructure throughout Europe varies greatly. Some regions have largely complete networks, with some parts built more than 50 years ago. Extreme weather events and the long term effects of climate change, together with increasing traffic loads will put further strain on Europe's infrastructure. Maintaining this infrastructure and protecting it against climate and traffic conditions not envisaged at the design stage is of great importance, and cost effective solutions to extend the service life are required[3]. According to the EC, weather stresses represent from 30% to 50% of current road maintenance costs in Europe (8 to 13 billion € p.a.). About 10% of these

costs (~0.9 billion € p.a.) are associated with extreme weather events alone, in which extreme heavy rainfalls & floods events represent the first contribution[4]. Conversely, some regions are still developing their road infrastructure networks, and cost-effective solutions to design and construct new roads with in-built resilience are thus desirable[3].

Transport activity across Europe is expected to continue growing. From 2010 to 2050, it is estimated that passenger transport will grow by about 42 percent. Freight transport is expected to grow by 60 percent[5]. The cost of EU infrastructure development to match transport demand has been estimated at over € 1.5 trillion for 2010-2030[ii].

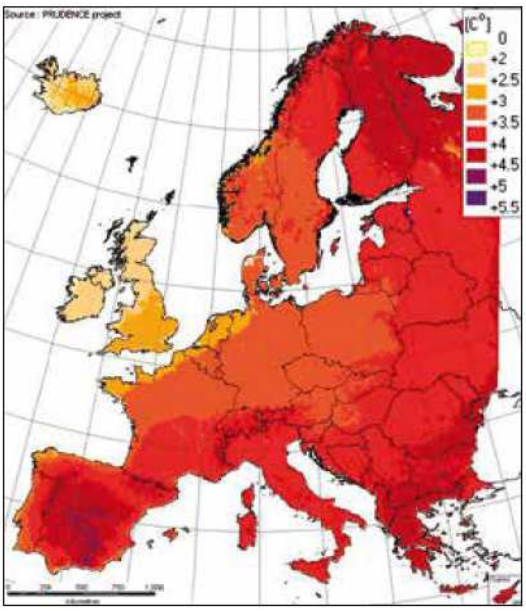
In this context, one of the greatest challenges facing transport operators and engineers today is the fast and efficient inspection, assessment, maintenance and safe operation of existing infrastructures including highways and the overall Road Infrastructure (RI) network.

2.1.1 Impact of climate change on road infrastructure[3]

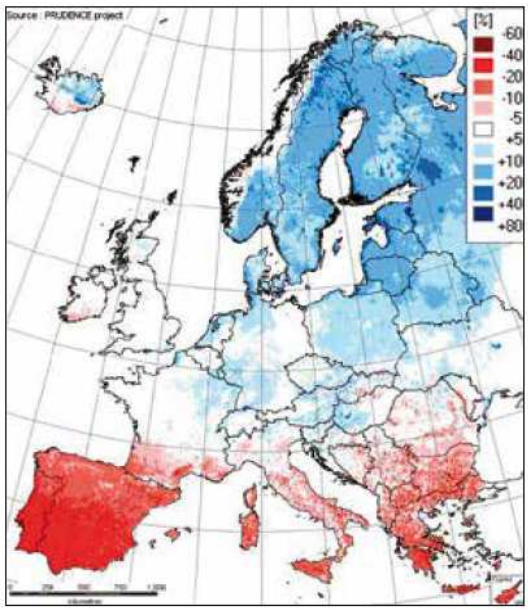
- **<u>Climate change forecast in Europe</u>**

Forecast temperature and rainfall patterns across Europe are presented below, showing a general increase in temperature across Europe, but particularly in the far south Mediterranean areas, in eastern and the far north of Europe and in mountainous regions. This generally corresponds to a decrease in precipitation in southern Europe and an increase in northern Europe, although this is unlikely to be uniform. Even in areas that appear to show little change, such as the United Kingdom and northern France, whilst annual precipitation might be broadly similar, it is predicted that summers will be drier, whilst the winters wetter. There will also be more intense rainfall events.

Temperature: change in mean annual temperature [C°]



Precipitation: change in mean annual amount [%]



[ii] *EC calculations based on TENtec Information System and the Impact Assessment accompanying the White Paper, SEC(2011) 358.*

Figure 1 Change in mean annual temperature (left) and mean annual precipitation (right) by the end of this century
Source: http://peseta.jrc.ec.europa.eu/docs/ClimateModel.html

As the climate changes, extreme weather events may become more frequent, more intense and longer lasting. Vulnerability to climate change varies widely across regions:

- In low lying countries with islands and extensive coastlines such as Denmark; sea level rise has affected land drainage, causing groundwater to reach the surface temporarily or permanently, causing 'blue spots' triggering road closures
- The Mediterranean area is becoming drier, making it more vulnerable to drought and wildfires, whilst Northern Europe is getting significantly wetter, and winter floods could become common
- Europe's far south, east and the Arctic show significantly increased temperatures, as do the Alps. In addition to changes in general precipitation, there could be changes to the proportion falling as snow or rain, changes in the melting of snow and ice, and in the freeze-thaw patterns

- **Potential Impacts of Climate Change on Transport Infrastructure**

Whilst there will be various changes across the geographic areas of Europe, some of the risks to the highway network are outlined below:

Flooding either through precipitation or potentially rapid snow/ice melt in some regions and some of the associated effects such as:

- Operational disruption, reduced network availability and blockages
- Bridge scour, inundation of tunnels and landslides
- Saturation of the unbound layers, resulting in loss of fine material, settlement and failure
- Saturation of the subgrade causing a reduction in strength

Hotter, drier summers lead to a reduction in sub-surface water, causing shrinkage of the sub-surface and inducing cracking. Increasing changes in sub-surface water can cause soil to shrink and expand significantly, causing the overlying pavement layers to heave and subside

In periods of hot weather, asphalt surface layers can become susceptible to rutting and deformation. In addition, high temperatures can make newly laid asphalt remain workable for an extended time, making it difficult to maintain profile during compaction

Thermal gradients can create uneven internal stresses, giving rise to curling or warping in concrete pavements

Reduction in vegetation due to higher temperatures and drought, and/or higher wind speeds could increase erosion processes on embankments, leading to them becoming unstable

Intense rainfall events cause erosion or landslips/landslides on embankments. Extreme rainfall events in areas with reduced vegetation, described above, would intensify erosion

A milder climate could have implications for northern areas of Europe where the ground is currently frozen during winter, through increases in the freeze-thaw process

Conversely, winter maintenance requirements may decrease in many areas due to a milder climate, whilst changes in springtime snow melt and the proportion of precipitation falling as rain or snow might result in less flooding

Table 2 Climate risk and impacts on transport infrastructure (Annex I from Adapting infrastructure to climate change accompanying the document An EU Strategy on adaptation to climate change)[6]

ROAD infrastructure	**TYPE**	**CLIMATIC PRESSURES**	**RISK**	**TIMEFRAME of expected impact**	**REGIONS mainly affected**
	Roads (including bridges, tunnels, etc.)	Summer heat	• Pavement deterioration and subsidence; • melting tarmac; • Reduced life of asphalt road surface (e.g. Surface cracks); • increase wildfires can damage infrastructure • expansion, buckling of bridges	Medium negative (2025; 2080) to high negative (2080)	Southern Europe (2025) West, East and Central EU (2080)
		Extreme precipitation/ floods	• Damage on infrastructure (e.g. pavements, road washout); • road submersion; • scour to structures; • underpass flooding; • overstrain drainage systems; • risk of landslides; • instability of embankments	Medium negative (2025; 2080) to high negative (2080)	European wide
		Extreme storm events	• Damage on infrastructure: roadside trees/ vegetation can block roads	No information	No information
		In general:	• Speed reduction; • road closure or road safety hazards; • disruption of "just in time" delivery of goods;		

			• welfare losses; higher reparation and maintenance costs		
	Coastal roads	Sea level rise	• Damage infrastructure due to flooding • coastal erosion • road closure	Medium negative (2080)	European wide
		Extreme storm events		No information	No information
		Heavy precipitation events		Medium negative (2025; 2080) to high negative (2080)	European wide
	Mountain road	Permafrost degradation	• Decrease of stability, rock falls; landslides; road closure	No information	No information
	Sewerage system	Heavy precipitation events	• Overload sewerage system can cause road flooding and water pollution	Medium negative (2025; 2080) to high negative (2080)	European wide

- **<u>Adaptation to Climate change</u>**

Member States and regions have allocated EUR 8 billion for climate change adaptation and risk prevention and management for the 2014-2020 period from the European Regional Development Fund (ERDF) and Cohesion Fund, including for cross-border and transnational cooperation. These investments address various types of risks, although the predominant focus is on flood prevention[7].

Adaptation options in the sector can generally be divided into engineering (structural) options (subsurface conditions, material specifications, cross section and standard dimensions, drainage and erosion, and protective engineering structures), and non-engineering options (maintenance planning and early warning, alignment, master planning and land use planning, and environmental management). In addition, it is important to recognize that in a number of circumstances, a "do nothing" response to climate change, for example, allowing an infrastructure to deteriorate and be decommissioned instead of climate proofing the infrastructure may be a preferred course of action.

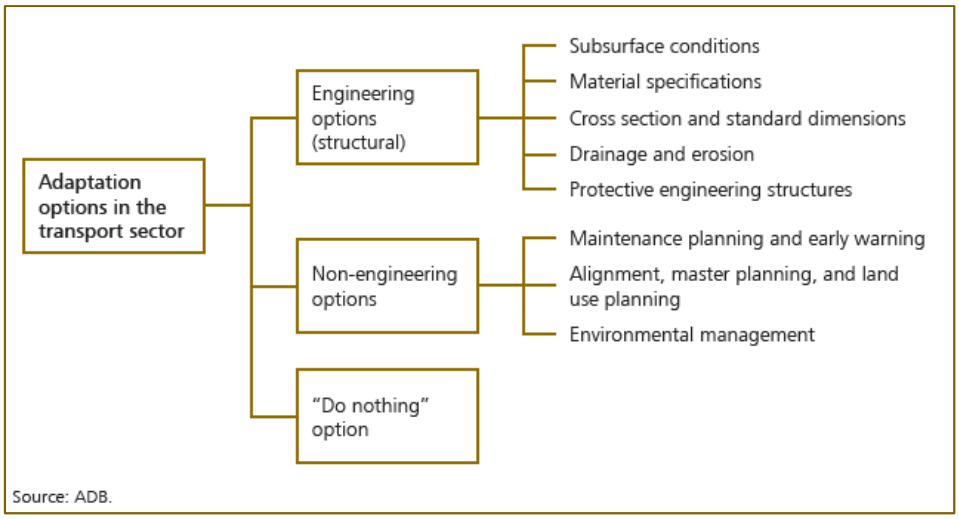


Figure 2 Nature of adaptation options in the transport sector. Source: ADB

A range of adaptation options are proposed in the table below

Table 3 A range of adaptation option. Source ADB

Climate issues	Potential Adaptation Options
Sea level rise and storm surges	• Monitoring certain roads that may be submerged • Using suitable materials and providing lateral protections • Raising the level of the road • Constructing levy bank with drainage/ seawall • Road realignment • Increasing maintenance Budget • Including additional longitudinal and transverse drainage systems • Protecting levy bank with suitable mangroves • Planting artificial reefs • Replacing metal culverts with reinforced concrete
Reduction in rainfall or increased erosion	• Using flexible pavement structures • Increasing maintenance budgets to clear dust and landslides • Increasing water retention capacity and slow infiltration through environmental measures and bio retention systems to recharge aquifers and reduce surface flow runoff • Re-vegetating with drought-tolerant species • Mulching • Using matting/erosion control blankets • Applying granular protection • Moistening of construction materials • Obtaining the optimum level of compaction (to avoid any subsequent settlement) • Ensuring the selection of materials with high resistance to dry conditions
Increase in precipitation	• Apply a safety factor to design assumptions • Reducing the gradients of slopes • Increasing size and number of engineering structures /hydraulic structures, high river crossings) • Increasing water retention capacity and slow infiltration through natural or bioengineered systems • Raising pavement and adding additional drainage capacity • Increasing monitoring of vulnerable roads in order to prevent disasters

Climate issues	Potential Adaptation Options
	• Using water capture and storage systems • Realigning natural water courses (river training) • Enclosing materials to protect from flood water (i.e. impermeable linings) • Using materials that are less affected by water • Allowing for alternative routes in the event of a road closure
Increased wind strength	• Modifying the design of supports and anchorages • Installing protection systems such as windbreaks • Planting coastal forest and mangroves

2.2 A Road Transport Strategy for Europe

2.2.1 Europe on the move[8]

The European Commission is today taking action for a fundamental modernisation of European mobility and transport. The Commission has adopted a long-term strategy to deliver smart, socially fair and competitive mobility by 2025. The aim is to help the sector to stay competitive in a socially fair transition towards clean energy and digitalisation. "*Europe on the Move*" is a mobility package released by the European Commission, ranging a set of initiatives that will make traffic safer; encourage smart road charging; reduce CO_2 emissions, air pollution and congestion; cut red-tape for businesses; fight illicit employment and ensure proper conditions and rest times for workers.

The European Commission has recently undertaken the third and final set of actions to modernise Europe's transport system. This third "Europe on the Move" consist of:

- A Communication outlining a new road safety policy framework for 2020-2030. It is accompanied by two legislative initiatives on vehicle and pedestrian safety, and on infrastructure safety management[9];
- A dedicated communication on Connected and Automated Mobility to make Europe a world leader for autonomous and safe mobility systems;
- Legislative initiatives on CO_2 standards for trucks, on their aerodynamic, on tyre labelling and on a common methodology for fuels price comparison. These are accompanied by a Strategic Action Plan for Batteries**.** Those measures reaffirm the EU's objective of reducing greenhouse gas emissions from transport and meeting the Paris Agreement commitments.
- Two legislative initiatives establishing a digital environment for information exchange in transport
- A legislative initiative to streamline permitting procedures for projects on the core trans-European transport network (TEN-T[iii]) (*See next section*).

[iii] The Trans-European Transport Networks (TEN-T) are a planned set of road, rail, air and water transport networks in the European Union. The TEN-T networks are part of a wider system of Trans-European Networks (TENs), including a telecommunications network (eTEN) and a proposed energy network (TEN-E or Ten-Energy).

They are supported by a call for proposals under the Connecting Europe Facility with €450 million available to support projects in the Member States contributing to road safety, digitisation and multimodality. The call will be open until 24 October 2018.

2.2.2 The Trans-European Transport Network (TEN-T)[10]

The Trans-European Transport Network (TEN-T) is a European Commission policy directed towards the implementation and development of a Europe-wide network of roads, railway lines, inland waterways, maritime shipping routes, ports, airports and rail-road terminals. It consists of two planning layers:

- The Comprehensive Network: Covering all European regions
- The Core Network: Most important connections within the Comprehensive Network linking the most important nodes

The ultimate objective of TEN-T is to close gaps, remove bottlenecks and eliminate technical barriers that exist between the transport networks of EU Member States, strengthening the social, economic and territorial cohesion of the Union and contributing to the creation of a single European transport area. The policy seeks to achieve this aim through the construction of new physical infrastructures; the adoption of innovative digital technologies, alternative fuels and universal standards; and the modernising and upgrading of existing infrastructures and platforms.

Following a 2013 review of TEN-T policy, nine Core Network Corridors were identified to streamline and facilitate the coordinated development of the TEN-T Core Network. They represent 800 km of key European corridors. These are complemented by two Horizontal Priorities, the ERTMS (European Rail Traffic Management System) deployment and Motorways of the Sea; both established to carry forward the strategic implementation of the objectives of the Core Network, in-line with the funding period, 2014 to 2020.

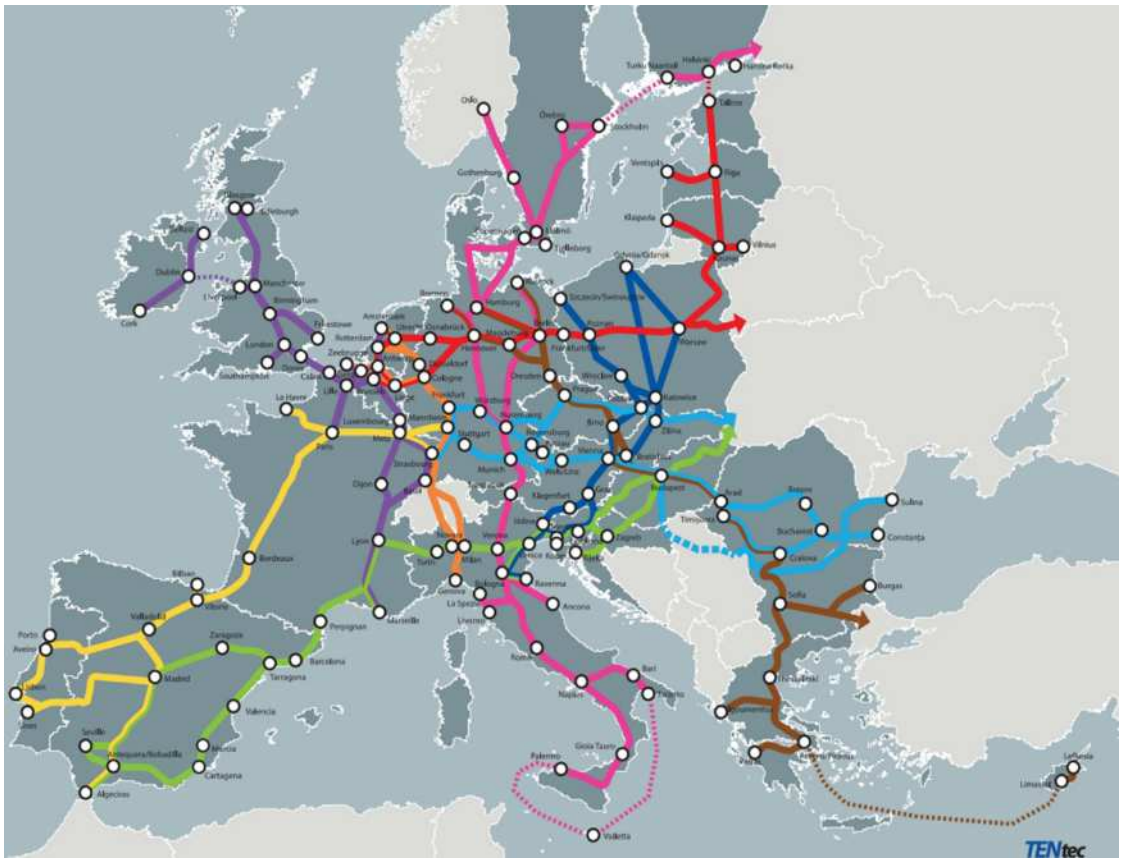


Figure 3 The Core Network Corridors

An estimated EUR 500 billion of financial investment is required for projects necessary for the implementation of the TEN-T in the current EU programming period, 2014 to 2020. By 2030, the completion of the TEN-T Core Network Corridors alone will require approximately EUR 750 billion worth of investments. The largest percentage of this amount will come from the national budgets of Member States, who are obliged to align national infrastructure investment policy with European priorities. EU grants will form another significant contribution[11]. In particular, *Connecting Europe Facility (CEF) for Transport* is the key funding instrument to realise European transport infrastructure policy[12].

TEN-T core Network corridors are regulated under EU Regulation 1316/2013[13].

2.3 Research needs: FEHRL's Strategic European Road Research Programme

The Forum of European Highway Research Laboratories (FEHRL) is an international association governed by the Directors of each of the national institutes nominated by their respective countries. It currently includes 30 members from European countries as well as international affiliates from the United States, South Africa, Australia and Israel. FEHRL has significant role in providing scientific input to Europe and national government policy on highway engineering and road transport matters.

FEHRL produced in 2013 the Strategic European Road Research Programme (SERRPV) covering the 2011 to 2016 period. This version has recently been updated to

the FEHRL *Strategic European Road and cross-modal Research and implementation Plan 2017-2020*[14]. The main FEHRL priorities are presented in the figure below:

Figure 4 Priorities of FEHRL Strategic European Road and cross-modal Research and implementation Plan 2017-2020[14]

PANOTPIS project is well aligned with the FEHRL's Strategy for European Roads 2017-2020, and contributes to most of the priority areas set out by FEHRL. More specifically, PANOPTIS could strongly contribute to meet the targets established by FEHRL in the areas *of Digitalisation, Maintenance and Upgrading of aging infrastructure, Security & Resilience and Health & Safety.* To a lesser extent, *PANOTPIS* also contributes to the area of *governance for implementation, and Cross and Multimodal integration.*

The table below summarises the targets defined in these priority areas by various national and European transport agencies and industrial plans, and collected by FEHRL in the Strategic plan for 2017-2020.

Table 4 Targets by priority area set on the FREHRL Strategic plan for 2017-2020[14]

FEHRL priority area	Target	Basis of target

FEHRL priority area	Target	Basis of target
Maintenance and upgrading of multimodal infrastructure		
Upgrading	-50% time lost to upgrades	Research for Future Infrastructures in Europe (reFINE) target works towards Joint European Construction Technology Platform Zero transport disruption caused by intrusion from inspection, upgrading and maintenance target
Life extension	+50% extension of infrastructure life	Research for Future Infrastructures in Europe (reFINE) target for long distance corridors
Self-explaining and forgiving road	+40% reduction in KSIs[iv]	Research for Future Infrastructures in Europe (reFINE) target of -40% casualties by 2030
Prefabrication	Increase in off-site construction	No target set
Maintenance (including development of robotics)	Undertake technology scan. Prepare research document on potential for robotics to increase lane availability, reduce costs, and reduce time operations.	
Digitalisation		
Adaptation of infrastructure to automated vehicles	Increase capacity of infrastructure for mobility by optimisation of space sharing (+20%)	Conservative estimate based on lower number of accidents, increased through put of vehicles and narrower lanes. Lower limit of capacity increase noted in study[15]
Infrastructure investment decisions	Support 20 – 30% improvement in cost versus 2010 baseline by 2030 Production of document detailing potential traffic scenarios as a result of mobility changes	Joint European Technology Platform Target. 30% target in Research forFuture Infrastructures in Europe (reFINE) document
Big Data, BIM, Internet of Things & related cyber security	30% structural cost savings for design and construction by 2025	Estimated savings in UK[16]
Traffic Management	+30% reduction of congestion	Research for Future Infrastructures in Europe (reFINE) target of 30% improvement and increase of infrastructure utility (capacity, safety and efficiency)
Smart, connected cities	Identify smart, connected city requirements and prepare FEHRL statement on infrastructure response	Engage with Smart Cities Electro mobility and New Mobility Services https://eu-smartcities.eu/content/sustainable-urban-mobility-0

[iv] People killed or seriously injured

FEHRL priority area	Target	Basis of target
Security and resilience		
Adaptation of infrastructure to extreme weather, climate change & man-made hazards	+50% reduction in downtime +10% improvement in service levels	Research for Future Infrastructures in Europe (reFINE) target is 100% reliable urban infrastructure in extreme events. Supports Mobility Continuity Plans outlined in EC White Paper
Health and safety		
Improved safety in extreme weather conditions. Safety improvement due to digital environment	+40% improvement +40% reduction in KSIs (by 2030)	Research for Future Infrastructures in Europe (reFINE) target of -30% accidents and -40% casualties Highways England target Supports EC White Paper 'zero vision' for road fatalities by 2050 ERTRAC target 60% improvement by 2030 vs 2010 baseline
Safety for road users and operatives	Eliminate need for road workers to be on foot on live carriageway Reduce exposure of road workers to live traffic – set KPI	Highways England target Highways England target
Safety for vulnerable road users	Set KSI in view of proposed increase in active travel Adaptation of infrastructure to new users.	Active Travel (Wales) Act 2013[17] makes it a legal requirement for local authorities in Wales to map and plan for suitable routes for active travel, and to build and improve infrastructure for walking and cycling every year

2.3.1 The fifth generation road: The resilient road[3]

Within the FEHRL's Strategic European Road Research Programme, the *Forever Open Road* (FOR) programme deserves special attention. The FOR programme, started in 2013 and still active, forms the flagship research programme of the FEHRL. It aims to produce the fifth generation road: a road that is adaptable, automated and climate change-resilient (whether motorway, rural or urban, and regardless of region or country).

- The Adaptable Road: focusing on ways to allow road operators to respond in a flexible manner to changes in road users demands and constraints
- The Automated Road: focusing on the full integration of intelligent communication technology applications between the user, the vehicle, traffic management services and the road operations
- The Resilient Road: focusing on ensuring service levels are maintained under extreme weather conditions

Towards the resilient road, the FOR presented in 2013 a programme of research[3] based on three innovation themes, and specific topics.

- **Development and implementation of risk-based methodologies**

  1. Development of risk-based methodologies to assess the vulnerability of the road network to extreme weather events, longer term impacts of climate change and shifts in climatic zones.
  2. From the results of the vulnerability assessment, production of maps showing potentially vulnerable elements of the TEN-T road network.
  3. Estimation of economic costs of adaptation measures and development of risk-based procedures to consider the cost of disruption due to extreme weather versus the cost of adaptation.

- **Development and application of technologies**

  1. Design of resilient drainage systems, soil strengthening and rock stabilisation techniques, and early warning systems
  2. Resilient asphalt and concrete pavements (mixture and pavement design, paving technologies) and methods of increasing skid resistance.
  3. Resilient, long life and low maintenance measures for increasing the resilience of existing bridges, including foundations, preventive protection systems for tunnel structures against flooding and solutions for the conservation of groundwater reserve during tunnel construction and operation.
  4. Rapid and automated inspection and survey methods, as well as sustainable maintenance measures and techniques for pavement, sub-surface, structures and drainage.
  5. Automated and remote sensors for measuring environmental conditions and change.
  6. Interaction between vehicle/road/driver.

- **Development and introduction of management and adaptation strategies**

  1. Develop guidelines for the expected performance levels of infrastructure systems and guidelines to cope with restricted flow during extreme weather events.
  2. Development and improvement of models to predict weather events and traffic congestion, and to assess the impact of real time management systems to provide the early warning of extreme events and instigate intelligent re-routing and modal shift.
  3. Development and implementation of adaptation strategies and development of guidelines to assist implementation for new build and adaption of existing infrastructure.
  4. Integration of the above with emergency services systems.
  5. Sensor and communication systems to provide real time information for the road user.

PANOPTIS project addresses several of the topics mentioned above, such as:

- Development of risk-based methodologies to assess the vulnerability of the road network to different risk events;
- Application of preventive and low maintenance measures for increasing the resilience of road infrastructure assets; this is expected to be achieved through the introduction of more often, but still less expensive inspections;
- Automated inspection and survey methods;
- Automated and remote sensors for measuring environmental conditions and change;
- Improvement of models to predict weather events, and to assess the impact of real time management systems to provide the early warning of extreme events;
- Adaptation strategies to assist implementation for new build and adaption of existing infrastructure;
- Sensor and communication systems to provide real time information

The Roadmap of the FOR will provide proven solutions that are ready to be implemented by the national, regional and local infrastructure authorities. The generic build up is from single technology trials from around 2013 towards full systems proving on a network scale around 2020. From 2020, the Roadmap will be concerned with supporting and facilitating the roll-out activities by the authorities. It is in this stage that climate change resilient transport will be implemented at a network level.

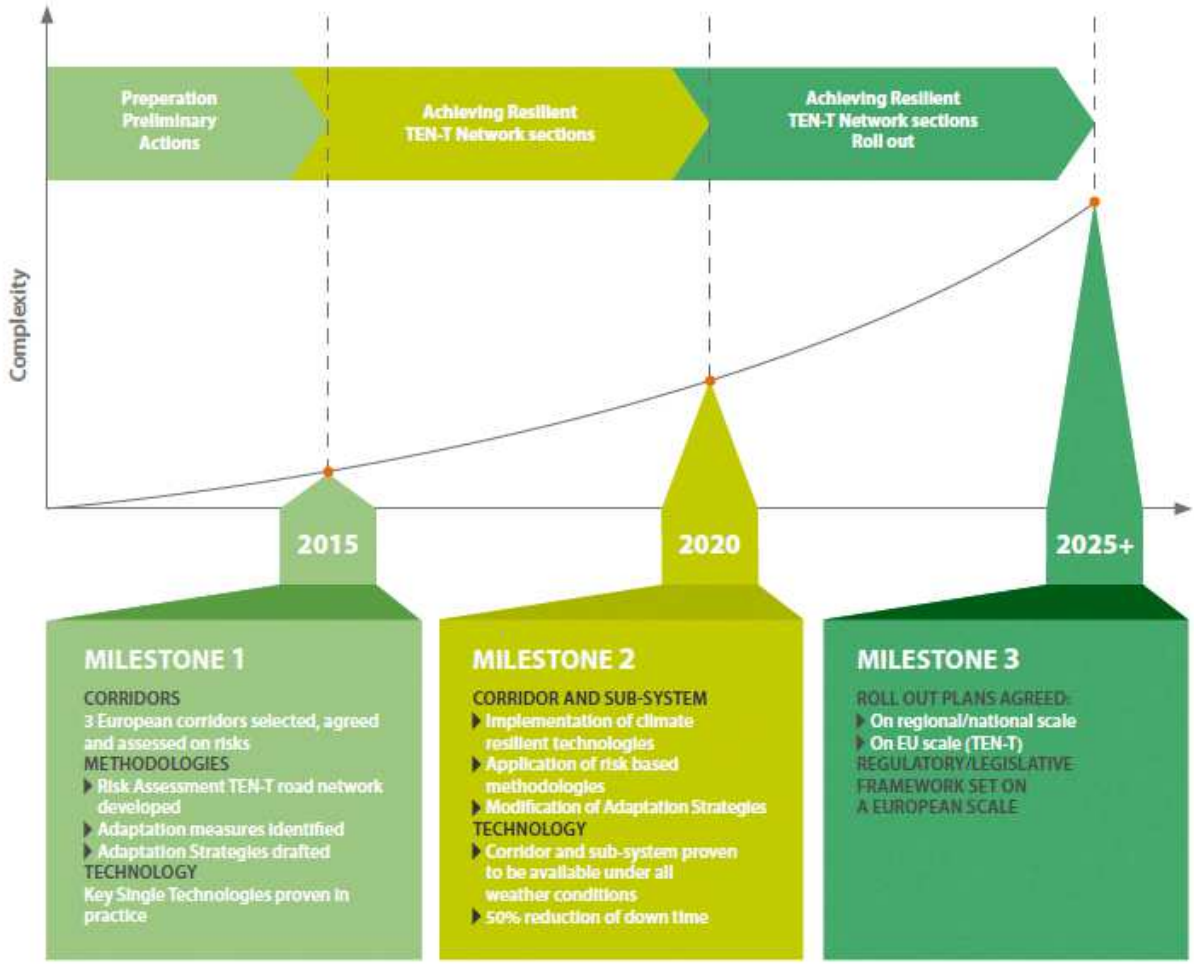


Figure 5 Outline Milestones for Climate Change Resilient Transport

In delivering the Forever Open Road Programme, co-operation will be sought with a number of 'sister' National Programmes with shared aims and goals. The sister programmes that are already under development are named below:

- Route 5ème Génération – R5G (The 5th Generation of Roads). France
- Strasse im 21. Jahrhundert (Road in the 21st Century, R21C). Germany
- Coastal Highway Route E39 – Norway
- Exploratory Advanced Research Program (EAR) – USA

3. Regulatory and policy framework

PANOPTIS project lies on the intersection of several European policies and initiatives spanning across different domains. This chapter provides a deep analysis of EU and National regulations, strategies, guidelines, standards and good practices that shall be considered for the development of PANOPTIS integrated system.

3.1 Risk Management

3.1.1 EU Policies contributing to Disaster Risk Management

The table below lists some EU policies contributing to Disaster Risk Management. It is part of the Commission Staff Working Document SDW(2014)133[18], accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *The post 2015 Hyogo Framework for Action: Managing risks to achieve resilience*[19].

The table only includes the policies affecting somehow the implementation of the PANOPTIS system. Some of them are particularly important for the project approach, and therefore they have been addressed in detail in the next sections.

Table 5 EU Policies contributing to Disaster Risk Management concerning PANOPTIS.

Policy Area	EU strategies, legislation or programmes	Relevance for disaster risk management
Civil protection	Decision 1313/2013 on a Union Civil Protection Mechanism	Strengthens the cooperation between the Union and the Member States and facilitates coordination in the field of civil protection in order to improve the effectiveness of systems for preventing, preparing for and responding to natural and man-made disasters, including through risk assessments, improved risk management planning, peer reviews and assessment of risk management capabilities.
	COM(2009) 82 Communication on a 'Community approach to the prevention of natural and manmade disasters'	Aims at (1) improving the knowledge base on disasters, their impacts and their prevention, (2) linking the diversity of players that should be involved in disaster prevention, (3) spreading and stimulating the uptake of good practice, (4) making existing financial and legislative instruments perform better for disaster prevention.
Climate Change	COM (2013) 216 An EU strategy on adaptation to climate change (together with accompanying documents, including Staff Working Documents and the Green Paper on insurance of natural and manmade disasters – see below)	Aims to contribute to a more climate-resilient Europe through adaptation actions at national, regional and local level developed in synergy and full coordination with disaster risk management policies
Environment	Decision 1386/2013 on a General Union Environment Action Programme to 2020: "Living well, within the limits of our planet" (7th Environmental Action Programme to 2020)	Provides an overarching framework for environment policy to 2020, identifying nine priority objectives under which systemic risks to environment and human health are also addressed. The 7th Environment Action Programme notes that dedicated action should be taken to ensure that the Union is adequately prepared to face the pressures and changes resulting from climate change, and to strengthen its environmental, economic and societal resilience. Since many sectors are and will be increasingly subject to the impact of climate change, adaptation and disaster risk management considerations need to be further integrated into Union policies.

Policy Area	EU strategies, legislation or programmes	Relevance for disaster risk management
	Directive 2007/60/EC on the assessment and management of flood risks ('Floods Directive')	Aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity through specific actions undertaken by Member States, including flood risk assessment and risk management plans
	DIRECTIVE 2012/18/EU on the control of major accident hazards involving dangerous substances (Seveso III Directive, amending and subsequently repealing the Seveso II Directive 96/82/EC on the control of major-accident hazards involving dangerous substances)	Establishes a framework for the prevention of major accidents which involve dangerous substances, and the limitation of their consequences for human health and the environment through risk assessment, prevention and management actions. Rules apply to establishments and competent authorities and focus on risk assessment, safety management, land-use planning, information, inspections, and mitigation actions.
	COM(2012) 628 Proposal to amend Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment	Aims to improve the quality of the environmental impact assessment procedure for projects likely to have significant effects on the environment, including through consideration of new topics such as risk prevention and resilience, climate change and biodiversity.
	Directive 2007/2/EC establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)	Improves the provision of information and good quality data across EU Member States.
Cohesion policy	Regulation (EU) No 1303/2013 laying down common provisions on the EU Structural and Investments Funds Council Regulation (EC) No 1300/2013 on the Cohesion Fund Regulation (EC) No 1301/2013 on the European Regional Development Fund	Supports Member States through all five European Structural and Investment Funds to define priorities of investments, including on climate change adaptation, risk prevention and management, and ensures that disaster resilience is a horizontal principle for sustainable development

Policy Area	EU strategies, legislation or programmes	Relevance for disaster risk management
Solidarity Fund	COM(2013) 522 Proposal to amend Council Regulation (EC) 2012/2002 establishing the European Union Solidarity Fund	Aims to improve the functioning of the existing Solidarity Fund instrument by making it quicker to respond to disasters, simpler to use, and encouraging more effective disaster prevention action by affected countries.
Research	Council Decision establishing the Specific Programme Implementing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020)	Supports specific research and innovation activities related for example to the societal challenges part of H2020: challenge 7 –Secure societies- through the topic increasing Europe's resilience to crises and disasters; or challenge 5- Climate action, environment, resource efficiency, through the topic Fighting and adapting to climate change or the topic protecting the environment
Industry and Infrastructure	SWD(2013) 318 New approach to the European Programme for Critical Infrastructure Protection Making European Critical Infrastructures more secure	Sets new approach to ensure a high degree of protection of EU critical infrastructures and increase their resilience against all threats and hazards.
	COM (2011)0650 Proposal for a Regulation on Union guidelines for the development of the trans- European transport network	Aim to create a real trans-European and transport networks that should also ensure that the transport and energy projects to be developed are disaster and climate resilient.
	Directive on Road Infrastructure Safety Management (2008/96/EC)	Aims to improve the road infrastructure management that can help to reduce the number of people killed or injured in road accidents
	Directive on River Information Services (2005/44/EC)	Information provided within River Information Services is also important with regard to Disaster Risk Reduction DRR and adaptation to climate change (e.g. fairway information, navigation support, transport logistic)
	COM(2012) Strategy for the sustainable competitiveness of the construction sector and its enterprises	Aims to ensure a sustainable construction sector in Europe, recognising also the need to for long term investments to ensure that buildings are disaster resilient.
	Regulation 1285/2013/EU on the implementation and exploitation of European satellite navigation systems	Sets the provisions for the implementation of the Galileo and EGNOS systems that provide operational emergency management services.

Policy Area	EU strategies, legislation or programmes	Relevance for disaster risk management
	COM (2013)3012 Proposal for a Regulation establishing the Copernicus Programme and repealing Regulation (EU) No 911/2010 Regulation (EU) No 911/2010 establishing the European earth monitoring programme (GMES) and the rules for the implementation of its initial operations	Aims to ensure an autonomous Union capacity for space borne observations and provide operational services in the field of environment, civil protection and security. Provides an emergency management service of information for emergency response in relation to different types of disasters, including meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters, as well as the prevention, preparedness, response and recovery activities.
	European Investment Bank's Environmental and Social Principles and Standards (2009) and Statement on Climate Action (2013)	Outlines the standards that the Bank requires of the projects that it finances, and the responsibilities of the various parties that encourages promoters to identify and manage climate change risks, including through risk management approaches to increase the resilience of assets, communities and ecosystems related to EIB projects.
Security and Conflict prevention	COM(2010) 673 EU Internal Security Strategy	Puts forward a shared agenda to deliver responses to the security challenges through inter alia increasing Union's resilience to crises and disasters
	JOIN (2012) 039 Joint Proposal for a Council Decision on the arrangements for the implementation by the Union of the Solidarity clause	Sets the arrangements for the application of the Solidarity Clause where Member States act jointly in a spirit of solidarity if a Member State is the object of a terrorist attack or the victim of a natural or man-made disaster whether on land, sea or in the air. This includes also carrying our regular threat and risk assessments.
	JOIN(2013) 1 Cyber security Strategy of the European Union COM(2013) 48 Proposal for a Directive concerning measures to ensure a high common level of network and information security across the Union	Promotes cyber resilience in the EU through inter alia coordinated prevention, detection, mitigation and response mechanisms, enabling information sharing and mutual assistance.

3.1.2 EU Civil Protection Mechanism (UCPM)

In 2001, the EU Civil Protection Mechanism was established, fostering cooperation among national civil protection authorities across Europe. The Mechanism currently includes all 28 EU Member States in addition to Iceland, Montenegro, Norway, Serbia, the former Yugoslav Republic of Macedonia and Turkey.

The Mechanism was set up to enable coordinated assistance from the participating states to victims of natural and man-made disasters in Europe and elsewhere. The legal basis of the UCPM is the Decision of the European Parliament and of the Council on a Union Civil Protection Mechanism -1313/2013/EU[20].

The operational hub of the Mechanism is the Emergency Response Coordination Centre (ERCC) which monitors emergencies around the globe around the clock, and coordinates the response of the participating countries in case of a crisis. In 2016 alone, the ERCC was engaged in 37 operations, including activations of the UCPM for assistance requests in the face of forest fires, flash floods and the European refugee crisis.

Article 5(1).c of the UCPM decision (Decision No 1313/2013/EU)[20] tasks the European Commission to produce an overview of natural and man-made risks the EU may face. Among its main prevention priorities, the Commission shall improve the knowledge base on disaster risks and facilitate the sharing of knowledge", "best practices and information", "support and promote Member States' risk assessment and mapping activity" and "establish and regularly update a cross-sectoral overview and map of natural and man-made disaster risks the Union may face".

3.1.3 Overview of Natural and Man-made Disaster Risks the European Union may face[21].

In the context of the Union Civil Protection Mechanism (UCPM), the European Commission has established a cross-sectoral overview of natural and man-made disaster risks the Union may face in the staff working document SWD(2017) 176[21] The Overview is developed using the results of National Risk Assessments (NRAs)[v] of the main risks of natural and man-made disasters across the EU 28 Member States and the six non-EU countries participating in the UCPM (Iceland, Norway, Serbia, Montenegro, former Yugoslav Republic of Macedonia, and Turkey).

NRAs identify and assess the natural and man-made disaster risks which would, if faced, require a response at a national or supra-national level. Disaster risk types range from meteorological (flooding, extreme weather), climatological (forest fire, drought), geo physical (earthquake, landslide, volcano) and biological (pandemic, epizootic, animal and plant diseases) natural disaster risks, to non-malicious man-made disaster risks of technological origin (industrial accident, radiological accident, critical

[v] Based on Article 6 of the UCPM decision, Participating States submitted summaries of NRAs by 22 December 2015, and will do so every three years thereafter.

infrastructure disruption), and malicious man-made disaster risks and security threats (cybercrime, terrorism) closely associated with the European Agenda on Security[22].

Based on a comprehensive picture of disaster risks in a country, NRAs contribute to the establishing the risk-informed basis on which national disaster management is carried out. They inform capability assessments required for preparedness and response planning, and contribute to an improved recovery and reconstruction. Risk assessments also play an important risk reduction and preventive role by improving understanding of risks and contributing to the planning of preventive measures and the prioritisation of risk-informed investments.

Hazards identified for analysis in NRAs can have origins beyond national borders, due to the nature of the event. The cross border dimension of risks is usually underlined across NRAs, and can serve as a basis for further work to improve understanding and preparedness planning of risks on a regional level

Below, the risk fiche of the main disaster risks concerning the PANOPTIS project is provided.

- ***Flooding Risk***[21]

Flooding affects more people worldwide than any other hazard. It is the main risk faced by European emergency management authorities. While flood risks in some areas of Europe can be considered of limited significance, (in areas of low population density, low economic or ecological value) many areas are prone to one or more flood type. The most common source of reported historical flood events is by far fluvial (66% of events) followed by pluvial (20%) and sea water (16%)[23].

In terms of economic impact, a number of recent major flood events resulted in important estimated economic losses across Europe, for which the Solidarity Fund was activated; examples include: EUR 400 million in Greece (Central and Evros regions) in 2015; over EUR 1.5 billion in Croatia, Serbia and Romania in 2014; EUR 2.2 billion in Italy in the same year; EUR 9.5 billion in Germany, Austria, Hungary and the Czech Republic in 2013; EUR 4.6 billion in the United Kingdom in 2007. Overall, the EU Solidarity Fund has mobilised over EUR 1.9 billion in financial assistance in response to flood events since 2002[24].

With regard to the policy context, the Flood Directive 2007/60/EC[25] was adopted in 2007. Its main provisions include the requirement to assess if all river basin districts (or other unit of management including coastal areas) are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures (flood management plans) to reduce this flood risk. Article 4 of the Directive requires Member States to undertake a Preliminary Flood Risk Assessment (PFRA) for each River Basin District, Unit of Management, or the portion of an international River Basin District or Unit of Management lying within their territory (a revision of the PFRA reports are to be submitted to the Commission by the end of 2018).

Table 6 Flooding risk in National Risk Assessments (DG ECHO)

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[vi]	Climate change	Cross border risk	Cascading effects
Austria	National scale flood	Medium Likelihood/ High Impact			
Belgium	River basin flood	Top 10 risks	X		
Bulgaria	River basin flood			Danube river basin	
Croatia	Spill of inland water bodies– Danube basin	Very high / High risk	X	Danube river basin	Critical Infrastructure
Cyprus	Short-term flash flood		X		Transport/ Communication /energy/ health
Czech Republic	Flood/ Flash flood				
Denmark	Storm surge	Critical risk	X		Result of severe weather
Estonia	Flood in populated area	High Risk			
Finland	Rapid urban flooding	3/5 L. / 2.5/5 I.			
France	All slow & sudden onset events				
Germany	Winter/ summer flood			River basin authorities / bilateral cooperation	
Greece	Fluvial/flash flood				Hazardous material release
Hungary	Fluvial flood	Highest priority risks	X	Danube river basin	Critical Infrastructure
Iceland	Glacial outburst/ River flood	High risk	X		Infrastructure
Ireland	Fluvial flood	Likely / High I.			Result of severe weather
Italy	Fluvial flood				Infrastructure
Latvia	Fluvial/coastal flood	Significant risk			Hydro-technical infrastructure
Lithuania	Fluvial/coastal flood	Acceptable to High risk		Neighbouring countries	Power supply / transport
Malta	Storm water/ coastal flood/ tsunami	Highly likely / Minor I.	X		Fishing / tourism
Netherlands	River overflow + dike breach	Somewhat likely / Serious I.		Neighbouring countries	Dike failure
Norway	Major flood (1/500 years) in populated area	Moderate risk	X		Landslide /flood defence breach
Poland	Pluvial/snowmelt/ storm surge/ hydro technical failure	Moderate risk			
Portugal	Fluvial/coastal flood	High risk	X		Transport
Romania	Fluvial/coastal flood	High risk	X		Danube river basin /Black sea
Serbia	X				
Slovakia	Pluvial/Flash				
Slovenia	Pluvial/Flash	Very high risk			

[vi] L: Likelihood; I: Impact

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[vi]	Climate change	Cross border risk	Cascading effects
Spain	Fluvial/coastal				Infrastructure
Sweden	Fluvial/pluvial				
United Kingdom	Coastal/inland	1/200–1/20 L. 4/5 (coastal) 3/5 (inland) I.	X		Infrastructure

L: Likelihood; I: Impact

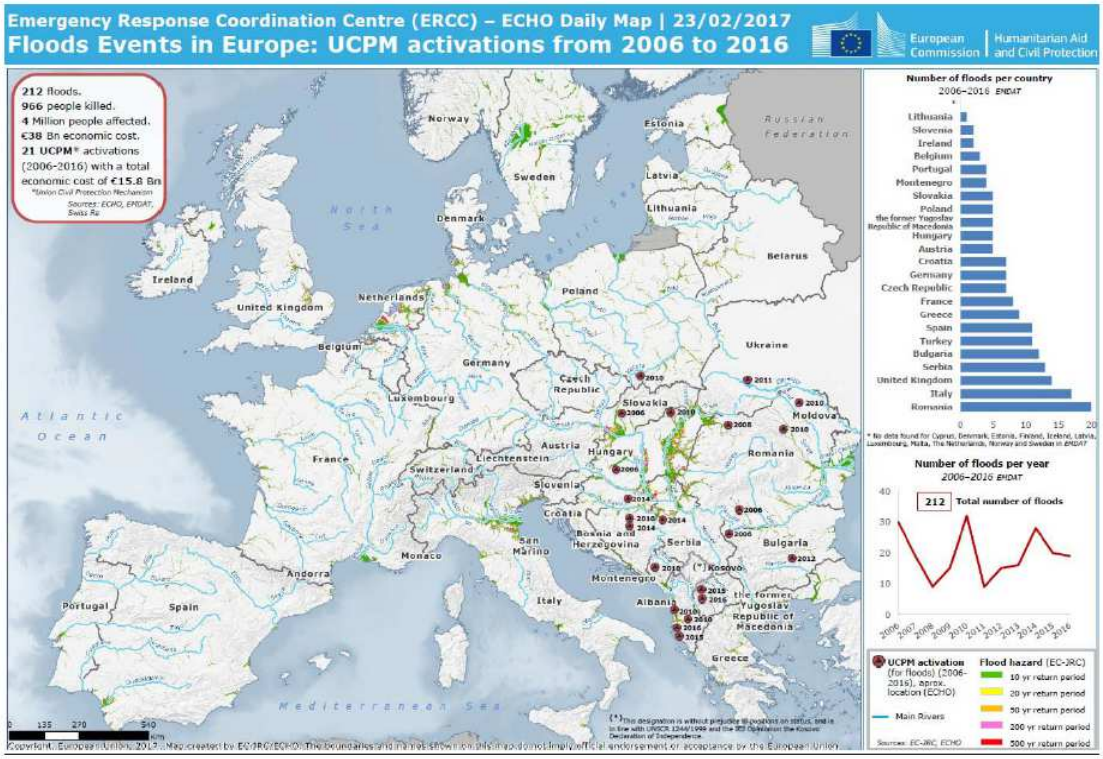


Figure 6. Mapping of flood events in Europe. UCPM activations from 2006 to 2016. DG ECHO/JRC

European research and capacity-building projects looking into this topic are among others: FLOODsite (Integrated Flood Risk Analysis and Management Methodologies), http://www.floodsite.net/; CORFU (Collaborative research on flood resilience in urban areas), http://www.corfu-fp7.eu/; IMPRINTS (Improving preparedness and risk management for flash floods and debris flow events), http://www.imprints-fp7.eu/en/projectes; STARFLOOD (Strengthening and redesigning European flood risk practices towards appropriate and resilient flood risk governance arrangements), http://www.starflood.eu/; HAREN (Hazard Assessment based on Rainfall European Nowcasts); FLOOD CBA (Knowledge Platform for Assessing the Costs and Benefits of Flood Prevention Measures); ACHELOUS (Action of Contrast to Hydraulic Emergency in Local Urban Site); ENHANCE (Partnership for Risk Reduction), http://enhanceproject.eu/.

- ***Extreme weather***[21]

Meteorological phenomena or severe weather events that are disruptive and necessitate the intervention of emergency services and civil protection and/or lead to other natural disasters (such as flooding or drought) are considered a major risk by large number of national authorities in charge of emergency management.

Extreme weather events are estimated to have caused the death of over 700 people and be the most costly of all natural hazards in Europe in terms of economic losses, between 1998 and 2009. Extreme weather is also an important cause of disruptions of critical infrastructure and can cause accidents at hazardous installations. The environmental impacts of storms are also identified as causing "noticeable damage" to forests in Europe in the past 60 years and storms are responsible for over 50% of all primary abiotic and biotic damage by volume from catastrophic events to forests in Europe[26]. France's risk assessment underlines that, between 2001 and 2015, storms represented the most costly natural disasters on its territory (39% of all incurred costs). The heat wave and drought event of 2003 in Europe affected over 100 million people across a third of the European territory. Its cost was estimated to at least EUR 8.7 billion. In terms of economic impact, EU Solidarity Fund mobilised over EUR 460 million since 2002 to address the impacts of extreme weather events in the EU[27].

Heavy rainfall and snowfall also have both an economic and social impact on a country and/or region. In the case of severe snow event affecting large areas, i.e. a number of countries or regions or an entire part of the country, transport services are usually severely affected (restrictions/disruptions of train operations; road traffic safety issues such as increased risk of collision; risk of weather-related delays in all modes of services) and healthcare services are disrupted (increased demand and reduced ability to provide services), in addition to other economic and social impacts (Access to work, schools, damage to physical assets, etc.).

Risks associated with extreme weather may increase exposure to other forms of natural hazards, such as landslides. Reducing the risks of landslides by improving land management practices is therefore important to reduce the vulnerability of exposed areas to other forms of cascading risks.

While no clear trend of meteorological events has been identified, related losses have increased in recent years due to increased exposure. Current projections of increased extreme events resulting from climate change indicate that the risk of meteorological hazards in Europe will increase in the future. As a result, ecosystems and communities may be more exposed to increased intensity and frequency of severe weather events, particularly in the coastal zones: sea level rise (in combination with storm surges) could increase the risk of flooding, coastal erosion and salt water intrusion into groundwater resources and rivers, deltas and estuaries in these areas.

Table 7 Extreme weather risk in National Risk Assessments (DG ECHO)

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact) [vii]	Climate change	Cross border risk	Cascading effects
Austria	Winter storm/heatwave/ Mesoscale convective system	High-very high / Low & high (heatwave)			
Belgium	Extreme Temperature	Top 10 risks			
Bulgaria	Extreme temperature/ drought/storm/heavy snow/wind		X		Transport/ energy infrastructure
Croatia	Extreme temperature-City of Zagreb / Snow & ice – Croatian mountainous area / Drought – Osijek-Baranja County	Extreme temp: Moderate risk Snow &ice: Low /High Drought: Low / Moderate	X	X	Infrastructure
Czech Republic	Drought/extreme temperature/heavy rain/extreme wind				
Denmark	Storm/hurricane/heavy rain/cloudburst	Storm/hurricane: critical risk Rain/cloudburst: very serious risk	X	North sea region	Energy Infrastructure
Estonia	Severe storm/extreme temperature	Storm: High Extreme T°: Low			
Finland	Winter-/ Thunder-storm	W: 4/5 / 3.5/5 T: 2/5 / 4/5	X		Infrastructure + health
France	Storm/cyclone/snow/heavy rain/extreme temperature				
Germany	Storm/extreme temperature				
Hungary	Storm/extreme temperature/ drought	Highest priority risks	X	Carpathia n region	Infrastructure
Iceland	Extreme events		X		Infrastructure
Ireland	Storm/extreme temperature/heavy snow/drought				Agriculture/ energy/ transport
Latvia	Storm	High risk			
Lithuania	Storm/hurricane/snowfall/ drought	Drought: very high risk Other: high risk	X	Drought: regional	Electricity Infrastructure
Luxemburg	Storm/heavy rainfall/extreme (high) temperature	Medium L. / Serious I.			
Malta	Hurricane/extreme temperature/drought	Drought: Likely/ Moderate Weather: Highly likely/ Minor	X		Infrastructure /tourism
Netherlands	Very severe storm / Severe snow	Likely/ substantial serious			
Norway	Inland storm/ Long-term power rationing	Storm: High /Medium Rationing: Moderate/ large	X		Energy infrastructure/ Storm surge
Poland	Heavy rain/extreme temperature/wind		X		Natural hazards
Portugal	Snow/extreme temperature	High risk	X		
Serbia	Storm/hail/snow & ice/drought				
Slovakia	Storm/extreme temperature/heavy rain/drought				Infrastructure
Slovenia	Drought/sleet	Drought: Medium risk / Sleet: High risk			
Sweden	Storm/ heat-wave	Heat-wave: serious human/economic/ envi. impact			

[vii] L: Likelihood; I: Impact

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact) [vii]	Climate change	Cross border risk	Cascading effects
United Kingdom	Storm/gale/ extreme temperature/heavy snow/drought	1/200-1/20 (drought) & 1/20-1/2 3/5 (T°) & 4/5	X		Infrastructure

L: Likelihood; I: Impact

European research and capacity-building projects in this topic are, among others, MICORE (morphological impacts and coastal risks induced by extreme storm events), http://www.micore.eu/; PEARL (Preparing for Extreme and Rare events in coastal regions), http://www.pearl-fp7.eu; RISC-KIT (Resilience-Increasing Strategies for Coasts – toolKIT), http://www.risckit.eu; RISES-AM (Responses to coastal climate change: Innovative strategies for high end scenarios Adaptation and Mitigation), http://risesam.eu/; ANYWHERE (Enhancing Emergency Management and Response to Extreme Weather and Climate Events), http://anywhereh2020.eu/; I-REACT (Improving Resilience to Emergencies through Advanced Cyber Technologies), http://www.i-react.eu/.

- ***Earthquake***[21]

Many countries in the South-Eastern part of Europe are particularly exposed to earthquake hazards, which is consistent with the main fault lines in Europe located where the Eurasian plate meets the African plate and runs through the Mediterranean Sea (more than 90% of earthquakes are caused at plate boundaries).

While the frequency and magnitude of earthquakes at a specific location cannot be predicted with accuracy, risk management in earthquake-prone areas across Europe can be informed using scientific modelling (e.g. fault rupture models, vulnerability and loss models for buildings, lifelines and critical infrastructure, the Global Earthquake Model), early warning and impact assessment tools. Effective preparedness, appropriate response capacities and adequate resilience-building measures reducing the risk of these disasters are essential. Preventive measures such as seismic proofing of infrastructure through the application of building codes (EN Eurocodes), and zonation for land use planning can considerably reduce the severity of human, structural and economic impacts of earthquakes.

The impacts of earthquakes can vary from highly localised events to having dramatic impacts on communities, infrastructure, the economy and the environment, across large regions. Occurrence of a major seismic event in a built-up urban area can have a particularly severe impact, resulting in the complete disruption of economic and social functions in the community.

In terms of economic impact, a number of recent major earthquake events resulted in important estimated economic losses across Europe, for which the Solidarity Fund was activated; examples include: in Italy[viii], a series of earthquakes in 2012 resulted in EUR

[viii] No official figures are available to quantify the impacts of the 2016 earthquakes in Central Italy; Munich Re estimates physical damage around €10 billion; see: https://www.munichre.com/topicsonline/en/2017/topics-geo/earthquake-italy

13.2 billion in damages, the Abruzzo earthquake of 2009 resulted in EUR 10.2 billion in damages, and the impacts of the Molise/Apulia region earthquake in 2003 is estimated at EUR 1.5 billion; in the Lorca region of Spain in 2011, costs amounted to EUR 842 million in damages; and in Greece, the earthquake of Kefalonia in 2014 resulted in EUR 147 million in damages, and most recently in Lefkada in 2016 resulting in EUR 66 million in damages. The EU Solidarity Fund mobilised over EUR 1.2 billion in financial assistance to respond to earthquakes that have affected EU countries since 2002[27].

Earthquakes can trigger secondary effects (landslides, damage to vital infrastructure, liquefaction, tsunamis, debris avalanche) and affect severely people, the economy and the built environment. For instance, potential disastrous secondary damage caused by earthquakes, which can also result in Natech (Natural Hazard Triggering Technological Disasters) events such as the release of hazardous materials and the destruction of vital transport and technical infrastructure, residential buildings, industrial buildings and facilities.

Regarding the policy context, Provisions of the Eurocode 8[28] contribute to reducing the vulnerability of buildings by ensuring that, in the event of earthquakes, lives are protected, damage is limited and civil protection structures remain operational. Exposure of built infrastructure and the potential impacts on the levels of performance of vital services requires particular attention to the location and structural characteristics of buildings, the applicable zonation and building codes, and the level of compliance with the codes.

Table 8 Earthquake risk in National Risk Assessments (DG ECHO)

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[ix]	Climate change	Cross border risk	Cascading effects
Austria	Earthquake Western Austria	Low Likelihood High Impact			
Bulgaria	High degree earthquake	Important infrastructure / building damage		Seismic sources may originate in neighbouring countries (Danube region)	Infrastructure/ flooding/landslide/ epidemic/ chemical& radioactive release
Croatia	Earthquake city of Zagreb	Small L. Catastrophic I.			Composite risk scenario: flooding
Cyprus	1. Localised event 2. Worst case scenario	Likelihood: 1. 10% in 50years; 2. 2% in 50years Severe structural / human impact			
France	X	Low to medium seismicity level. High exposure of Caribbean territories			Infrastructure disruption/ Industrial accident
Germany	X				
Greece	X				
Hungary	1. Magnitude above 6 2. Magnitude	1. Possible L. / Very serious I. 2. Possible L. /			

[ix] L: Likelihood; I: Impact

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[ix]	Climate change	Cross border risk	Cascading effects
	5-6[x]	Substantial I.			
Iceland	X				Volcanic event
Italy	X				
Malta	X	Unlikely / Significant I.			Tsunami/ Landslide/ Hazardous material release
Norway	Earthquake in a city (6.5 magnitude[xi])	Low L. Very large I.			Landslide/Infrastructure damage
Portugal	Event in Algarve region (1755 event)	High risk: Low L. / Critical I.			
Romania	Worst case scenario event	Very high risk: Conditionally L. / Very high I.		Impacts abroad	
Serbia	X				
Slovakia	X	Average level of seismicity			
Slovenia	Intensity of VIIVIII on EMS[xii] scale	High risk: Low L./ Very high I.			
Spain		Low L./ Potentially catastrophic I.			
Sweden	X				Landslide/ Mine collapse

Relevant research and capacity-building projects in this topic are, among others: Syner-G (Systemic Seismic Vulnerability and Risk Analysis for buildings, lifeline networks and infrastructure's Safety Gain), http://www.vce.at/SYNER-G/; REAKT (Strategies and tools for Real Time Earthquake Risk Reduction), http://www.reaktproject.eu/; NERA (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation), http://www.nera-eu.org/; SHARE (Seismic Hazard Assessment in Europe), http://www.share-eu.org/; STREST (Harmonised approach to stress tests for critical infrastructures against natural hazards), http://www.strest-eu.org.

- ***Critical infrastructure disruption***[21]

European Critical Infrastructure (ECI)[29] is an asset or system which is essential for the maintenance of vital societal functions, health, safety and security, economic and social well-being of people.

Critical infrastructures include, inter alia, energy, nuclear, ICT, transport, water, finance, food, health, space, research and emergency and security services. Interconnected critical infrastructure networks, such as transport (road, rail, fluvial, maritime and air transport); energy (electricity, gas, oil, etc.); digital communications (fixed, mobile); water (supply, waste water treatment, flood protection) and to some

[x] Richter magnitude scale
[xi] Idem
[xii] European Macroseismic Scale

extent finance, bring huge opportunities for society and the economy but also increased risks.

The resilience of critical infrastructures, i.e. their ability to bounce back from shocks, is essential for the provision of many societal functions post-disaster and the efficient response during emergencies. In the case of recent events involving the disruption to critical infrastructures, the European Commission has provided monitoring support to EU Member States emergency services through the Emergency Response Coordination Centre. This was the case of a major train accident in France (2013); a major ship accident off the coast of France (2014); and a major train accident in Italy (2016).

Critical infrastructures are complex interconnected systems that are subject to a wide range of hazards and threats, such as terrorist and other criminal acts, and natural events. Risks of disruption/failure of vital infrastructure are interdependent and can extend well beyond the geographical boundaries and scope of jurisdiction of one Member State. As interdependencies increase, there is growing potential for systemic failures to cascading across networks and affect society at multiple levels. The impacts arising from the disruption to, or complete cessation of, critical infrastructures affect the delivery of essential services, including the provision of energy, water, food, communications, health and emergency response services, and transport. The impacts will depend on the duration of the disruption, the time of year, the resilience of the service, and the response by the authorities, but may involve severe societal effects, economic consequences, and in extreme cases casualties.

Due to increased inter-dependence of essential services, the disruption of one piece of critical infrastructure (e.g. power outtakes) may trigger a domino effect causing disruption in the functioning of other key services. While technological developments have improved the quality and resilience of essential services, increased reliance on and use of services (transport, communication, energy) increase the impact and potential likelihood of loss of critical infrastructure. The interdependency between transport on power and other systems is well documented. Dependencies and interdependencies can certainly increase the impact of loss of critical infrastructure, but the link to the likelihood of such a loss is unclear. In effect, the Commission is encouraging a systems approach of risk assessment methodologies in which critical infrastructures are treated as an interconnected network.

The role played by climate change as a risk driver on extreme natural events may in turn lead to an increased risk of disruption of critical infrastructures. For instance, Malta highlights the potential impacts of climate change on the probability of transport network disruptions. To date, the rise in temperatures and sea levels as well as the increased frequency and intensity of extreme weather events, such as storms, heat waves and flooding, is already having a significant impact on the functioning of transport and energy infrastructure.

The policy framework of critical infrastructure lies in the Directive 2008/114/EC[30]. Given the importance of the Critical Infrastructure regulatory framework for the PANOPTIS development, dealing with transport resilience, the Directive 2008/114/EC has been addressed in an individual chapter (see section 3.2).

Table 9: Critical infrastructure disruption risk in National Risk Assessments (DG ECHO)

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[xiii]	Climate change	Cross border risk	Cascading effects
Austria	Traffic accident	Medium L./ Medium I.			
Belgium	Transport accident with harmful substances / casualties	Medium-low L./ Medium I			Chemical/ radioactive release
Bulgaria	Transport accident				
Cyprus	Energy supply				
Czech Republic	Food & energy supply/ Information infrastructure disruption				
Denmark	Transport accident	Serious-very serious I.	X		Other transport networks
Estonia	Severe maritime accident	Very high risk: High L./ Very serious I.			Widespread environment contamination
	Aircraft accident	Medium risk: Very low L./ Catastrophic I.			
	Rail accident	Medium risk: Very low L./ Serious I.			
	Road accident	High risk: Medium L./ Serious I.			
Finland	Fire in a critical infrastructure	Average L./ 2.5/5 Impact			Strain vital societal service
	Major road traffic accident	High L./ 1/5 Impact			
	Major rail transport accident	Average L./ 2/5 Impact			Chemical release
	accident: runway collision	Low L./ 2/5 Impact		Many foreign passengers/ Foreign airline	Disruption of international airways
	Major maritime accident: collision	High L./ 3/5 Impact		Baltic sea region	Possible water contamination
Germany	Power outage				
Hungary	Waterway accident	Likely/Serious			
	Airway accident	Possible/Serious			
	Railway accident	1.Likely/Substantial 2.Very unlikely/ Catastrophic			
	Road accident	Possible/v. serious			
Iceland	Critical Infrastructure				Tourism
Ireland	Rail/road accident	Unlikely/moderate			
	Air/maritime accident	Unlikely/high		International dimension	Impact on the environment

[xiii] L: Likelihood; I: Impact

National Assessment	Risk type/ Scenario	Relative Risk (likelihood/impact)[xiii]	Climate change	Cross border risk	Cascading effects
Latvia	Significant transport accident (rail, maritime)	Significant risk: Very high L./ Significant I.			
	Significant transport accident (road)	Significant risk: High L./ Significant I.			
	Significant transport accident (aviation)	Significant risk: Very low L./Medium I			
	Electricity grid damage	Medium risk: Medium L/Severe I			
	Damage to gas transport pipeline	Significant risk: Medium L./ Significant I.			
Luxemburg	Energy supply disruption	Low L./ Severe I			National impact
Malta	Major mass casualty incident		X (on transport)		
Netherlands	Flooding and dike breach	Somewhat likely/ Serious I.		Cross-border flooding	
Norway	Oil and gas blowout on a drilling rig	Low L./ Medium I			Marine pollution
	Collision at sea .	Moderate L./ High I			Result of extreme weather/ flooding
	Tunnel fire	Moderate L./ Low I.			
Poland	Electricity / fuel / gas supply disruption	Moderate risk			
Portugal	Transport accident	Moderate-high risk			
	Collapse of tunnels/bridges/ infrastructure	Moderate risk			
	Dam failure	High risk			
Serbia	Transport accident				
Slovakia	Traffic accident / Fire in mine/ Energy supply disruption / Vital societal infrastructure disruption				
Slovenia	Plane crash in populated area	High risk		X	
	Train collision	Low risk			
Sweden	Transport accident				
	Dam failure	Serious human I./ Catastrophic eco & envi I.			
	Disruption to technical infrastructure and supply systems	Limited human I./ Limited-very serious eco&envi I.			
United Kingdom	Major transport accidents	1/2000-1/200 L. 3/5 I.			
	Widespread electricity failure	1/200-1/20 L. 4/5 I.			

European research and capacity-building projects addressing this topic are, among others: STREST (Harmonised approach to stress tests for critical infrastructures against natural hazards),http://www.strest-eu.org; INFRARISK (Novel Indicators for identifying critical infrastructure at risk from natural hazards); WEATHER, assessing the impacts of weather extremes on transport systems and hazards for European regions, www.weather-project.eu; EWENT, assessing the impacts and consequences of extreme

weather events on EU transport systems, http://ewent.vtt.fi/; MOWE – IT, corroborating existing information from previous projects and providing short and long - term policy recommendations on mitigation, http://www.mowe-it.eu; CASCEFF (Modelling of dependencies and cascading effects for emergency management in crisis situations); DORATHE, development of a methodology for risk assessment for enhancing security awareness in air traffic management; ASTROM, assessment of resilience to threats to systems of data and control management of electrical transmission networks; RAIN (Risk Analysis of Infrastructure Networks in Response to Extreme Weather), http://rain-project.eu/; European Commission Geospatial Risk and Resilience Assessment Platform (GRRASP), developed to assess interdependencies among infrastructures, https://ec.europa.eu/jrc/en/grrasp

3.2 The European Programme for Critical Infrastructure Protection

Reducing the vulnerabilities of critical infrastructure and increasing their resilience is one of the major objectives of the EU. An adequate level of protection must be ensured and the detrimental effects of disruptions on the society and citizens must be limited as far as possible.

In 2006, the EC adopted the communication on a European Programme for Critical Infrastructure Protection (EPCIP), to address the challenge of critical infrastructure security (EC, 2006). The EPCIP establishes an overall framework for transparency with regard to critical infrastructure protection and cooperation across national borders. The threats to which the programme aims to respond are not only confined to terrorism, but also include other causes of accidents (e.g. natural disasters, criminal activities, malicious behaviour and technological threats). In other words, although priority is given to terrorism, the programme provides an all-hazards approach to ensure the high degree of protection and resilience of EU infrastructures. Subsequently, the Council of the European Union adopted the Directive 2008/114/EC (EC, 2008), which constitutes a key pillar of EPCIP.

The Directive 2008/114/EC[30] establishes a procedure for identifying and designating European critical infrastructures and a common approach for assessing the need to improve their protection. With respect to national critical infrastructures, the Commission's role is limited to encouraging and supporting Member States to establish their own national programme.

The Directive 2008/114/EC (EC, 2008) has a sectoral scope, applying only to the energy and transport sectors. Based on these sector categories, one can list several subcategories as presented in Table 10. The Directive requires the development of an Operator Security Plan (OSP) procedure, for the identification of critical infrastructure assets as well as the identification of existing/implemented security measures applied

for assets protection. The minimum requirements that should be covered by a European critical infrastructure OSP procedure are:

a. identification of important assets,
b. a risk analysis based on major threat scenarios, vulnerability of each asset and potential impact,
c. identification, selection and prioritization of counter-measures and procedures with a distinction between:
    - Permanent security measures, which identify indispensable security investments and means which are relevant to be employed at all times. This heading includes information concerning general measures such as technical measures (including installation of detection, access control, protection and prevention means), organizational measures (including procedures for alerts and crisis management), control and verification measures, communication, awareness raising and training and security of information systems,
    - Graduated security measures, which can be activated according to varying risk and threats levels.

Table 10 List of European critical infrastructure sectors based on Directive 2008/114/EC (EC, 2008)

Sector	**Subsector**	
Energy	Electricity	Infrastructure and facilities for generation and transmission of electricity in respect of supply electricity
	Oil	Oil production, refining, treatment, storage and transmission by pipelines LNG terminals
	Gas	Gas production, refining, treatment, storage and transmission by pipelines LNG terminals
Transport	Road transport	
	Rail transport	
	Air transport	
	Inland waterway transport	
	Ocean and short-sea shipping and ports	

The 2006 EPCIP communication was reviewed, and following this review the EC adopted a 2013 Staff Working Document SWD (2013) 318[31], on a new approach to the European Programme for Critical Infrastructure Protection. As the 2008 Directive focuses on European Critical Infrastructures in the fields of energy and transport, the revised approach to EPCIP (EC, 2013) broadens the scope of critical infrastructures to include assets and systems essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people. The new approach sets out a revised and more practical implementation of activities under the three main work streams: prevention, preparedness and response.

The 2013 version also aims at building common tools and a common approach in the EU to critical infrastructure protection and resilience, taking better account of interdependencies. It outlines initiatives of the Commission regarding risk assessment methodologies, mainly under the European CIPS Programme[xiv]." In particular, the Commission has developed a Critical Infrastructure Warning Information Network (CIWIN), (explained in chapter 4 of good practices) providing an internet based multi-level system for exchanging critical infrastructure protection ideas, studies and good practices. The CIWIN portal, which has been up and running since mid-January 2013, also serves as a repository for CIP related information. This initiative seeks to raise awareness and contribute to the protection of critical infrastructure in Europe.

A European Reference Network for Critical Infrastructure Protection (ERN-CIP) has also been created by the Commission to "foster the emergence of innovative, qualified, efficient and competitive security solutions, through networking of European experimental capabilities". It aims to link together existing European laboratories and facilities, in order to carry out critical infrastructure-related security experiments and test new technology, such as detection equipment.

3.3 EU Climate Adaptation Strategy

The European Commission adopted the EU Climate Adaptation Strategy on 16 April 2013. The overall aim is to make Europe more climate-resilient: enhance the preparedness and capacity of all governance levels to respond to the impacts of climate change. It is supported in three main objectives:

1. Promoting action by Member States: The Commission encourages all Member States to adopt comprehensive adaptation strategies and will provide guidance and funding to help them build up their adaptation capacities and take action.
2. Promoting better informed decision-making by addressing gaps in knowledge about adaptation and further developing the European Climate Adaptation Platform (Climate-ADAPT)[xv] as the "one-stop shop" for adaptation information in Europe.
3. Promoting adaptation in key vulnerable sectors through agriculture, fisheries and cohesion policy, ensuring that Europe's infrastructure is made more resilient, and encouraging the use of insurance against natural and man-made disasters.

For some EU policy areas, climate "proofing" has already been taken up as a parameter in obligatory cost-benefit analyses during the project development phase, and a number of activities are under way to effectively extend this obligation to other types of critical infrastructure projects. The EU Climate Adaptation Strategy (SWD (2013) 299[32]), acknowledges that climate related hazards will have a defining impact on the

[xiv] The Prevention, Preparedness and Consequence Management of Terrorism and other Security-related Risks (CIPS) programme is designed to protect citizens and critical infrastructures from terrorist attacks and other security incidents. The EU allocated EUR 140 million for the period 2007–13

[xv] Climate-ADAPT Platform can be found at https://climate-adapt.eea.europa.eu/about

status and operational capacity of European critical infrastructures, and society as a whole. More specifically, the following points have been identified:

- asset deterioration and reduced life expectancy,
- increases in Operational Expenditure (OPEX) and the need for additional Capital Expenditure (CAPEX),
- loss of income,
- increased risks of environmental damage and litigation,
- reputation damage,
- changes in market demand for goods and services, and
- increased insurance costs or lack of insurance availability.

To support project managers to make their physical assets more climate resilient, the Commission has published, as part of the EU Adaptation Strategy package, *"Guidelines for project managers: Making vulnerable investment climate resilient".*[33] They include a methodology and step-by-step guidance to systematically assess the climate resilience of infrastructure projects and improve their sustainability and liability in changing climate conditions. The guidelines are intended to complement existing project appraisal and development procedures but not to replace them.

3.3.1 Adapting infrastructure to climate change

"*Adapting infrastructure to climate change*" is a staff working document, SWD(2013)137[34] accompanying the communication from the European Commission COM(2013) 216 "*An EU Strategy on adaptation to climate change*"[35]. This paper presents the contribution of the European Union to climate change adaptation in selected infrastructure sectors. It covers energy and transport infrastructure as well as buildings in the EU, sectors which were given priority for adaptation policy mainstreaming in the 2009 White Paper on Climate Change Adaptation.

Adapting infrastructure to climate change is a fast-growing, global business in which European know-how and experience could open up new economic opportunities. By promoting public and private investment in climate-resilient buildings and in smart, upgraded and fully interconnected transport and energy infrastructure, EU climate action makes an important contribution to delivering growth and jobs in Europe. In line with Europe 2020[xvi], it simultaneously contributes to progress towards more sustainable transport and a secure and clean energy market.

3.3.2 EU policy mainstreaming in Climate Adaptation

Mainstreaming efforts at EU level lies in The *EU White Paper* on adaptation (EC, 2009)[36] setting out a framework to reduce the EU's vulnerability to the impact of climate change. The EU is working with other partner countries in the United Nations

[xvi] Europe 2020 is a 10-year strategy proposed by the European Commission on 3 March 2010 for advancement of the economy of the European Union. It aims at "smart, sustainable, inclusive growth" with greater coordination of national and European policy

Framework Convention on Climate Change (UNFCCC) towards a post-2012 climate agreement.

With regard to mainstreaming efforts at national level, 16 EU Member States have adopted a national adaptation strategy (NAS) so far. Each of the NAS has been developed with sectoral focus. Some NAS set out concrete action plans (Austria, Denmark, Finland, France, Germany, Malta and Spain). Only two of the NAS in place (Belgium and Ireland) consider transboundary issues, i.e. those issues affecting neighbouring countries (linking to EU projects and/or requirements for transposing EU legislation into national law). However, none of the NAS make direct links to macro-regional perspectives and interregional coordination.

Within its competences and building on the 2009 white paper, the European Union is engaged in mainstreaming climate change adaptation in various EU policies and financial instruments including the European Transport Policy, the Connecting Europe Facility or EU cohesion policy. The following section provides an overview of the current EU policy approach and the uptake of climate change adaptation in EU legislation.

- ***The trans-European transport (*TEN-T) Guidelines[37]**

As explained in section 2.2.2, the Trans-European Transport Networks (TEN-T) are a planned set of road, rail, air and water transport networks in the European Union. The proposal for the new TEN-T Guidelines[38] includes climate resilience, in particular under article 41: during infrastructure planning due consideration shall be given to risk assessments and adaptation measures adequately improving the resilience to climate change. Additionally, where appropriate, due consideration should be given to the resilience of infrastructure to natural or man-made disasters.

TEN-T projects, co-financed under the *Connecting Europe Facility (CEF)*, are expected to contribute to promoting the transition to a climate- and disaster-resilient infrastructure. All transport modes are eligible for funding. Co-financing rates may be increased by up to 10 percentage points for actions enhancing climate resilience.[39]

- ***Technical Standards: Eurocodes***

At European level, Eurocodes can be a suitable instrument for addressing climate resilience in different infrastructure sectors. Eurocodes are a set of European Standards (EN) for the structural design of buildings and civil engineering works, produced by the European Committee for Standardisation (CEN) to be used in the European Union. They provide for compliance with the requirements for mechanical strength, stability and safety as basis for design and engineering contract specifications. The Eurocodes embody national experience and research output together with the expertise of CEN Technical Committee 250 (CEN/TC250) and of International Technical and Scientific Organisations and represent a world-class standard for structural design. The Commission has asked CEN to prepare a proposal for how to incorporate climate change and extreme weather events in the Eurocodes. Based on ISO Guide 64, CEN has

developed and adopted CEN Guide 4 "*Guide for the inclusion of environmental aspects in product standards*"[40], which aims to provide a helpful tool for people involved in standardization to take the potential environmental aspects related to their standards into account. Following discussions with the Commission, CEN is currently considering how to amend Guide 4 to take into account climate change in the development and revision of standards.

Furthermore, the Commission is currently in dialogue with the three European standardisation organisations (CEN, CENELEC and ETSI) to prepare a programming and standardisation mandate. Its main objective is to contribute to building and maintaining a more climate resilient infrastructure in three selected sectors (transport, energy and buildings/construction). The scope of the mandate is both to identify and prioritise all standards relevant for climate change adaptation and to revise "priority standards" accordingly. Additionally, if deemed necessary during this exercise, new relevant standards could be developed. The mandate also includes the development of tools (i.e. guidance or other type of documents) that will ensure that adaptation to climate change is taken into account in a systematic way when new European standards are developed.

3.4 EU Internal Security Strategy

In 2010 the European Union (EU) adopted an Internal Security Strategy (ISS)[41]. The 5th Objective was devoted to Increase Europe's resilience to crises and disasters. The cross-sectoral threats posed by natural and man-made crises and disasters necessitate improvements to long-standing crisis and disaster management practices in terms of efficiency and coherence. This should to be achieved through:

- **making full use of the solidarity clause**: a proposal on the application of the solidarity clause is to be adopted;
- **developing an all-hazards approach to threat and risk assessment**: guidelines for disaster management are to be drawn up, national approaches are to be developed, cross-sectoral overviews of possible risks are to be established together with overviews of current threats, an initiative on health security is to be developed, and a risk management policy is to be established;
- **linking the different situation awareness centres**: links between sector-specific early warning and crisis cooperation systems are to be improved, and a proposal for better coordination of classified information between EU institutions and bodies is to be adopted;
- **developing a European Emergency Response Capacity for tackling disasters**: the establishment of a European Emergency Response Capacity is to be proposed.

The EU Internal Security Strategy for the period 2015-2020 (also called "renewed internal security strategy") was defined in Council Conclusions of 16 June 2015. It

constitutes the EU strategy shared by EU institutions and Member States aiming at tackling the security challenges and threats facing the EU until 2020.

3.5 Intelligent transport systems

3.5.1 Directive 2010/40/EU deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport[42]

Intelligent Transport Systems (ITS) can significantly contribute to a cleaner, safer and more efficient transport system. A new legal framework (Directive 2010/40/EU)[42] was adopted on 7 July 2010 to accelerate the deployment of these innovative transport technologies across Europe. This Directive is an important instrument for the coordinated implementation of ITS in Europe. It aims to establish interoperable and seamless ITS services while leaving Member States the freedom to decide which systems to invest in.

The following have been identified as priority areas for the development and use of specifications and standards:

- optimal use of road, traffic and travel data, for example to allow road users plan trips;
- continuity of traffic and freight management ITS services (i.e. services that are uninterrupted when trucks cross borders);
- ITS road safety and security applications (e.g. alerting to risks of reduced visibility or of people, animals and debris on the road);
- linking the vehicle with the transport infrastructure, i.e. equipping vehicles to allow for exchange of data or information.

Within these four priority areas, there are six priority actions which focus on:

- EU-wide multimodal travel information services (for journeys involving different transport modes, e.g. train and ship);
- EU-wide real-time traffic information services;
- how to provide road safety-related traffic information free of charge to users;
- the harmonised availability of an interoperable EU-wide eCall service
- information services for safe and secure parking places for trucks and commercial vehicles;
- reservation services for safe and secure parking places for trucks and commercial vehicles.

With regard to the deployment of ITS applications and services, EU countries must do what is necessary to ensure that the related specifications adopted by the Commission are applied. Individual EU countries keep the right to decide on the deployment of these applications and services in their own territory.

The initiative is supported by five co-operating Directorates-General: DG Mobility and Transport (lead), DG Communications Networks, Content & Technology, DG Research & Innovation, DG Enterprise and Industry and DG Climate Action.

3.5.2 Telematics: deployment of road telematics

Road telematics (RT), which is part of a rapidly growing information society, is to expand as part of a Common Transport Policy.

The Communication COM (97) 223[43] from the Commission published on 20 May 1997 defines a strategy, framework and initial action for the increased use of telematics on the highways of Europe. The communication lists the advantages of RT, which:

- makes driving safer;
- gives logistical support to transport-service providers;
- enables traffic to be managed efficiently;
- offers policy makers an alternative to building new roads by making infrastructure use more efficient;
- has a positive impact on the environment;
- helps to provide new niches for industry and the providers of "added-value" services.

The Commission's RT aims are as follows:

- providing a background for the development of RT services and systems to meet both local and community needs;
- being open to all technologies;
- encouraging the authorities to incorporate RT into projects at the transport-infrastructure planning stage;
- taking advantage of the trans-European network projects and of the corresponding financial support;
- encouraging involvement by the private sector;
- providing stable conditions for the small and medium-sized businesses using RT services;
- guaranteeing that interworking between infrastructures and services possible in order to provide users with the best possible service.

The Communication sets out the division of RT responsibilities among the European Union, the Member States, the regions and local authorities, European standardisation bodies, providers of commercial services, the motor industry, equipment manufacturers, systems designers and suppliers.

The aim pursued by the European Union as regards **driver information**, which is based on the RDS-TMC (Radio Data System / Traffic Message Channel), is to guarantee cross-frontier interworking and make it easier to create a European market for such

products and services. Both technical harmonisation and political coordination are needed for that purpose.

The aim concerning **electronic-payment systems** is likewise to achieve an adequate level of interworking. This requires not only the development of a convergence strategy for all electronic payment systems but also a solution to the problems concerning the classification of vehicles, non-equipped users, and the legal and institutional aspects. Technical harmonisation will have to take account of the multi-lane environment and the introduction of other telematics services using the same technology, such as reservation and payment systems.

Close cooperation between countries and regions will be necessary with regard to the **exchange of transport data and information** management. The Commission will make it easier for the parties concerned (highway authorities, service providers) to provide a common vector for applying data exchange standards on the TERN.

The **man/machine interface** is characterised by two main types of device that alter the driver's task: the display of the information needed to help drivers to take decisions while driving and vehicle-control devices such as self-contained intelligent speed regulators and collision-prevention systems. The Commission advocates the application of codes of good practice to the interface between human beings and the information equipment.

The **architecture of the intelligent transport systems** must enable various concepts and technologies to be used and to incorporate factors such as public transport and integral payment.

These priority activities could be funded, as required, by part of the trans-European network budget or the use of specific programmes such as that on the exchange of data between administrations.

In addition to the priority applications listed above, other activities have been covered by proposals with a view to their subsequent implementation. These are:

- the supply of information and vehicle guidance before and during the journey;
- improvements to the management, monitoring and regulation of both urban and interurban traffic;
- the large-scale application of high-performance telematics to electronic payment and reservations;
- the development of public transport applications, more particularly for ticketing services, vehicle positioning systems, operational support systems covering bus timetabling or maintenance, real-time customer information services (public terminals, electronic guides);

- the introduction on the market of advanced safety and vehicle control systems such as stand-alone speed regulators or the automation of intermittent traffic;
- improving the safety and efficiency of commercial vehicles by monitoring and locating goods consignments electronically and making greater use of electronic recording systems, such as electronic tachometers, smart driving licences and continuous customs clearance.

3.6 Navigation by satellite

Galileo[44] is a flagship programme of the European space policy, together with Egnos, is part of the GNSS (global navigation satellite system) providing a range of positioning, navigation and timing services. This European GNSS is being created through the European GNSS Agency (GSA) headquartered in Prague (Czech Republic). Galileo gives the European Union (EU) an independent technology to compete with the American GPS and Russian GLONASS systems.

3.6.1 Europe's 2 satellite navigation systems moving forward

Regulation (EU) No 1285/2013 of the European Parliament and of the Council of 11 December 2013[45] on the implementation and exploitation of European satellite navigation systems lays down the rules for the European satellite navigation programmes Galileo and EGNOS.

The aim of the EU's satellite navigation policy is to provide the EU with 2 satellite navigation systems, namely Galileo and EGNOS (European geostationary navigation overlay service). Each set of infrastructure consists of satellites and a network of ground stations.

Galileo aims to set up and operate the first global satellite navigation and positioning infrastructure (system providing navigation, time and location data) specifically designed for civilian purposes, which can be used by a variety of public and private actors in Europe and worldwide. The new system is being designed to function independently of other existing systems, such as the United States' global positioning system (GPS) or Russia's Glonass system, or potential systems.

Galileo is to be interoperable with GPS and Glonass. This interoperability will allow manufacturers to develop terminals that work with Galileo, GPS and Glonass.

EGNOS aims to improve the quality of open signals from existing global navigation satellite systems (GNSS) as well as those from the open service offered by the Galileo system when it becomes available. EGNOS offers certain sophisticated safety-critical applications such as for guiding aircraft both vertically and horizontally during landing approaches or navigating ships through narrow channels.

The EU is making around €7 billion of funding available for related activities from 2014 until 2020. The European Commission has overall responsibility for the two programmes and manages the funds.

3.6.2 Satellite navigation applications

The Green Paper of 12 December 2006 on Satellite Navigation Applications COM (2006) 769[46] launched by the Commission, sets-out the various applications which the introduction of the Galileo satellite navigation system should open up. The Green Paper outlines the sectors set to benefit from the introduction of the Galileo system as a result of the large number of applications that it will be possible to develop. The areas of application for satellite navigation include the road transport.

The Road Transport area also covers a wide range of applications, from navigation devices to automatic toll systems, safety applications and pay-per-use insurance. Galileo thus ties in with the *eSafety*[xvii] initiative, which includes a wide range of applications that could make use of accurate vehicle positioning;

Regarding the impact that the development of satellite navigation systems can have on privacy, the Green Paper points out that all the Member States of the European Union are signatories to the European Convention on Human Rights, which guarantees respect for "private and family life, home and correspondence". Directive 2002/58/EC[47] governs the processing of personal data and the protection of privacy in the electronic communications sector.

The public authorities are encouraging the development of satellite navigation technologies. Measures have been taken in a number of areas including support for research and the adoption of the right regulatory framework. The areas of action are:

- research and innovation;
- cooperation between SMEs and the European business networks;
- international cooperation;
- standardisation, certification and liability;
- safeguarding the radio electrical frequency spectrum and promoting the allocation of new frequency bands;
- protecting intellectual property rights;
- adapting legislation to new technologies and innovation.

3.7 Copernicus[xviii]: The European Earth Observation Programme

The Copernicus programme is the European system for monitoring the Earth and is coordinated and managed by the European Commission. The development of the observation infrastructure is performed under the aegis of the European Space Agency

[xvii] eSafety the use of information and communication technology (ICT) for road safety
[xviii] Copernicus can be found at www.copernicus.eu

for the space component and by the European Environment Agency and EU countries for the in situ component.

It consists of a complex set of systems which collect data from multiple sources: earth observation satellites and in situ sensors such as ground stations, airborne sensors, and sea-borne sensors. It processes this data and provides users with reliable and up-to-date information through a set of services related to environmental and security issues.

The services address six thematic areas: land, marine, atmosphere, climate change, emergency management, and security. They support a wide range of applications, including environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection, and tourism.

In the context of PANOPTIS project, three of the six Copernicus Services are of utmost relevance: Emergency Management, and, to some extent, the Security and Climate Change Services.

The Emergency Management Service (EMS)[xix] operates as a tool for emergency response to natural and man-made disasters as well as facilitating the other parts of the disaster management cycle (preparedness, prevention, and recovery) with risk assessment, vulnerability assessment and recovery plans. Hazards mapped by the EMS include: earthquake, volcano, flood, tsunami, landslide, storm, hurricane, cyclone, technological accident, border control and maritime surveillance. The Copernicus EMS consists of two components:

1. a mapping component;
2. an early warning component.

The mapping component of the service (Copernicus EMS - Mapping) has a worldwide coverage and provides the above-mentioned actors (mainly Civil Protection Authorities and Humanitarian Aid Agencies) with maps based on satellite imagery.

The early warning component of the Copernicus EMS consists of three different systems: the European Flood Awareness System (EFAS), the European Forest Fire Information System (EFFIS) and the the European Drought Observatory (EDO), explained in detail in Chapter 4 of good practices.

Regarding the Regulatory framework, the Copernicus is regulated under the Regulation (EU) No 377/2014 of the European Parliament and the Council 3 April 2014 establishing the Copernicus Programme and repealing Regulation (EU) No 911/2010[48]. The Regulation requires Copernicus data and information to be made available on a full, open and free of charge basis, subject to limitations concerning registration, dissemination formats, and access restrictions. The key elements of free, full and open access in terms of the Copernicus data policy are that 1) there are no restrictions on the

[xix] The Copernicus EMS can be found at http://copernicus.eu/main/emergency-management

use (commercial and non-commercial) nor on users (European and non-European); 2) a free of charge version of any dataset is always available on the Copernicus dissemination platform; and 3) data and information are available worldwide without limitation in time. Users shall, however, inform the public of the source of the data and information and notify any modifications made thereto.

3.8 Infrastructure for Spatial Information in the European Community (INSPIRE[49])

The INSPIRE Directive, Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007[50], establishes an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. The Directive entered into force in May 2007.

INSPIRE is based on the infrastructures for spatial information established and operated by the 28 Member States of the European Union. The Directive addresses 34 spatial data themes (see table below) needed for environmental applications, with key components specified through technical implementing rules. This makes INSPIRE a unique example of a legislative "regional" approach.

Table 11 34 spatial data themes of INSPIRE Directive

ANNEX: 1	
Addresses	Administrative units
Cadastral parcels	Coordinate reference systems
Geographical grid systems	Geographical names
Hydrography	Protected sites
Transport networks	
ANNEX: 2	
Elevation	Geology
Land cover	Orthoimagery
ANNEX: 3	
Agricultural and aquaculture facilities	Area management / restriction / regulation zones & reporting units
Atmospheric conditions	Bio-geographical regions
Buildings	Energy Resources
Environmental monitoring Facilities	Habitats and biotopes
Human health and safety	Land use
Meteorological geographical features	Mineral Resources
Natural risk zones	Oceanographic geographical features
Population distribution and demography	Production and industrial facilities
Sea regions	Soil
Species distribution	Statistical units
Utility and governmental services	

To ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context, the Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting). These IRs are adopted as Commission Decisions or Regulations, and are binding in their entirety.

3.9 Drones (unmanned aircraft) regulatory framework

Unmanned aircraft (or "drones") are a fast developing sector of aviation. The term "unmanned aircraft" includes very large aircraft similar in size and complexity to manned aircraft, but also very small consumer electronics aircraft[51].

Research suggests the rapidly-developing drone sector will create more than 150,000 new jobs by 2050 and that in 10 years the industry could account for 10% of the EU's aviation market (about €15 billion a year)[52].

Implementation of drones in road maintenance contracts has a great potential, supporting the maintenance crews with numerous supervisory tasks such as surveillance, inspections, incident control and accident response.

Especially smaller drones are increasingly being used in the Europe Union (EU), but under a fragmented regulatory framework. Although national safety rules apply, the rules differ across the EU and a number of key safeguards are not addressed in a coherent way.

On June 2018, Members of the European Parliament (MEPs) approved an agreement reached between Council and Parliament negotiators in November 2017 on EU-wide principles for drones and drone operators to ensure a common level of safety and give operators and manufacturers the predictability to develop products and services. Until that moment most drones fall under differing national rules, which can hamper market development[53].

Under new rules, drones would need to be designed so that they can be operated without putting people and goods at risk (as risk 0 does not exist, the probability of occurrence should be very low but most importantly the impact should be acceptable). Based on risk related to, for example, the weight of the drone or area of operation, the drone would need additional features, such as automated landing in case the operator loses contact with the drone or collision avoidance systems.

The most blocking directive nowadays (for civilian use in shared airspace) is the compulsory presence of a pilot permanently in visual contact with the drone. While this modus operandi is acceptable for local inspection of infrastructure where safety perimeters can be established, it is a blocking issue for large area monitoring.

To help identify the drone operators if there is an incident, operators of drones would need to be on national registers and their drones marked for identification. This would not apply to operators of the smallest drones.

Based on the key principles, the EU Commission is tasked with developing more detailed EU-wide rules, such as maximum altitude and distance limits for drone flight, and which drone operations and drones would need to be certified based on the risk they pose. The rules would also determine which operators need additional training and to be registered and which drones would need to have additional safety features.

3.9.1 PANOPTIS demo sites

PANOPTIS UAVs will be validated for road applications, as part of the Demonstration work package (WP7) in two selected road premises in Spain and Greece. The regulation applying to each country is outlined below:

- ***Spanish demosite***

In Spain, the civil use of unmanned aircraft is regulated by the Royal Decree 1036/2017, from 15 of December 2017[54]. Main regulations affecting PANOPTIS project are summarised under "Professional use of drones" as described in RD 1036/2017[54] with the following remarks:

- Habilitation as professional pilot
- Altitude limitation: 120 m above highest point in the route. (150 m surrounding)
- Able to flight drones beyond eye contact with observers each 500 m, under authorization.
- Flights in Controlled Traffic Region (CTR) requires special permissions.
- Night flight. only if less than 2 kg
- Beyond eye contact only with drones more than 2 kg.

- ***Greek demosite***

In Greece, the civil use of unmanned aircraft is regulated by the following Presidential Decrees, since September 30, 2016.

- Drones flights regulations: *ΦΕΚ-Β-3152/30.9.2016* [55]
- Drone pilot license regulations *ΦΕΚ Β-4527/30.12.2016*[56]
- Drone flight license fees ΦΕΚ Β-1607/10.5.2017[57]
- IT system for the support of UAV flight regulations[58]

Drone flights are regulated by the Governmental Journal ΦΕΚ/Β/3152/30-9-2016. The following criteria shall be taken into account for the categorization of UASs:

- Maximum take-off mass (MTOM)
- Type of use
- The height above the surface of the land or sea where it is allowed to fly

- The areas (exclusive or not)
- the technical capabilities of each UAS
- the complexity of the UAS flight operating environment

Taking into account the criteria in the previous paragraph, the following categories of UAS are defined:

- The UAS Open Category
- The UAS "Special" Category
- The UAS "Certified" category
- The "Open" category of UASs is divided into three subcategories:
  - ✓ A0: "Miniature Unmanned Aerial Systems" with a maximum take-off mass (MTOM) of less than 1 kg (<1 Kg).
  - ✓ A1: "Very Small Unmanned Aerial Systems" with a maximum take-off mass (MTOM) equal to or more than one kilo (=> 1 Kg) to four kilograms (<4 Kg).
  - ✓ A2: "Small Unmanned Aerial Systems" with a maximum take-off mass (MTOM) equal to or greater than four kilograms (=> 4 kg) and up to twenty-five kg (<25 kg).

The following licenses and certificates are provided for the UAS:

A Broader Operator License is required for:

- Sub Categories A0 & A1 of the "Open" category (professional use only)
- A2 of "Open" (for all uses - amateur & professional),
- the "Special" category and
- the "Certified" category

The Operating License concerns the Special Category.

The Certificate of Airworthiness (Certificate of Airworthiness) concerns self-constructions and UASs of the Certified category.

A Certificate of Registration and Remote Operations Certificate (ROC) are also granted in the Certified category.

Exploitation License UAS is granted to all operators / professionals of the UAS.

- Greek Presidental Act PD77/1998 for overweight/ oversize vehicles.
- According to Greek Traffic Regulations, in order a “special transport” to take place (transport of overweight/oversized vehicles/loads), the issuance by the road operator of a special permit is required. Egnatia Odos SA has developed a Vehicle Permits Management System (VPMS) for this task. With this system Egnatia Odos SA has a fairly good picture of the number and the routes of overweight/oversized vehicles that are using legally the motorway each day.

Main regulations affecting PANOPTIS project are summarised under “Professional use of drones” as described in PD ΦΕΚ Β-2152/20.9.2016[54] with the following remarks:

- All Drones with flight capability >50m must be registered. Registration in HCAA's Data Base requires Greek Tax Registry identification.
- For citizens of EU countries national state registration is accepted. For non EU countries citizens CAA's approval & registration policy will be considered (FAA registration is accepted).
- In order to operate a Drone in Greece there is a general rule permitting drone operation in a distance as shown in the picture below. Flights are prohibited beyond sunset and above persons and infrastructure (at least 50m distance) and all safety measure must be undertaken. All national and EU Data Privacy legislation must be observed.

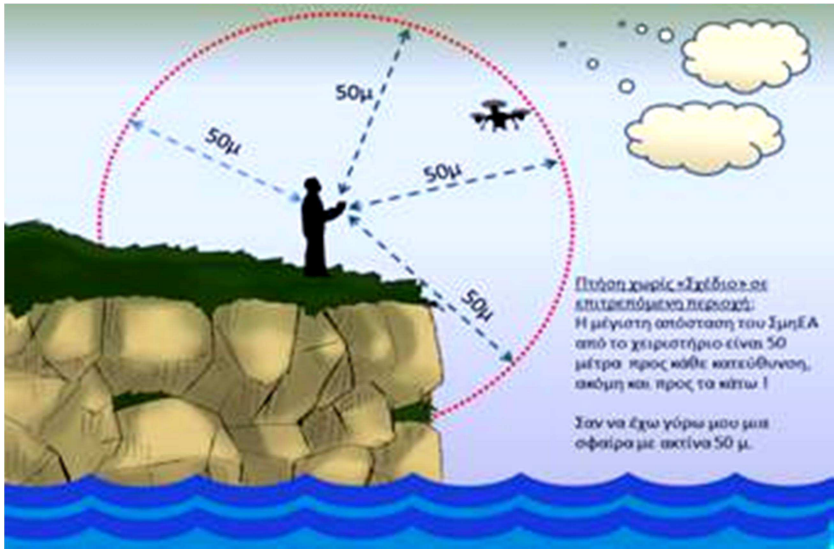


Figure 7 Distance restrictions applying drone operation in Greece.

- Drone flights are permitted in areas (Free Flying Zones) where no restriction applies (Civil Aviation, Military, Security, Archaeological, etc). This information can be retrieved using a new on-line application that can be found in our website: http://dagr.hcaa.gr.

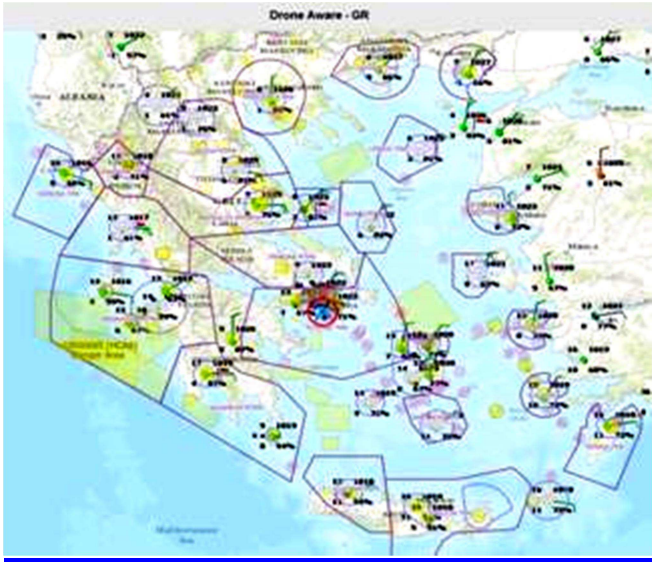


Figure 8 Free-flying zones for drones in Greece

- All other fights must be approved by HCAA. An application form can be filled and send via email.
- In the form it has to be included drone Registration No and if this is N/A it has to be submitted full drone details (S/N, Model, characteristics, etc.). Flying area in WGS84 coordinates must be stated.
- All personal details must be included (Name, ID, Address, etc) and a valid Mobile Number in order HCAA or local authorities (Local ATC units, Police, etc) may contact the user. There is the obligation to inform the local authorities (Police and Municipality Authorities) for flights.
- As far as the flight plan is, in Free Flying Zones, it can be submitted, via email, maximum 3 days prior to your flight and applicant will receive HCAA's response. Liability international insurance is optional for recreational flights but strongly advised for flights beyond 50 m.

4. Good practices analysis

This chapter aims to compile present good practices, solutions and tools that can be used in Roads Infrastructure Management. The focus topics are organised as follows:

1. *Use of data, scientific models and tools to predict, monitor and assess risk events (affecting RI),*
2. *Implementation of Intelligent Transport Systems (ITS) technology in Smart roads,*
3. *Use of vehicle-based mobile mapping and Unmanned Aerial Vehicles (UAV) technology in roads maintenance*
4. *Use of Management systems (MS) and Decision Support System (DSS) in roads management.*

4.1 Data, scientific models & tools of different hazards affecting roads infrastructure

A number of initiatives in place provide monitoring and an inventory of data for different hazards which can affect the Transport Infrastructure, such as multi-hazard early warning systems; climate risk models and risk maps. Some tools can be useful for the PANOPTIS system, and are described below.

- **European Flood Awareness System (EFAS)**

The European Flood Awareness System (EFAS)[59], started in 2002, is the first operational system that monitors and forecasts flood events across Europe. This Early Warning component of the Copernicus Emergency Management Service provides its partners (national/regional authorities, as well as the ERCC) with a wide range of complementary, added value flood early warning information including related risk assessments up to 10 days in advance.

Figure 9 Overview of EFAS flood probability maps several days before the devastating Central European floods in May/June 2010.

- **European Forest Fire Information System (EFFIS)**

EFFIS consists of a modular web geographic information system that provides near real-time and historical information on forest fires and forest fire regimes in the European, Middle Eastern and North African regions. Similarly to EFAS, EFFIS is part of the Early Warning Systems of Copernicus Emergency Management Service

EFFIS includes, starting from the pre-fire state, the following modules:

1. Fire Danger Assessment,
2. Rapid Damage Assessment, which includes (2.1.) Active fire detection (2.2.) Fire severity assessment and (2.3.) Land cover damage assessment
3. Emissions Assessment and Smoke Dispersion,
4. Potential Soil Loss Assessment, and
5. Vegetation Regeneration.

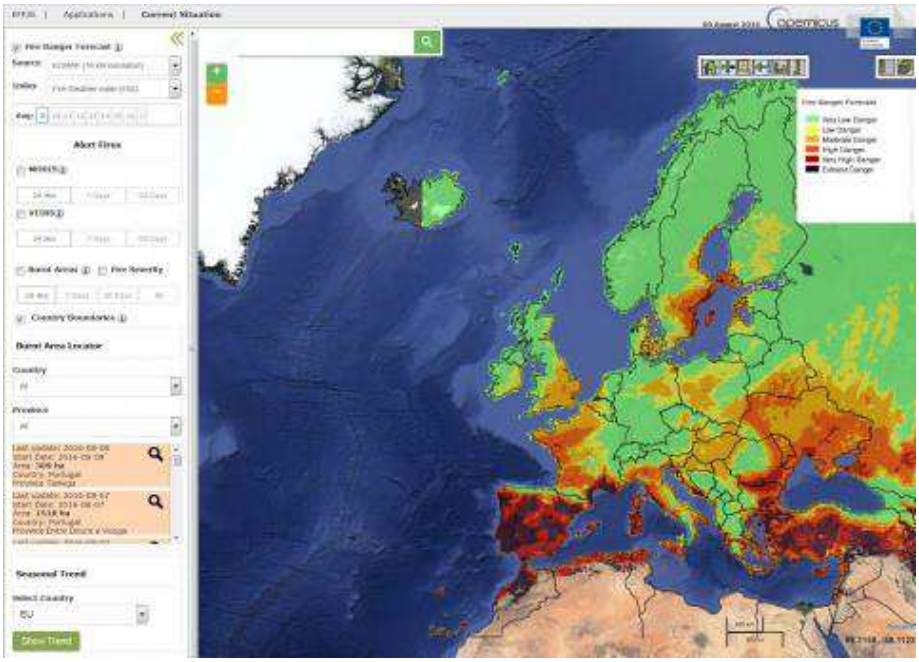


Figure 10 Overview of EFFIS viewer showing near real time information of fire danger.

- **Drought Observatory (DO)**

The Drought Observatory is also a Copernicus Emergency Management Service (EMS). The EMS Drought Observatory (DO) provides drought-relevant information and early warnings for Europe (EDO) and the globe (GDO). Short analytical reports (Drought News) are published in case of imminent droughts. EDO and GDO build on open web services and connect drought data providers and users from global to regional levels.

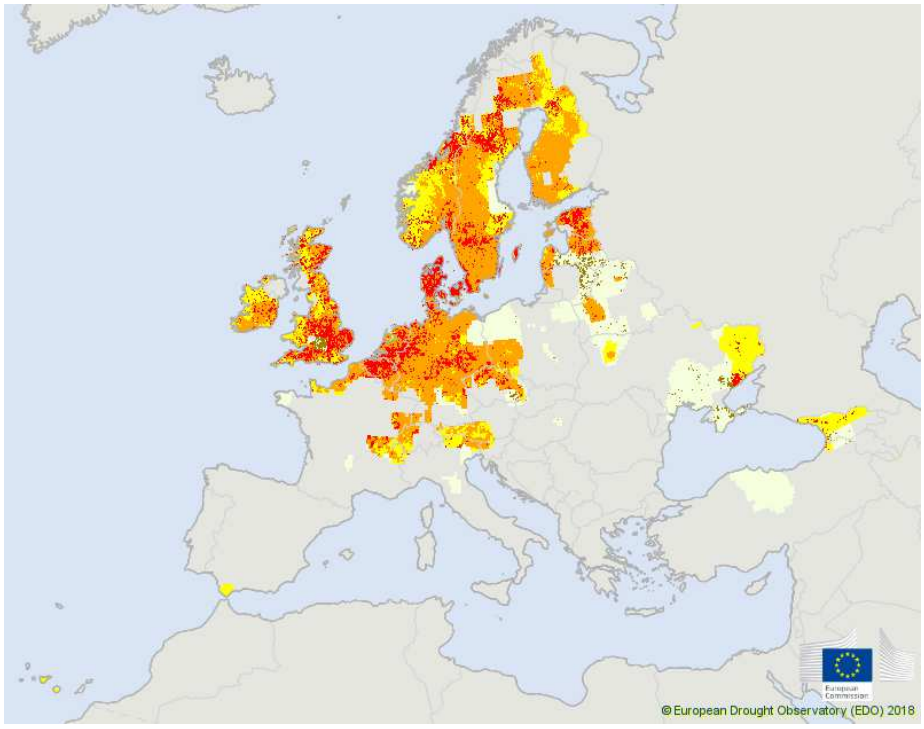


Figure 11 DO map Situation of Combined Drought Indicator in Europe - 2nd ten-day period of August 2018

- **Early warning systems for severe weather**

Most European countries have a public warning system for severe weather. The warning is usually provided on the internet in the form of a map with a colour code indicating the severity of the danger and symbols indicating the type of event. The individual warnings for 35 different European countries are collected by METEOALARM[60] (www.meteoalarm.eu). These include Austria, Bosnia-Herzegovina, Belgium, Bulgaria, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Luxemburg, Latvia, Former Yugoslav Republic of Macedonia, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Sweden, Slovenia, Slovakia and the United Kingdom. METEOALARM uses the following colour scheme:

- White: Missing, insufficient, outdated or suspicious data.
- Green: No particular awareness of the weather is required.
- Yellow: The weather is potentially dangerous. The weather phenomenon that has been forecasted is not unusual, but one should be attentive if one intends to practice activities exposed to meteorological risks and should keep informed about the expected meteorological conditions.
- Orange: The weather is dangerous. Unusual meteorological phenomena have been forecasted. Damage and casualties are likely to happen. It is advisable to keep regularly informed about the detailed expected meteorological conditions and should follow any advice given the authorities.
- Red: The weather is very dangerous. Exceptionally intense meteorological phenomena have been forecasted. Major damage and accidents are likely, in many cases with threat to life and limb, over a wide area. It is advisable to keep frequently informed about detailed expected meteorological

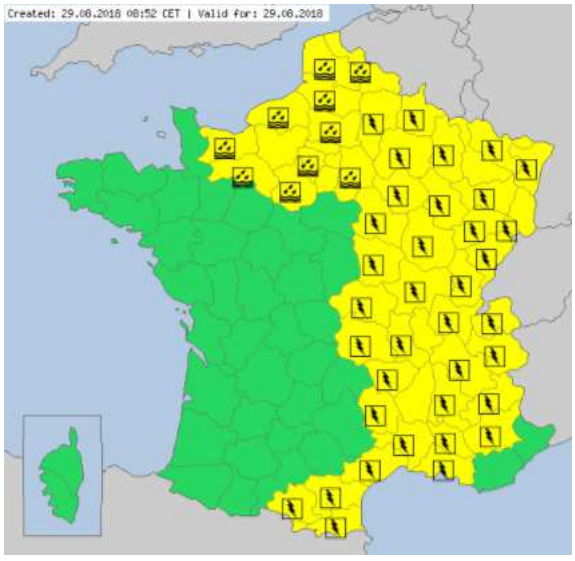


Figure 12 Example France Severe Weather map on 28.08.2018.

The national warning sites usually offer more regional information and further details about the situation than METEOALARM. They can be reached directly or through a link from the METEOALARM site. The thresholds behind the different warning categories (colours) are specified by the national weather services and differ between the countries.

In many countries free warning and forecast software (apps) for smartphones is available. The German weather service for example offers the warning app (WarnWetter). It is also possible to subscribe to a service that issues warnings via SMS (e.g. the German KatWARN service, which is also free of charge). Warnings are also broadcast on the radio and on television. The weather services also offer customized warnings for infrastructure providers. Warnings to emergency services, state owned railway companies and road administrations are mostly based on non-commercial agreements and free of charge.

- **European Severe Weather database (ESWD)**

The main goal of the ESWD[61] is to gather and provide detailed and quality-controlled in situ reports of severe convective weather events (dust, sand- or steam devils, tornado sightings, gustnados, large hail, heavy rain and snowfall, severe wind gusts, damaging lightning strikes and avalanches) all over Europe using a homogeneous data format. The ESWD is the most important database for such events in Europe[62]. It has become available only recently (in 2006). ESWD has large potential in applications for storm detection and forecast or now-casting/warning verification purposes.

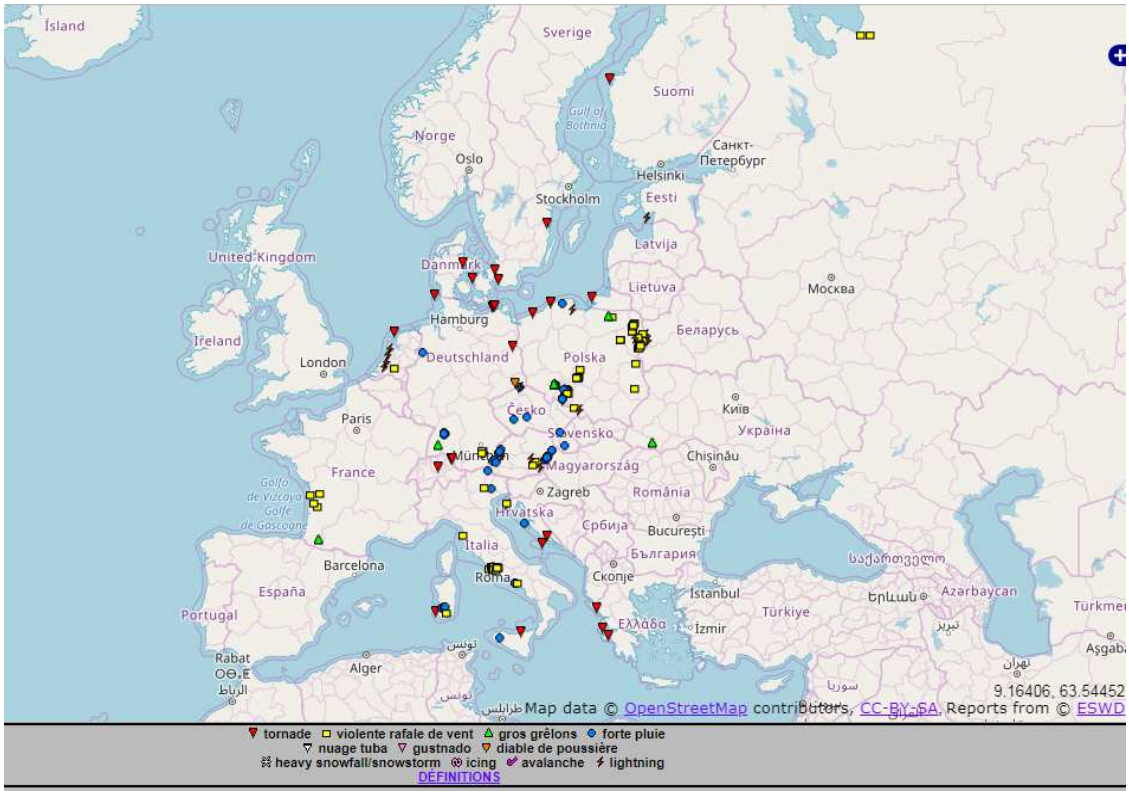


Figure 13 ESWD map featuring severe weather events

- **HAILCAST**[63]

HAILCAST is a one-dimensional, physically-based hail forecasting model. It will produce forecasts of hail size, and if desired, hail density and terminal velocity. It appears to be the best tool presently available to forecast hail size. HAILCAST could also be made in now-casting**.**

Warnings for (extremely) large hail are routinely available in the USA but not in Europe. Ingredients based forecasting would substantially help to prepare such warnings, as no direct NWP model output for hail is available. The HAILCAST one-dimensional maximum hail size model should be tested in Europe[64].

- **RAPID-N tool**[65]

The RAPID-N tool has been developed by the European Commission for the assessment of Natural-hazard triggered technological accidents (Natech) risks at local and regional levels. RAPID-N allows estimating the risk of hazardous-material releases following natural disasters. It also identifies Natech-prone areas to support land-use planning, emergency-response planning, damage estimation and early warning. It has currently been implemented for earthquakes.

- **Modelling, risk mapping and forecast tools for forest fires (Italy)**

There are two types of tools used by Italy regarding forest fires: risk maps, which are static, and forecast models. While the first tool gives valuable information for prevention, the second is basic for the response phase. For example, the system RISICO, which simulates and predicts the behaviour of fire given the moisture content of vegetation, wind and topography, provides information before the event, allowing to distribute and allocate resources in the more exposed areas. Another simulator, named PROPAGATOR, is under evaluation and aims to provide the probability of spread of fire based on the fire line dynamics.

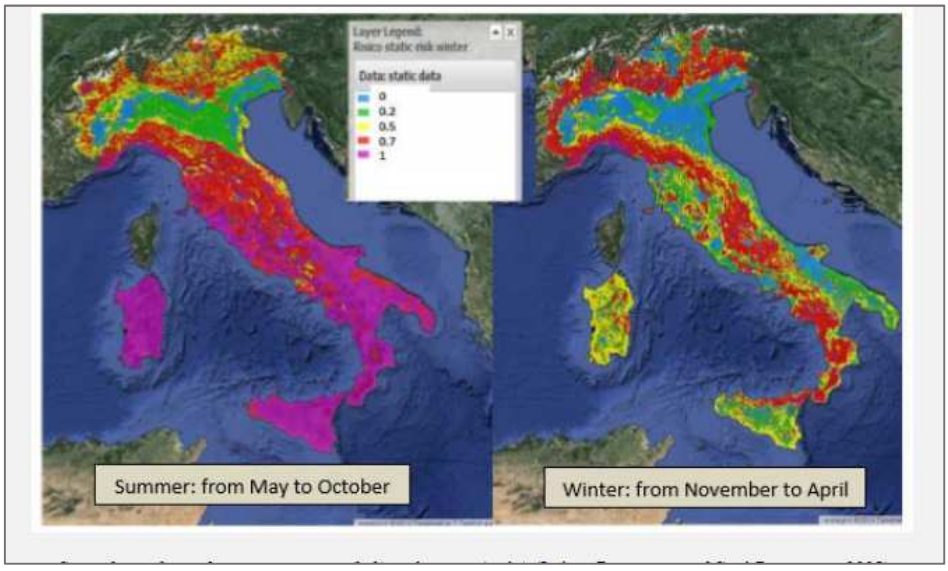


Figure 14 Static fores fire risk map, in summer (left) and Winter (right). Soruce: Italian Department of Civil Protection 2015.

- **Earthquake risk assessment using exposure and vulnerability (Spain)**

Vulnerability:

The NRA uses the studies made at regional level which consider that vulnerability depends on many factors (age, type of construction, use, geometry, height, conservation degree, etc.). For the assessment, three factors are defined regarding buildings:

- Age (before 1950, 1950-1975, 1976-1995, 1996-2001)
- Constructive and structural typology
- Use (residential, health, leisure, industry and services or singular buildings like big infrastructure).

Different matrices of vulnerability show the number of buildings that would suffer damages depending on the magnitude of the earthquake.

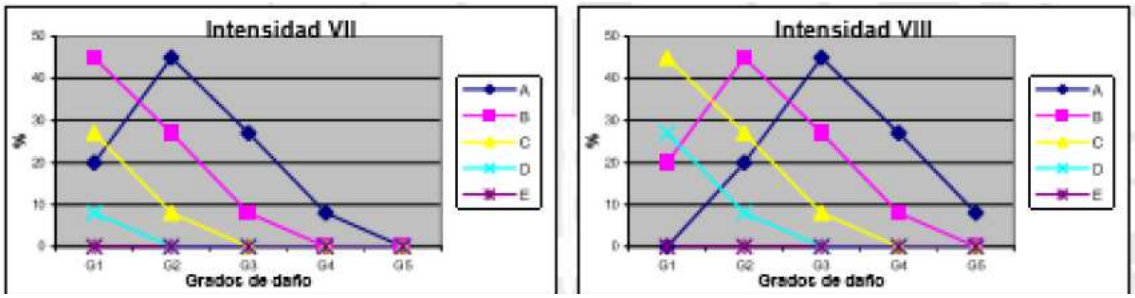


Figure 15 Vulnerability matrices, for: different types of buildings (A to E); for two intensities (VII and VIII). The degree of damage goes from light damage (G1) to collapse (G5) (Spain, Ministry of Interior, 2015)

Exposure:

In the absence of relevant studies, the NRA bases its indicators on the data of the Insurance Compensation Consortium, which covers for extraordinary incidents occurring in the country, and existing vulnerability studies.

- **Earthquake risk assessment using exposure and vulnerability (Greece)** [66]

The Egnatia Motorway Authority has developed a software package to assess the vulnerabilities of structures along the motorway to seismic activity of an earthquake[67]. The software brings together data from a number of sources and analyses various bridges or motorway sections for probabilistic damage, or damage caused by real or theoretical seismic scenarios.

The vulnerability functions are formulated in terms of the hazard intensity, which is ln(PGA) in the Egnatia software. Egnatia software can be used herein for the seismic risk assessment of all the bridges of Egnatia motorway, where for each of them a proper vulnerability function was assigned.

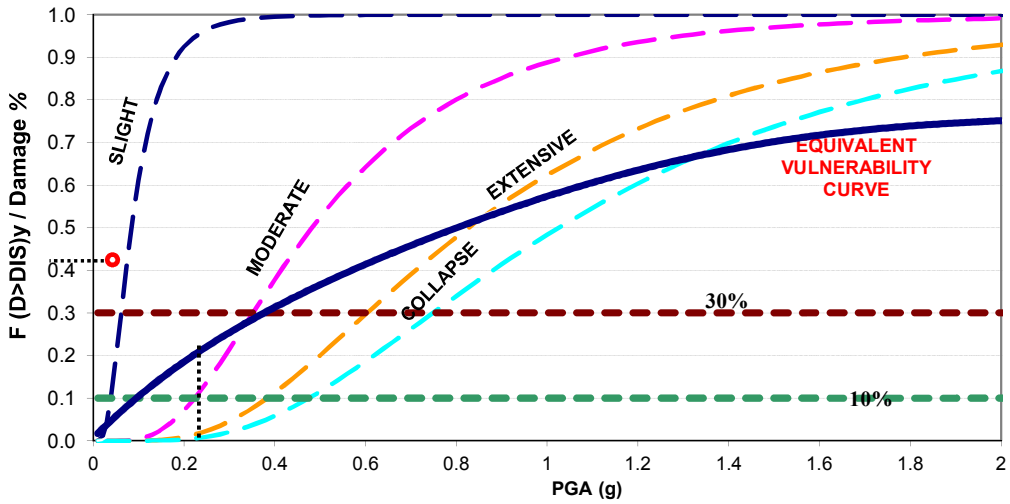


Figure 16 Vulnerability functions for bridge type 332 for 4 limit states and the equivalent vulnerability functions in terms of damage %. Transverse direction

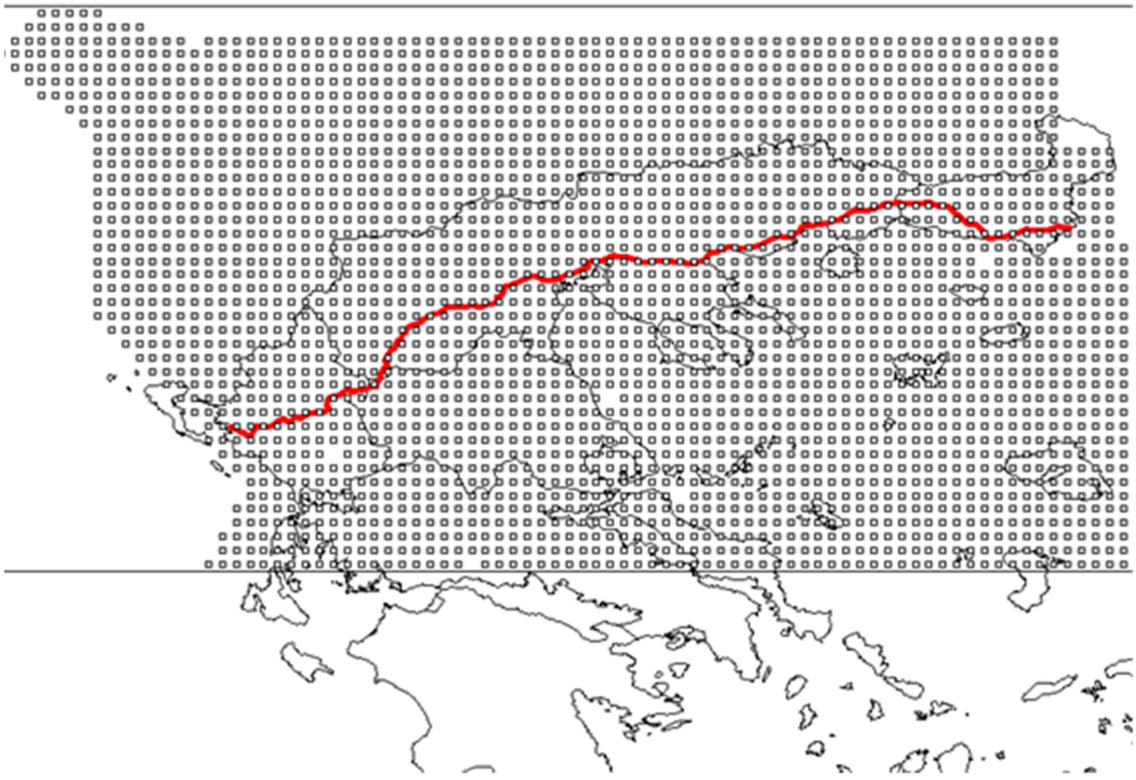


Figure 17 Egnatia Motorway sections most at seismic risk

- **Seismic Risk maps (Italy)**

The country has made an important effort to develop seismic risk maps at national level in the last years. The maps are based on recent seismic hazard studies and improved damage probability matrices and fragility curves. The vulnerability of residential building stock was modelled and categorized in 4 classes of vulnerability. The result was the "loss risk", showing the percentage of damaged buildings, and the "life risk", showing the percentage of people involved in this building collapses.

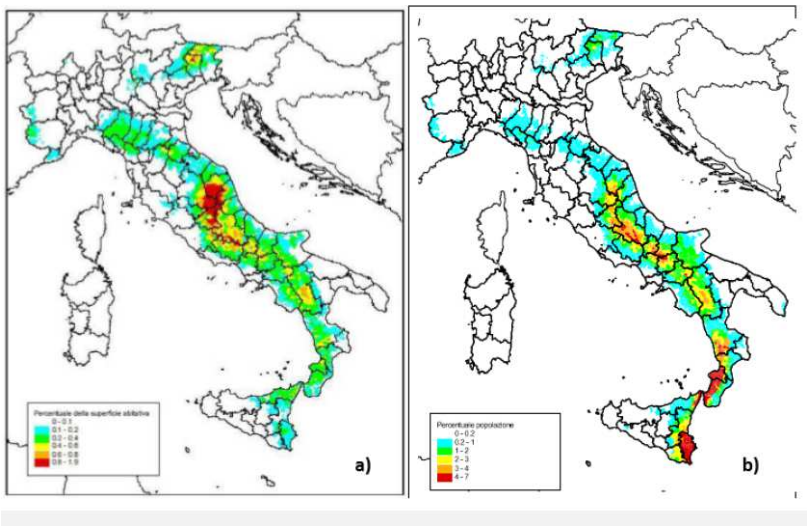


Figure 18 “Loss risk” map (left) and “life risk” map (right), 100 year return period (Italian Department of Civil Protection, 2015)

- **DACEA project: Cross-border Danube System for Earthquake Alert**

The DACEA project (Cross-border Danube System for Earthquake Alert) started in 2010 to increase capacity to respond to disasters generated by earthquakes in the cross-border area of Romania and Bulgaria by developing an early warning system integrated network and building capacities in both countries regarding the risk. Sixteen seismic stations were installed in the area of interest, and the emergency authorities of both countries were provided with equipment to receive the alert. The system implemented uses shake-maps that are generated automatically after an earthquake and based on these, together with exposure and vulnerability studies previously carried out, the structural damage estimates inflicted by the ground shaking are obtained. This way, a nearreal- time earthquake damage assessment is obtained, which is crucial for rescue and recovery actions.

Figure 19 Cross border area of the DACEA project, with the seismic stations. Source: DACEA, 2013. (http://www.quakeinfo.eu/en)

- **Critical Infrastructure Warning Information Network (CIWIN)**

In October 2008, the European Commission issued a Proposal for a Council decision on a Critical Infrastructure Warning Information Network (CIWIN). The proposal aimed at assisting Member States and the European Commission to exchange information on shared threats, vulnerabilities and appropriate measures and strategies to mitigate risk in support of Critical Infrastructure Protection (CIP).

The CIWIN network has been developed as a Commission owned protected public internet based information and communication system, offering recognised members of the EU's CIP community the opportunity to exchange and discuss CIP-related information, studies and/or good practices across all EU Member States and in all relevant sectors of economic activity. The CIWIN portal, following its prototype and pilot phases, has been up and running since mid-January 2013.

- **Climate Change vulnerability toolkits**

There are a number of vulnerability toolkits available, with the RIMAROCC[68] method being used to assess sections of both the Dutch and German TEN-T networks. An additional tool is SWAMP[69], which, along with RIMAROCC, was developed as part of the 2009 ERA-NET Road call "Road Owners Getting to Grips with Climate Change". The FHWA has a five stage vulnerability assessment process, whilst other methods such as Bayesian Probability Networks are increasingly being used. The 2012 ERA-NET Road call "Road Owners Adapting to Climate Change" funded projects in climate modelling, vulnerability assessment and adaptation technologies that were undertaken over the 2012 to 2015 period. One of that projects was the ROADAPT[70] project, which developed guidelines and tools to be used with the RIMAROCC risk assessment framework, to better inform detailed vulnerability and socioeconomic impact assessments, and selection of adaptation strategies. The ROADAPT guidelines (2015)[71] include an extensive database of over 500 adaptation measures related to geotechnical and drainage assets, pavements, and traffic management.

- **Climate-ADAPT[72]**

The European Climate Adaptation Platform (Climate-ADAPT) is a partnership between the European Commission (DG CLIMA, DG Joint Research Centre and other DGs) and the European Environment Agency. The platform helps users to access and share data and information on:

- expected climate change in Europe;
- current and future vulnerability of regions and sectors;
- EU, national and transnational adaptation strategies and actions;
- adaptation case studies and potential adaptation options; • tools that support adaptation planning.

The platform includes a database that contains quality-checked information that can be easily searched applying a range of different filters: type of data, adaptation sectors, climate impacts, adaptation elements, countries, publication year and keywords. These filters can be also used to retrieve Climate-ADAPT case studies.

- **EURO-CORDEX[73]. Coordinated Downscaling Experiment-European Domain**

EURO-CORDEX is the European branch of the international CORDEX initiative, which is a program sponsored by the World Climate Research Program (WRCP) to organize an internationally coordinated framework to produce improved regional climate change projections for all land regions world-wide.

The CORDEX regional climate model (RCM) simulations for the European domain (EURO-CORDEX) are conducted at two different spatial resolutions, the general CORDEX resolution of 0.44 degree (EUR-44, ~50 km) and additionally the finer resolution of 0.11 degree (EUR-11, ~12.5km).

- **Road Structural Safety Support Systems**

Table 12 lists a number of DSS tools providing information about the structural health of key infrastructure (bridges, tunnels) to support Road agencies in maintenance operations.

Table 12 Road Structural Safety DSS

DSS tool	Developer	Description of the DSS tool
AEROBI DSS **(https://www.aerobi.eu)**	European research project AEROBI, funded by the H2020 Programme	The AEROBI Decision Support System provides detailed interactive information on the defects, the structural condition, the deflections, the safety factor of the bridges to be inspected by drones
SENSKIN DSS **(https://www.senskin.eu)**	European research project SENSKIN, funded by the H2020 Programme	The SENSKIN Decision Support System provides detailed interactive information on the structural condition, the structural loss the necessary maintenance actions, the safety factor of the bridges to be monitored by SENSKIN strain sensors
ROBOSPECT DSS **(https://www.robospect.eu)**	European research project ROBOSPECT funded by the FP 7 Programme	The ROBOSPECT Decision Support System provides detailed interactive information on the structural condition, the structural loss the necessary maintenance actions, the safety factor of the road tunnel concrete intrados to be monitored by ROBOSPECT unmanned inspection robotic vehicle

- **Road Safety Decision Support Systems (DSS)**

Finally, regarding Road safety management, there are several risk assessment tools available worldwide modelling the relation between traffic risks and safety countermeasures.

Table 13. Road Safety DSS Worldwide

DSS tool	Developer	Description of the DSS tool
Crash Modification Factors Clearinghouse (www.cmfclearinghouse.org)	by NHTSA (USA)	A crash modification factor (CMF) is used to compute the expected number of crashes after implementing a countermeasure on a road or intersection. The Crash Modification Factors Clearinghouse provides a searchable online database of CMFs along with guidance and resources on using CMFs in road safety practice.
Road Safety Engineering Kit (www.engtoolkit.com.au)	by Austroads (Australia)	It outlines best-practice, low cost, high return road environment measures to achieve a reduction in road trauma. The Toolkit seeks to reduce the severity and frequency of crashes involving road environment factors
PRACT Repository (www.pract-repository.eu)	by CEDR (Europe)	This Repository contains the most recent Accident Prediction Models and Crash Modification Factors, highlighting effectiveness of road safety measures worldwide, for use by road safety decision makers and practitioners worldwide
iRAP toolkit (toolkit.irap.org/)	by iRAP	The Road Safety Toolkit provides free information on the causes and prevention of road crashes that cause death and injury.
SafetycubeDSS (https://www.roadsafety-dss.eu/#/)	European research project SafetyCube, funded within the H2020 Programme the EC	The SafetyCube Decision Support System provides detailed interactive information on a large list of road accident risk factors and related road safety countermeasures.

4.2 Use of Intelligent Transportation Systems (ITS) in European Road Network

As explained in *section 3.5* of this document, dealing with Intelligent Transport Systems (ITS), in the last decade the EU has strongly promoted the implementation of ITS services in the European Roads Network, specially creating an appropriate European

legal framework for intelligent technologies by supporting the drawing up of Directive 2010/40/EU[42].

As consequence, the core European Highways are increasingly equipped with ITS technologies (i.e., ITS in France represents a turnover of 4.5 billion Euros, 45,000 jobs in the private sector, and more than 1,000 companies[74]).

Most of ITS applications are aimed to enhance the efficiency of the of highly stressed roads and increase road safety. Some typical applications are: monitoring and management of traffic and merchandise transportation, exchange of transport information with travellers including alerts of risks, linking the vehicle with the transport infrastructure (eparkings), people counting, automation of processes (automated access control on motorways, toll collection systems).

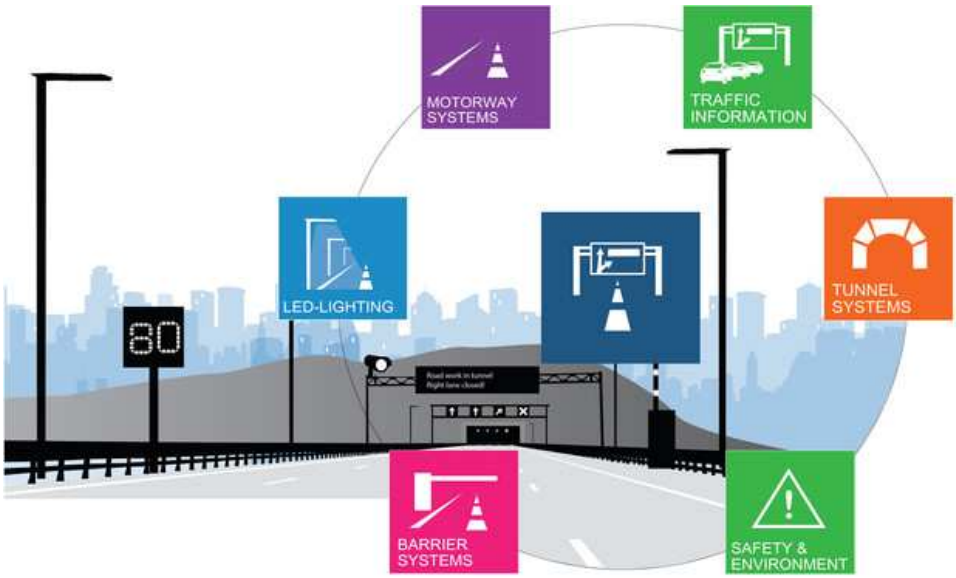


Figure 20 Smart Roads applications. Source: swarco group

Many nations in Europe, have rolled out related technologies and solutions to reduce traffic and convenience travellers[75].

There is a current joint initiative of European Member States and road operators, the C-Roads Platform[76], for testing and implementing C-ITS services[xx] in light of cross-border harmonisation and interoperability. The deployment of C-ITS is an evolutionary process that will start with the less complex use cases. These are referred to as "Day-1-services", encompassing messages about traffic jams, hazardous locations, road-works and slow or stationary vehicles, as well as weather information and speed advice to harmonise traffic. Using probe vehicle and infrastructure-related data, all C-ITS services shall be transmitted directly into the vehicles in a way that allows users to get informed, but not distracted.

[xx] C-ITS or cooperative systems encompass a group of technologies and applications that allow effective data exchange through wireless communication technologies between components and actors of the transport system, very often between vehicles (vehicle-to-vehicle or V2V) or between vehicles and infrastructure (vehicle-to-infrastructure or V2I).

Figure 21 C-Roads Road pilot sites

More information about the pilots can be found at public document: *Detailed pilot overview report*[77]

4.3 Mobile damage mapping technologies for roads maintenance

4.3.1 Vehicles based-mapping

There are specialized vehicles that use cameras or lasers to acquire accurate visual data from the road surface. Nowadays, there are some solutions based on vehicles which are adapted for road crack detection, with similar characteristics between each solution. These systems typically use area or line scanning cameras with an image resolution that allows the detection of cracks wider than 1 mm. The differences among them are mainly the width of the scanned area, ranging from 2 to 4 m[78, 79]. Some known available systems are the Road Crack Detection from the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO)[80], the Fugro Roadware's Automatic Road Analyzer (ARAN)[81] and WayLink's Digital Highway Data Vehicle (DHDV)[82]. In Europe, the PAVUE system[78] is operated in The Netherlands and Finland. This system can be equipped with either multiple video cameras or line scan cameras for the acquisition of continuous images of the road surface. Highways Agency Road Research Information System (HARRIS)[78] is another system developed as a result of 10 years' research program carried out by the Transport Research Laboratory of the United Kingdom. Laser Road Imaging System (LRIS)[83] was the name given to the system developed by a Canadian company named INO (Québec, QC, Canada) for longitudinal and lateral road cracking detection based on laser imaging systems.

The vehicles are essentially based in adapted commercial vans. The cost of the vehicle itself plus the adaptation can go up to around several hundred thousand euros[84]. The

process is considered accurate, but too expensive for many road maintenance agencies and therefore it is performed only once every two years or so[84].

4.3.2 UAV's based (drones) - mapping

Implementation of drones in road maintenance contracts has a great potential, supporting the maintenance crews with numerous supervisory tasks such as surveillance, inspections, incident control and accident response.

Conventional UAV's can be categorized as fixed-wing or Vertical Take-Off and Landing (VTOL) UAV's. Each category has its own advantages and disadvantages. Fixed wing UAV's can cover larger distances and therefore monitor larger areas. VTOL's can take of vertically and thus they do not need a large runway. They are mostly used for detailed inspection of vertical objects such as buildings or bridges. A new trend in UAV's is hybrid drones. Hybrid drones combine the advantages of VTOLs and fixed wings. They can take off vertically, they can hover vertically and they can cover large distances. This allows a single drone to cover a variety of tasks where earlier two types of drones were needed[85].

The combination of drone technology with photogrammetry, (or even better with other advanced vision technologies such as thermal infrared, LIDAR[xxi] used in PANOTPIS), enables organizations to tackle operational and maintenance challenges, allowing them to perform frequent inspections and create up-to-date, digital asset databases.

From an operational point of view, keeping an up-to-date database and performing periodic surveys of roads, bridges and other civil engineering objects have traditionally been considered costly and time-consuming. The use of drones for data capture and photogrammetry/other vision techniques to transform this data into digital spatial models responds to these operational barriers.

The benefits of using drones in assets management inspection ranges from making it safer, quicker and easier to assess vital infrastructure such as roads, bridges and tunnels. Below, a range of benefits of using drones are highlighted[86]:

Figure 22 Benefits of drone-technology for roads surveying and mapping.

[xxi] *Light Detection and Ranging* or *Laser Imaging Detection and Ranging* (LIDAR)

- **High cost of traffic disruption.** With traditional surveying methods, highways need to be closed to traffic for several hours. Drone mapping missions can be performed in 20% of the time, without disrupting traffic.
- **Need for expensive equipment and large teams.** Data acquisition missions no longer need to use total stations, highly specialized, expensively trained operators, and a large support team. A drone pilot, with a drone and a small team, can effectively perform such a survey.
- **Survey time on the field.** With a traditional land surveying method, a data acquisition mission for 10 km of a highway would typically take 10 hours accessing only assets that can be viewed from the eye level. With a drone, it would take under 2 hours providing full access and visibility to everything that can be viewed from above.
- **Limited geospatial data as output.** Photogrammetry software not only transforms images into measurable 3D models, it transforms data into visual information, providing an up-to-date visual database of all assets that can be visually inspected.
- **Safety issues for surveying and road staff.** Surveying sites with difficult access, dense vegetation, complex topography, or unstable geological formations with traditional surveying methods can pose safety issues to surveyors and road staff. Aerial methods such as drone-mapping reduce the risk of accidents and exposure.
- **Human error.** Carelessness, miscommunication, or fatigue can lead to significant discrepancies. Drone-mapping does not rely on field notes or any type of manual data entry system. Photogrammetry software extracts data from images and geotags of specialized sensors.

The use of drone-mapping in Roads Management is one of the technologies that infrastructure managers are willing to embrace more rapidly. There are several examples of pilot experiences and projects investigating drone applications for Road Maintenance and Operation, leading to the conclusion, that drones will be soon implemented at commercial level in the main highways. Some pilot-experiences and projects are described below.

- Drone-mapping for asset management in Motorway A5, in northern Greece. The goal of the project was to produce documentation for asset management of 11km of new highway and an as-built survey on a radius of 80 meters around it. The required accuracy was of 10 cm[87].
- ACCIONA, part of the PANOPTIS consortium, has made some trial flights over the A2 road corridor to test the potential of drones in maintenance operations.
- Spanish competitor Ferrovial Agroman[88] also plans the implementation of drones in road maintenance contracts in Urola and Deba (Guipúzcoa) to support maintenance crews in a number of tasks including surveillance, inspections and incident control.[89]
- EGNATIA ODOS, beneficiary of PANOPTIS consortium, has prepared and carried out the final field trials of the AEROBI (H2020) aerial robotic inspection.

Two types of UAVs flew and inspected two bridges of Egnatia Motorway and identified successfully the location, the type and the severity of the defects. In addition, by the support of LEICA MS50 total station the drone measured the deflection of the bridges under load testing arrangements by an accuracy of 1mm. The final decision taking system based on the findings, images, measurements of the drone automatically calculated the safety factor of the bridge and predicted the future evolution of its reliability decay.

- Last year, British contractor Costain[90] reported that it had successfully used a miniature unmanned helicopter for aerial photography on a contract to dual the A8 road between Belfast and Larne in Northern Ireland. Costain said in a written statement that the four-rotor drone, measuring around 350 mm square and with a bolt-on video camera, made several test flights over the road. It also assisted following a road traffic accident[91].

4.4 Satellite imagery

Satellite technologies for innovative transport applications is a trending research topic nowadays. One of the main interest lies in applying very high-resolution satellite imagery in Traffic Monitoring.

Other type of satellite technology, Synthetic Aperture Radar (SAR) Satellites, can also be applied for infrastructure monitoring. SAR is a radar technique used in geodesy and remote sensing. This geodetic method uses two or more synthetic aperture radar (SAR) images to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the satellite or aircraft. The technique can potentially measure millimetre-scale changes in deformation over spans of days to years. It has applications for geophysical monitoring of natural hazards, for example earthquakes, volcanoes and landslides, and in structural engineering, in particular monitoring of subsidence and structural stability.

Various agencies support the different SAR missions:

- European Space Agency (ESA): ERS-1, ERS-2, Envisat, Sentinel-1
- Japan Aerospace Exploration Agency (JAXA): JERS-1, ALOS-1, ALOS-2
- Canadian Space Agency (CSA): Radarsat-1, Radarsat-2, Radarsat constellation
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR): TerraSAR-X, TanDEM-X
- Indian Space Research Organization (ISRO): RISAT-1, NISAR (w/ NASA)
- Comision Nacional de Actividades Espaciales: SAOCOM
- Italian Space Agency (ASI): COSMO-Skymed
- Instituto National de Técnica Aeroespacial (INTA): PAZ
- Korea Areospace Research Institute (KARI): KOMPSat-5
- National Aeronautics and Space Administration (NASA): NISAR (w/ ISRO)

A showcase of SAR use for landslide risk monitoring was performed with Sentinel-1 by the Norwegian authorities. Sentinel-1A radar scans from 23 September and 30 August 2014 were combined to create this "interferometric" image showing surface deformation of a landslide in the municipality of Kåfjord in Troms county, Norway. In the 24 days between the two acquisitions, the ground moved about 1 cm.

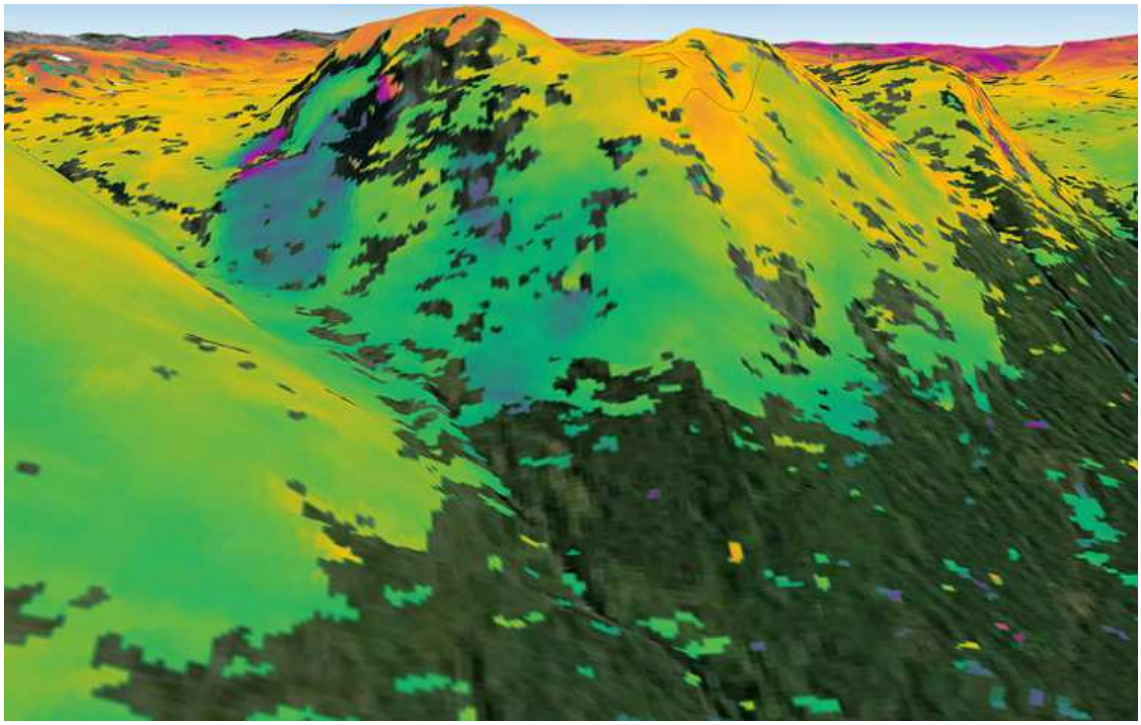


Figure 23 SAR "interferometric" image showing surface deformation of a landslide in the municipality of Kåfjord (Norway)

4.5 Use of Management Systems (MS) and Decision Support System (DSS) in Road Infrastructure

Highways agencies and operators are facing a transformation in the way that highways are funded, built and operated. New technologies such as "smart roads" are increasing the integration between information and operational technology, whilst increasing traffic volumes, especially in dense urban and sub-urban environments, this mean better planning and use of possessions and comprehensive management of the supply chain. Responding to these challenges requires excellence in Asset and Safety Management across the Enterprise[92].

There are some tools in the market helping road agencies with data management of ITS systems. Most of them focus on traffic management on highways, such as *Sitraffic Conduct+*[93] of *Siemens*[xxii]. *Sitraffic Conduct+* can be used to control variable message and direction signs as well as lane control signals or barriers. In addition, it provides important data for traffic information services and smoothly integrates toll systems,

[xxii] SIEMENS is a German conglomerate Company leader in the business sectors of *Industry*, *Energy*, *Healthcare* and *Infrastructure & Cities*, https://www.siemens-home.bsh-group.com/

video surveillance installations, emergency systems as well as all environmental and traffic data acquisition devices and systems as well as all traffic engineering facilities in road tunnels. What is more, *Sitraffic Conduct+* integrates strategy management or automatic incident detection modules into the highway management centre, full link-up with tunnel management systems, detection of hazardous cargo transports or height measurements including vehicle class identification and number plate recognition.

Figure 24 Sitraffic Conduct+: Modular system architecture

Other Highway Data Management software such *as Esri Roads and Highways*[94] have capacity *to* integrate a wide range of datasets from different nature: pavement, traffic, and safety systems enabling data interoperability and sharing across business units.

Figure 25 Sources of Datasets integrated in Esri Roads and Highways software.

There are also tools focusing on weather management, the so-called road weather information systems (RWIS). A Road Weather Information System (RWIS) is comprised of Environmental Sensor Stations (ESS) in the field, a communication system for data transfer, and central systems to collect field data from numerous ESS. These stations measure atmospheric, pavement and/or water level conditions. Central RWIS hardware and software are used to process observations from ESS to develop now casts or forecasts, and display or disseminate road weather information in a format that can be easily interpreted by a manager. RWIS data are used by road operators and maintainers to support decision making.[95] Real-time RWIS data is also used by Automated Warning Systems (AWS).

One widespread use of RWIS is the *Ice Detection Systems*. *Ice detection systems* are mainly used for winter service and provide information on wind strengths, wind directions, precipitation, barometric pressure, temperatures and relative humidity. In addition, a road weather sensor can be connected, which observes the conditions on the road surface. Examples of embedded road weather sensors are the active ARS31Pro[96] and the passive IRS31Pro[97] from the company *Lufft*[xxiii]. Embedded sensors detects road surface temperatures, water film heights, freezing point temperatures for various de-icing agents (NaCl, MgCl, CaCl), road conditions (dry / wet / wet / ice or snow, moist with salt, wet with salt), frictions & ice percentages. Optionally, two additional depth temperature sensors can be attached, typically in 5 and 30 cm depth. This system is typically used in airports runaways, and it is very advisable for highways with icing problems.

[xxiii] G. Lufft Mess- und Regeltechnik GmbH, located in Fellbach near Stuttgart, has been developing and producing professional components and systems for climate and environment measurement for more than 135 years (https://www.lufft.com/)

Other type of RWIS, MARWIS[98] also by Lufft, is a mobile road weather information sensor that measures road conditions and environmental data directly installed on the vehicle. This can be very useful for installing in the maintenance vehicles, especially for winter operations e.g. installation in icing agent-spreader vehicles, and optimize its operation, (e.g. allowing cost-effective use of icing agent in function of weather and road surface status). In addition MARWIS is capable to predict the increase in braking distance based on the measurement of friction coefficient.

Figure 26 MARWIS mobile road weather information sensor by Lufft.

Other useful technique for winter road maintenance operations is the Thermal mapping. Thermal Mapping (i.e. the acquisition of mobile RST measurements through infrared thermometry) provides the temperature relationship across a whole network identifying those sections of the road which are likely to freeze first. In addition, thermal Maps can extend the forecast from weather stations to adjacent areas, allowing ice prediction (based on minimum temperature measurements) across the whole network. Commercial examples are for example Vaisala[xxiv] system[99].

Within the RWIS management tools, it is worth to mention *RoadMaster*[100] application by *MeteoGroup*[xxv]. RoadMaster is a road weather platform delivering accurate weather forecast (e.g. integrating data from weather stations, thermal maps) to assess road operators in Winter operations. *RoadMaster* long-term forecasts can help operators estimate personnel needs and the amount of salting material and equipment that will be necessary, while short-term forecasts will help operators to decide whether a gritting action is needed, and when and where it should be carried out. *RoadMaster* also use historical figures and a logging of action decisions to help users in the decision making process. In addition, the web portal allow users to share

[xxiv] Vaisala is a Finnish company that develops, manufactures and markets products and services for environmental

[xxv] MeteoGroup is Europe's leading independent weather business with forecasting offices across Europe and customers worldwide. https://www.meteogroup.com/weathertech-works

information with other stakeholders in an effortless manner, eliminating the administrative burdens.

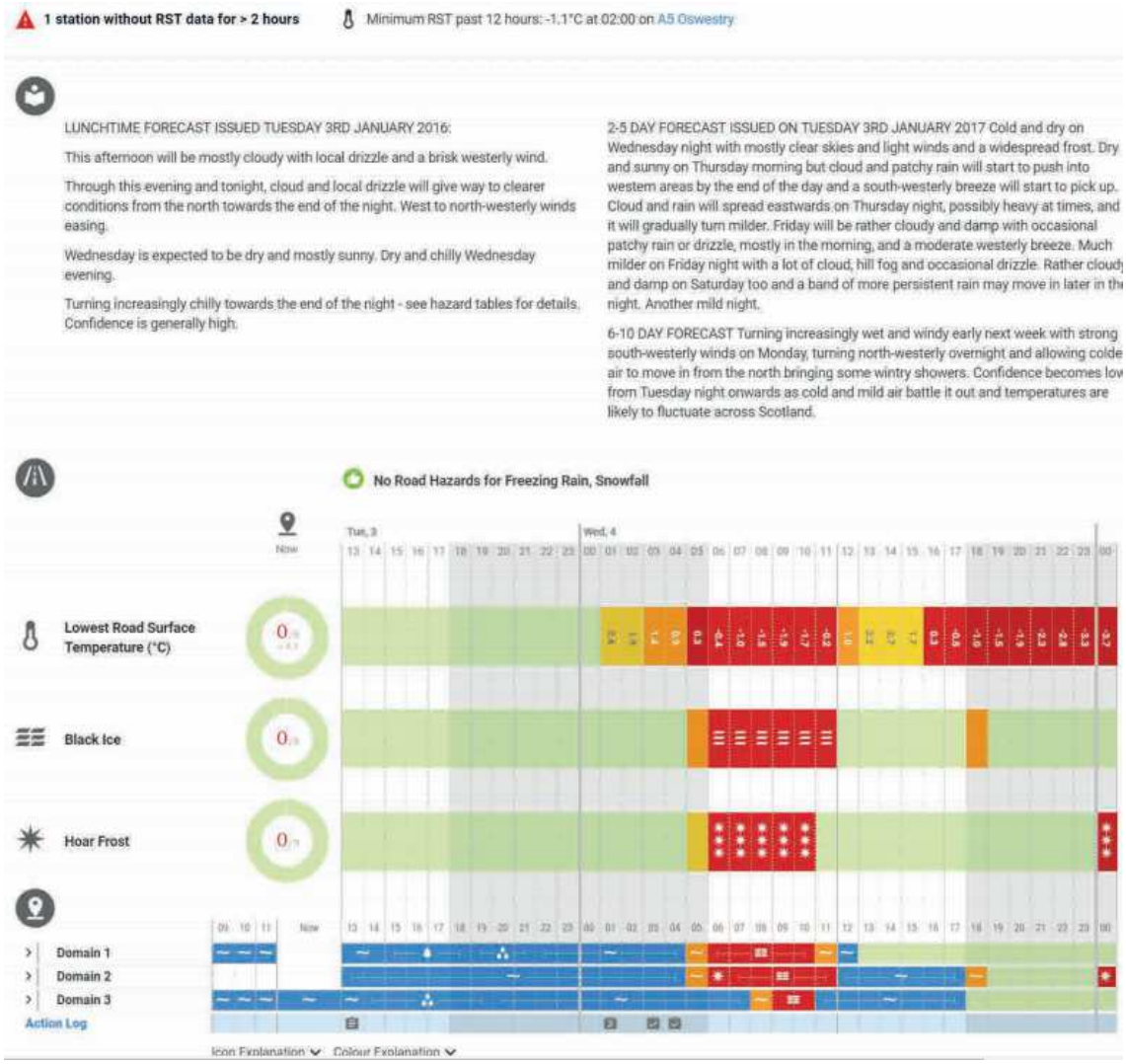


Figure 27 RoadMaster tool by MeteoGroup.

Regarding Incident Management Systems (IMS), there are already some commercial tools such as STREAMS Incident Management System (SIMS)[101] owned by the Australian TRANSMAX[xxvi]. SIMS is used by traffic management centres (TMCs) to manage road networks through detection, verification, logging, and response to: unplanned incidents such as accidents; planned events such as roadwork; and equipment faults. It enables road authorities to efficiently detect, respond to, and clear incidents to restore normal traffic conditions as safely and efficiently as possible. CCTV surveillance cameras can also be managed by STREAMS to assist with incident and fault detection and verification. Operators make use of a shared '"Handover Manager" between different traffic management centres to effectively coordinate cross-regional or

[xxvi] TTRANSMAX is an Australian provider of Intelligent Transport System (ITS) software and services https://www.transmax.com.au/

cross-organisational incidents and events or to effectively transfer control of an incident to the next operator on shift.

In summary, there are several tools in the market helping road operators with operational and strategic management, most of them dealing with traffic management, weather monitoring, or O&M data coordination. However, there is lack of a comprehensive and holistic management tool incorporating together traffic, climate and other natural and manmade disasters modules. A tool interconnecting various data sources and different applications, developing multi-risk analysis and modelling adaptation strategies based on multiple risk-scenarios.

PANOPTIS tool will feature a Common Operational Picture (COP) integrating all the information that will be provided by the various tools (e.g. weather modelling tools), the sensor data, the maintenance planning, etc. as different layers in a unified enhanced visualisation user interface. PANOPTIS tool will also comprise IMS module providing the integration of facilities, equipment, personnel, procedures, and communications for managing all incidents and emergencies. In addition, the PANOTPIS tool will include DSS module proposing customised actions in order to support the decision making of RI stakeholders during every phase of specific incident occurrence.

4.5.1 Management systems used in Spanish demo site

PANOPTIS will carry out a case study in a section of the A2 Highway in Spain. A2 connects Madrid and Barcelona. The highway is publicly owned, but the maintenance is done by the Concessions Division of ACCIONA. The section selected for the pilot has a length of 77.5 km, and lays in the province of Guadalajara. It has 4 lanes (2 per traffic direction) and crosses a region with Continental-Mediterranean climate, with long and severe winters, and long, dry and hot summers. CC projections in this area generally foresee an increase in the maximum temperatures in summer (~5ºC by the end of the century) and a decrease of minimum temperatures in winter (~3ºC by the end of the century).

In this road section, ACCIONA uses an web-based management system developed by the Company ITERNOVA[xxvii]. ITERNOVA web platform allows an integral and centralised management of all the activities and related resources involved in roads operation and maintenance. Some of the characteristics are depicted below:

- Modular system with absolute control over users roles and permissions
- Management agenda using indicators
- Daily maintenance: inventory of inspections
- Rehabilitation and inventory of road surfaces: analysis of data from pavement auscultation (deflection, IRI)

[xxvii] ITERNOVA is a Spanish Company founded in 2004, expert in technological systems for management and exploitation of Smart roads, Smart facilities and Smart cities (https://www.iternova.net/)

- Road safety management (including high accident concentration sections)
- ITS tools: integration of data from GPS-based fleets, video cameras, weather stations, weigh in motion system, etc.
- Planning and monitoring of contracts and projects
- Records management
- Custom reports

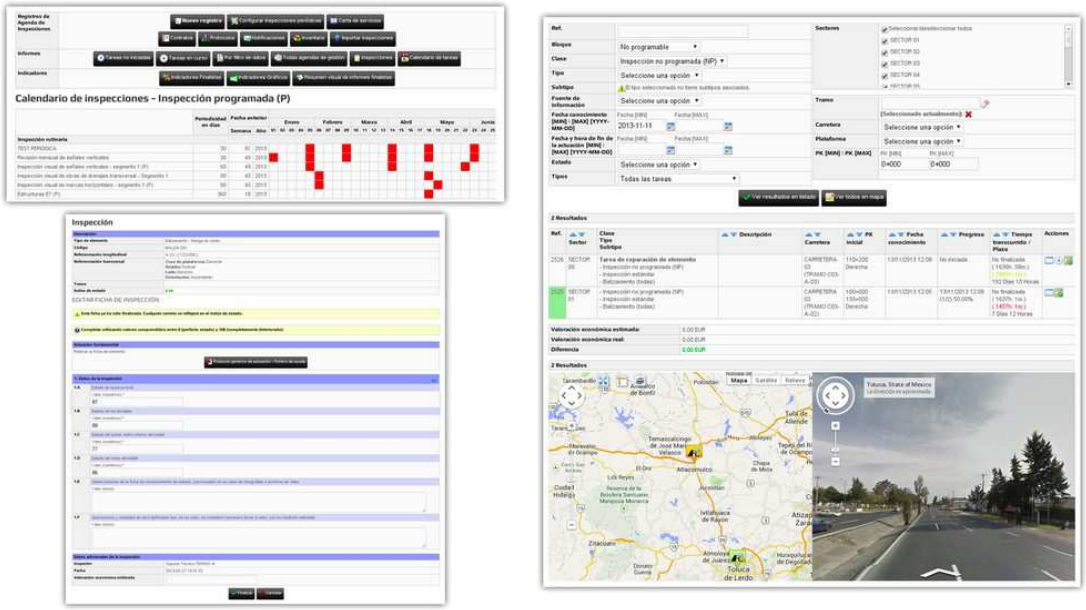


Figure 28 ITERNOVA Management system used in Spanish demo site

Regarding the ITC systems collecting data, this section is equipped with the following monitoring devices and supporting ICT infrastructure:

- ***Inductive loops:*** used for measuring traffic intensity with adequate precision. There are 4 loops along the section; each one has a local data collector and there is local intelligence and some remote control functions, as explained above for the Greek demonstration case.
- ***CCTV:*** used for general surveillance of the highway status.
- ***Weather stations:*** there are 3 weather stations along the section. Main monitored parameters are: air temperature and humidity, atmospheric pressure, precipitations, height of water film, wind speed and direction, surface temperature, dew temperature, salinity, and radiation.
- ***Communications network:*** optical fibre network with redundant ring topology: 4 nodes + central node in traffic control centre.
- ***Traffic Control Centre:*** located near the village of Torija (PK 73). From here it is possible to monitor the highway status using the date provided by the different systems described above. It is also the place where all assets needed for maintenance (e.g., machinery) are stored. Also ITERNOVA Management system is located here.

4.5.2 Management sytems used in Greek demosite

PANOPTIS will carry out a second demo-case in a section of 62.24 kms of the Egnatia Motorway in the Northern part of Greece, selected due to the high exposure of its structures, such as bridges and geotechnical works (high embankments, big cuts), and their increased vulnerability to catastrophic seismic events, high annual precipitations that affect active landslide areas, traffic overloading, and geotechnical movements (landslide, settlements, rock-falls). Records with the evolution over time of the dynamic characteristics of some seismic prone bridges, based on continuous ambient vibration monitoring are available. The highway is publicly owned, and the operation and maintenance of this stretch is done by the PANOPTIS partner Egnatia Odos.

This highway sections already comprises the following ITS:

- ***Inductive loops:*** used for measuring traffic intensity with adequate precision. Each loop has a local data collector that processes the signals and outputs the number and type of vehicles detected. There is some local intelligence that enables the detection of special events (e.g., simultaneous detection in adjacent lanes to avoid double counting the same vehicle, or detection of "kamikaze" drivers), and some specific remote control functions (e.g., reconfiguration of direction of traffic).
- **CCTV:** used for general supervision of highway traffic status, for surveillance of the highway assets, and for auditing the traffic intensity measurements done by the inductive loops.
- **Weather stations:** used for surveillance of weather parameters that may have an impact on highway operational status and/or safety of drivers. There are three weather stations along the specific motorway section. Main monitored parameters are: air temperature and humidity, atmospheric pressure, precipitations, height of water film, wind speed and direction, surface temperature, dew temperature, salinity, and radiation.
- **Communications network**: optical fibre network with redundant ring topology: 4 nodes + central node (traffic control centre).
- **Traffic Control Centre**: located near the village of Metsovo (Ch. + 111.50), where it is possible to monitor the highway status using the data provided by the different systems.
- **SHM network of bridges and tunnels:** T9/T11 bridge is instrumented by 14 strain-gages, 6 tilt meters and 4 joint-meters, acquired by one multi-channel acquisition unit, equipped by GPS and GPRS modem. Metsovo bridge is instrumented by 14 electric-resistances dynamic strain-gages, 2 dynamic joint-meters, 12 accelerometers and 1 anemometer, all acquired by a PC based acquisition unit, connected in the fibre optic network. G1, G7 and G8 bridges are instrumented by static strain-gages, static joint-meters, accelerometers acquired by multi-channel acquisition units, separately for accelerometers and static sensors, equipped by GPS and GPRS modem. A permanent SHM network is installed on T9/T11 bridge, including joint-meters, tiltmeters, strain gauges and thermistors, such as to detect any changes (joint gap openings, tilt of piers, strain increase of the balance cantilevered superstructure etc.) that may be induced by the active landslide. Egnatia Odos monitors the evolution versus time of the dynamic characteristics of the bridge through periodical ambient vibration monitoring using

servo-accelerometers. Tens of cross sections of the final concrete cover of the tunnels are also instrumented by sensors (strain gages, load cells, extensometers etc.).

- **SHM network of geotechnical works:** Inclinometers, piezometers are installed in Prinotopa (Ch. 97+100), the active landslide area that has been stabilized during the construction of the motorway, where the piers of ravine bridge T9/T11 are founded.

Regarding **Data Management software/Decision Support System** integrating all the data described above, there is a Bridge Management System based on an Oracle Based Data Base that considering the structural condition of the bridges, the cost of alternative maintenance actions, the prediction of the deterioration model, determined the optimal maintenance strategy for all the bridges considered in analysis.

PART II: USER NEEDS AND MODUS OPERANDI

5. End Users' needs (UN) and High Level requirements (UHLR)

The Users' Needs (UN) and high level requirements (UHLR) described in this chapter serves as initial terms of reference for the design, development and realization of the technical components of the PANOPTIS System.

PANOPTIS applications should be developed in dialogue with end users, in order to increase the likelihood that they cover areas that are relevant and currently not sufficiently covered. In addition, PANOPTIS modules should be developed in alignment with end users' management, operational and communication procedures, to guarantee that it can be easily integrated within the organization processes.

This chapter collects the current practices, needs and expectations from the two end-users of PANOPTIS consortium (Egnatia Odos and ACCIONA). Egnatia Odos and ACCIONA are Transport Infrastructure managers with long experience in road management, and at the same time, they are administrators of the road sections selected as PANOPTIS demo sites. Therefore, they can offer a solid basis for the future development of the project. In addition, since Egnatia Odos and ACCIONA are partners of the project, they are aware of the project technologies, and therefore, in addition to the gaps and needs in nowadays operation procedures, they have been able to provide (high level) requirements to the PANOPTIS components. Nonetheless, these high-level requirements will be further processed in the next steps of WP2, in order to produce a clear specification of requirements (functional and non-functional) for each one of the technology modules. The detailed set of requirements will be reported in D.2.2.

The needs and high-level requirements provided by Egnatia Odos and ACCIONA have been complemented by other end-users, external to the project, and linked to some of the partners of the consortium, such as ADS and ICT. These extra-needs and/or requirements from external stakeholders are also provided in this Chapter.

In order to guarantee that PANOPTIS will be agile enough so as to adapt its requirements to future findings in other WPs and to the setting-up of a "PANOPTIS" community, whose expertise could feed into designing the tool, the list of needs and requirements identified in this deliverable D.2.1, and in the subsequent D.2.2, will be monitored along the project and adapted based on future work and findings. What is more, the final log of *needs and requirements* coming from WP2 will be linked to specific implementation actions, to checklist that all the needs and requirements are covered in the project, and if not covered, understand why.

The subsections below gather the analysis of the current practices and needs of each one of the end-users interviewed. Each subsection refers to an individual end-user.

5.1. ACCIONA needs and high level requirements

Table 14 ACCIONA needs and high level requirements to PANOPTIS system.

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
Heavy rain/ hail storm	Overloading of drainage systems Scouring in roads, bridge decks and support structures Threat to stability of slopes and embankments (including mudslide) Damage to signs, lighting, fixtures, and supports	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• On-site visualization by worker, emergences, traffic authorities or road users • No sensors or prediction/risk models applied • Rainstorms forecast is displayed on National Meteorological Institutes web site.	Decisions over traffic (cuts, re-routing) are taken by Civil Protection agents. Road operators only inform about the storm or hail event to Civil Protection, and they manage the situation.	• Lack of predictive models (with 24 h accuracy) to adapt operation activities • Hail cannot be predicted • Lack of long term predictions to adapt maintenance plans and tenders • Lack of synergetic risk models, to analyse various scenarios/ multi-hazard assessment	Improved short-term prediction model including hail-storm prediction (24h) Improved long-term prediction (1 year) for improved planning of resources and maintenance actions. Sensorization of embankments and slopes to prevent mudslides due to loss of stability under heavy storm Warning alarm integrated to Smart Road tool Smart tool to track data from sensors or video system	Advanced meteorological models, coupling in situ sensors data Structural health monitoring sensors Geotechnical Analysis tool connected to ground sensors (to monitor vulnerability to landslides) Advanced multi-hazards models
		Sync-Post Hazard: damage assessment				
	Friction loss in areas where water accumulates Deterioration of structural integrity of roads, bridges,	• Visual assessment of the scope of damage	Post damage impact assessment of affected assets is man-made. There are response time indicators for	• Lack of erosion control measures • Lack of assessment of structural/geotechnical impact in structures • Lack of mobile damage	Use of SHM sensors to monitor damages and adapt daily maintenance plans. Structural and geotechnical analysis of structures after hazard event to detect possible loss of bearing capacity Model of ground surface deformations and slope displacements	Networked SHM sensors Geotechnical Analysis tool connected to ground sensors

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
	and tunnels due to increase in soil moisture levels (only if increase in frequency)		corrective actions in function of the severity/urgency of damage	mapping techniques	Implement mobile damage mapping techniques Use of drones for non-accessible areas and 3D model	Use of mobile-damage mapping Drone-mapping
Fog	Threat for driver's safety Impossibility of working on the road (work stoppage without warning)	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		No announcement from meteorological Agency Onsite visualization by workers	Works stoppage Contact traffic agencies	Currently fog formation cannot be detected No sensors, no models No early warnings (early warning would allow re-scheduling of works for the day, and avoid unnecessary preparation of machinery)	Improved short-term fog prediction models (24 h), for planning next day maintenance operations, and plan better safety measures for drivers Implement fog alarms in control centre Implement visibilimeters: integrate visibility data with fog forecasting models and associate information to decisions about works stoppage/ works continuing, and with traffic safety measures Improved decision making based on different and synergetic risk scenarios	• Advanced forecast models • Decision support tool • Visibilimeters
		Sync-Post Hazard: damage assessment				
		Own tracking, in situ visual inspection,	Civil Protection (through traffic agencies) decide over closing/opening traffic Civil protection (through traffic agencies)	Lack of monitoring techniques to follow-up evolution of fog Ground vehicles surveying the fog event can contribute to car accident. Better use UAVs.	Use of visibilimeters providing real time data coupled to short-term fog forecasting models and to data management tool. Possibility to share information with Traffic agents. Improved decision making based on different and synergetic risk scenarios Use of UAVs for incident follow-up to decrease risk of crash.	• Visibilimeters, connected to-now casting and to smart road tool • Special lighting system • UAVs

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
			intervene in case of traffic accident. Road operators only notify. Visual inspection of possible post-accident damage in roads			• Decision support tool • Incident Management Tool
Snowfall event	Circulation collapse, traffic accident vulnerability Deterioration of pavement due to increase freeze-thaw conditions Roads and structures corrosion (bridges, crossings with secondary roads) due to the penetration of de-icing agents used to defrost road surface and allow circulation	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• Snow events are predicted by National Meteorological Agency. Information is not coupled to an alarm system. • Use of microclimate stations data (measurement of Temperature, humidity) coupled to data base/ control system, but no alarm system	• De-icing Salt protocols: When T< 2ºC treatment of road surface with wet salt or solid salt and different scenarios depending on snow level • Corrosion is not monitored and no corrosion models are applied. • Traffic decision are taken by Civil Protection organisms	Currently protocols are based only in Temp. Measurement. Sometimes fail to predict reliable levels of ice, and salt is wastefully used (environmental and economic cost). Corrosion of reinforcement is not monitored, Very high and unpredicted costs associated to reparations. Lack of RWIS[xxviii] tools to support winter operations. Lack of alarm systems	Use of sensor techniques to collect data of road temperature, water film heights, freezing point temperatures of de-icing salts, moist, frictions, ice percentage. Sensors can be embedded on the road surface or preferably mobile (attached to cars or drones). The information of the different sensors should be processed in a smart roads tool to support decision making process. Early warning alarm system. Use of thermal maps to identify the sections of the road which are likely to freeze first and predict ice areas across the whole section Accurate weather forecast: long-term forecasts can help operators estimate personnel needs and the amount of salting material and equipment that will be necessary ; while short-term forecasts will help operators to decide whether a gritting action is needed	• Implementation of networked sensors coupled to a decision tool • Use of thermal mapping to detect ice prone areas across the whole section • Improved models (long term and short term) • Smart roads tool integrating all the information from sensors, thermal maps, and forecast models to support

[xxviii] Road weather information system

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
	Contamination of watersheds and aquatic ecosystems with de-icing agents. Loss of stability in slopes and embankments leading to mudslides		(traffic agents)		Management tool integrating information from sensors (temperature, penetration of salt, friction, ice percentage) together with weather forecast, and historical data of actions taken to support operators in decision process.	decisions • Algorithm for alarm
		Sync-Post Hazard: damage assessment				
		• Tracking from Meteorological Institutes, but not associated to warning system (operators should follow on the website) • Own tracking, visual follow-up, owned weather stations	• If there is a layer of snow on the road --> restriction to truck traffic. • If the layer of snow is considerable > more than 5 cm approx. → use of snow chains for cars.	Lack of sensors techniques (mobile road weather stations, embedded sensors to detect ice, amount of salt, and other variables) to support winter operations (i.e. efficiently use de-icing salts) Need for automated communication among different stakeholders (RI managers, RI operators, salt operators, traffic authorities) Need for more accurate impact assessment tools (effect of corrosion of structures) Lack of control in de-icing salt use	During snow event, mobile weather stations (such as MARWIS) can be installed in service vehicles to support operators with in situ data (temperature, salinity, friction, ice percentage). This can help operators in the optimization of gritting salt use, leading to important economic and environmental savings. Not to mention benefits in traffic management, and prevention of accidents and cuts. Volumetric sensor in storehouse for providing critical level of salt. Or volumetric sensors in vehicles to control the amount of salt dispersed. More agile communication with police, traffic regulators Use of drones for incident management because snow makes difficult and dangerous ground-vehicles circulation	Use of mobile sensors integrated in service vehicles Decision support tool integrating information from sensors and short-term forecast models Common operational picture with other stakeholders Drones for incident management
Vehicles goes to the wrong direction on a ramp near a service area or interchange	High probability of traffic accident	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		No tracking data. On-site visualization by worker, emergences, traffic authorities or road users	Contact traffic agencies. Broadcast warning messages on the road	Lack of kamikaze[xxix] detection equipment Lack of automatic warning messages for road users in danger	Sensors connected to Alarm in smart roads tool (to be shared with Civil Protection) When kamikaze is detected, automatic warning is send to show Visual warnings in signs, lighting, fixtures, and supports to drivers	Kamikaze detection, Automatic message associated to event (to be showed in panels)

[xxix] *Kamikaze* refers to drivers going the wrong direction, whether intentionally or not intentionally.

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
						Smart roads tool
		Sync-Post Hazard: damage assessment				
		Tracking data from cameras (no night vision) and visually	Contact traffic agencies very urgently	Lack of adequate surveillance, incident management, using drones (persecution with car can be dangerous) Lack of automatic warning messages for road users in danger	Visual warnings in signs, lighting, fixtures, and supports to reach road users effectively Alarm in smart roads tool Incident follow up by drones	Automatic message associated to event (to be showed in information panels) Decision support tool Incident Management tool Operational Common Picture Incident Management using drone
Landslides, mudslide, rock falls slide, loss of stability in slopes and embankments	Combination of intense precipitation, wind erosion and increase of maximum temperatures can increase the risks of landslides. Landslides can lead to traffic accident, and road closure.	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		Some slopes already experience intense erosion and need periodic inspection. But only visual inspection is applied.	Visual surveillance by stand-up personnel or using equipment attached to service vehicles (driven by man)	Programmed inspection (only visual inspection is insufficient to predict mudslides. Need for high resolution vision technologies). Lack of monitoring and control system (sensorization of critical assets, i.e. slopes displacement, vibrations...). Landslides can be frequently prevented if smart technologies are used in maintenance operations (unlike other hazards)	Use networked sensors to monitor and control slopes and embankments. Coupling sensors to a smart decision tools processing data and sending early warning alarms in case of risk. Use of vehicle or drone mapping to detect terrain displacements. Coupled to smart tool to interpret results and send early warning alarms. Use of UAV with attached sensors: high resolution visual spectrum and/or LiDAR, to monitor slopes and embankments. Automation of the process of detection of pathologies (volumes differentials, landslides, vegetative	Networked SHM sensors (embedded) Early warning alarm system Use of mobile mapping (preferably UAV) Use of SAR instruments

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
	Landslides lead to big damage in road infrastructure			Lack of mapping technologies for maintenance operations (monitoring of slopes and embankments with mapping technologies)	growth etc.). Comparison between different data acquisitions at different times. Use of SAR (synthetic aperture radar) data to detect small movements/displacements in embankments/cuts/slopes Smart tool to apply adequate daily maintenance operations in slopes and embankments	Computer vision techniques DSS tool
		Sync-Post Hazard: damage assessment				
		Visual post hazard assessment	When accident is detected, first thing is to send information to involved stakeholders (e.g. Civil protection to cut traffic if necessary). Second, assess damage and repair. Traffic might be interrupted during damage assessment and/or repair	Damage assessment and incident management is man-made	Use of drones for incident management	Use of drone mapping
Drainage collapse due to vegetation encroachment	Fail of drainage system in case of rain. Fail can be fatal in case of flood/ heavy storms. Unpredicted	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		Visual inspection	Visual surveillance through equipment attached to service vehicles (driven by man)	Visual inspection is not sufficiently accurate sometimes. In addition, man-made inspection can disrupt road traffic. There is lack of high resolution	Use of mobile damage mappers (in car or drones), advanced vision technologies, to detect inadequate vegetation growth, blocking critical infrastructure. Preferably UAV, to avoid disruption in road use.	High resolution vision technologies Mobile damage mapping Drone mapping-

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
	investments in corrective actions.		Occasionally, stand-up personnel carry out more careful inspection.	vision technologies to detect blockage of drainage or other critical assets.	UAV with attached sensors: high resolution in visual spectrum. Automatization of the process of detection of obstructions/incidences.	maintenance
		Sync-Post Hazard: damage assessment				
		Very difficult to detect. Only after several drainage-fail cases can be detected	Vegetation is withdrawn and substituted by a more suitable specie Fine-tuning of maintenance operations (pruning protocols)	Lack of adequate vision techniques	Support corrective actions with Incident management tool Adequate maintenance of vegetation supported by vision technologies.	Smart roads tool Drone mapping Vision technologies

- **Requirements for UAVs use**

ACCIONA has emphasized their willingness to implement UAV technology in the maintenance of roads. The following objectives have been identified:

- Roads daily surveillance through UAV-HR visual spectrum sensors, to localize the elements on the road affecting its normal use (e.g. obstruction or roadway)
- Daily/Programmed surveillance of fencing with UAV-HR visual spectrum and zoom capacity sensors, to detect defects, holes, interruptions.
- Programmed inspection of road surface with UAV-HR visual spectrum sensors-GPS. Detection of cracks >0,5cm and centimetre-deformations. Provide High Resolution orthophotography with georeferenced location of cracks.
- Daily inspection of structures and bridges using UAV equipped with HR visual spectrum and thermographic sensors. Provide report of pathologies in structures (e.g. corrosion, paints, screws, deformations).
- Programmed/daily inspection of slopes using UAV- HR visual spectrum and LiDAR sensors. Provide information about the status/evolution of the slopes and possible pathologies to adjust maintenance works.
- Daily inspection of drainage system using UAV-HR visual spectrum sensors to monitor status of drainage and detect possible incidences/obstructions.
- Programmed monitoring of neighbouring vegetation using UAV-HR visual spectrum sensors to adapt pruning and clearing operations.
- Programmed surveillance of fauna using UAV equipped with HR visual spectrum and thermographic sensors to monitor animal population in neighbouring areas and adapt decision process.
- Programmed inspection of vegetative development using UAV-multi-spectrum sensors and fuel-use models to implement fire risk assessment.
- Programmed inspection of water accumulation in road surface using UAV-HR visual spectrum and thermographic sensors.
- Works tracking using UAV.

- **Communication procedures applied and requirements**

<u>Procedures</u>

Ordinary reports

- Every day, a report describing the planned works, conditions of road practicability and incidences affecting the traffic flow for the next 24 hours is sent via email to the relevant agencies (National Department of Traffic, Traffic Police, Provincial unit of State Highways).
- During winter-season, every day, a summary of winter oparations undertaken is uploaded to a webpage designed for that purpose (website is property of the Ministry of Public Works)

Extraordinary reports

- There is a web application to report every unplanned incidence/incident (the same webpage)
- Unplanned incidences affecting traffic (use of chains, interruption of traffic >15 min, closure of lane >2 h) should be communicated to Traffic Agencies (Traffic Police, National Department of Traffic) via email (send pdf. Report generated by web application).
- Road cuts> 1h (e.g. for maintenance activities) should be communicated to the Tele-route service via email, as well as to the traffic agencies referred before.
- There is an especial *Communication Process for Severe Accidents* involving mortal victims, heavy vehicles, road cuts, vehicles transporting hazardous substances, damages in road infrastructure, fires, among other cases. This special protocol consist of:
    - Immediate telephonic communication to Provincial Highway Units followed by a report via email in the next 2-3 hours
    - Registration of incident in the next 30 minutes in a website designed for this purpose

Winter operations

- Winter operations not involving alerts are reported daily via webpage.
- Winter operations involivng alerts (e.g, traffic restrictions due to spreading of gritting salts, etc.) are uploaded to the website and also reported via email to the relevant agencies (Provincial Highway Unit, Traffic Police, National Department of Traffic).

Requirements

There are clear protocols of communication establishing the nature of the information to exchange, the frequency and timeslot to exchange this information, the relevant stakeholders involved in the communication and the communication channel. This channel is generally email, telephone and a designed webpage for sharing specific information, normally unplanned events (owned by Public Works Administration).

The communication could be more efficient, if a common software/tool is shared among all the relevant agencies, having each agent specific permits depending on the role. The agents with reporting responsibility can upload all the information to the tool, and the relevant agencies can access to the information depending on their permits. In case of accident, a common operational picture could allow all the stakeholders to follow-up the actuation processes. The addition of automated alarms, or automatic notice algorithms, could allow warning the relevant stakeholders when a change is introduced into the system. Besides, the alarms could be customized for each agency, depending on the role (e.g. when one user reports a traffic accident, an automatic notice is received by relevant traffic agencies). On the other hand, the maintenance vehicles could be geolocalized and followed by stakeholders with rights at every moment. This tool would allow a more agile communication and access online to the relevant information.

- **Stakeholders involved (Requirements for COP)**

Stakeholder	Asset	Monitoring responsibility	Reporting responsibility (if yes, to whom)	Maintenance responsibility (financial, operational)
Owners (Ministry of Public Works)	All	No	No	Yes
ACCIONA (Road Management Agency)	All primary	Yes	Yes	Yes
Farmers/ landowners	Soil, slopes	No	No	No
Police/ Civil Protection	Traffic	Yes (traffic)	Yes (traffic)	No
Firemen	Asset on fire	No	No	No
Power supply company	Transmission power lines	Yes (power lines)	Yes (power lines)	Yes (power lines)
Emergency telephone 112	None	No	No	No
Drivers	None	No	No	No

5.2. Egnatia Odos needs and high level requirements

Table 15 Egnatia Odos needs and high-level requirements to PANOPTIS system.

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
Seismic loads	Bridges, overpasses, tunnels, loss of stability Slopes and embankments loss of stability	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• Bridge equipped with vibration, tilt, sensors • geological measurements	"Tuned" dampers, fuses	When intensity Ritchter scale higher than the set point, stop traffic, protect bridges	Calculation of stability of structures (foundations, slopes and retaining structures) under the effect of different and synergetic hazards Model of ground surface deformations and slope displacements	Geotechnical Analysis tool connected to ground sensors
		Sync-Post Hazard: damage assessment				
		Post Damage assessment	After-incident impact assessment based on visual analysis.	• Tracking from National Geological Institutes (during accident) • computer vision and Machine Learning (ML) damage diagnostic, • mobile mapping making use of Unmanned Aerial Vehicles (UAV) technology in non-accessible regions	Calculation of stability of structures (foundations, slopes and retaining structures) after incident	Geotechnical-structural analysis computer vision and Machine Learning (ML) damage diagnostic, mobile mapping making use of Unmanned Aerial Vehicles (UAV) technology in non-accessible

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
						regions
Heavy rain/ hail storm	Overloading of drainage systems Scouring in roads, bridge decks and support structures Threat to stability of slopes and embankments (including mudslide) Damage to signs, lighting, fixtures, and supports Deterioration of structural integrity of roads, bridges, and tunnels due to increase in soil moisture levels (only if increase in frequency)	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• No current hail prediction • Announcement National Meteorological Agency • Alarm in SCADA system, associated to Traffic Control Centres (TCCs)	Monitoring of amount of waterfall + wind	• Lack of accurate prediction of hail • Lack of precise long term predictions to adapt maintenance plans • Lack of synergetic risk models, to analyse various scenarios/ multi-hazard assessment	Improved short and long-term prediction models Multi-Hazard vulnerability and assessment	Geotechnical Analysis tool connected to ground sensors Advanced meteorological models, coupling in-situ sensors data
		Sync-Post Hazard: damage assessment				
		• Tracking from National Meteorological Institutes and in situ sensors. Owned model. (during accident) • Post Damage assessment	Post damage impact assessment of structures, slopes, etc. (visual, and using ground vehicles)	• Lack of erosion control measures • Lack of assessment of structural/geotechnical impact in structures	Structural and geotechnical analysis of structures after hazard event Model of ground surface deformations and slope displacements Improved damage mapping techniques Use of drones for non-accessible areas	Use of drone-based sensors coupled with satellite observation
Fog	Traffic Accidents in Motorway, main road network	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		No detection of fog applied	No preventive protocol applied	No gaps	No needs	No requirements
		Sync-Post Hazard: damage assessment				
		Pilot installation in one	Connected to	No gaps	No needs	No

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
		Toll station (outdoor sensor)	Special lighting system			requirements
Snowfall event	Main road collapse, traffic accident susceptibility Deterioration of pavement due to increase freeze-thaw conditions Structures corrosion (salt penetration in bridge decks reaching the reinforcement) Loss of stability in slopes	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• Announcement from Road Weather Information Systems (ice warning meteorological station) • Early Alarm in SCADA	• salt spreading • Corrosion of reinforcement cannot be predicted. Only detected by visual inspection. • In case of poor visibility (ice, ground blizzard, accident) and on command of Police→ cut traffic	Currently protocols are based only in Temp. Sometimes fail to predict reliable levels of ice, and salt is wasted (environmental and economical cost). Corrosion of reinforcement is not predicted, Very high costs associated to repairs.	Improve decision-making tool, coupling wider range of variables (including salt amount, costs), to optimize operations. Advanced decision tool based in multi-hazard scenarios	Improved models, Implementation of networked sensors Decision support tool
		Sync-Post Hazard: damage assessment				
		• Own tracking, visual follow-up, owned meteorological models, • Salt spreading vehicles equipped with sensors sending data, to follow up event	• Salt spreading vehicles measures Temperature with IR, coupled with meteorological models, can predict the amount of salt to spread in function of	Need for automated communication among different stakeholders (RI managers, RI operators, salt operators, traffic authorities) Need for more accurate impact assessment tools (effect of corrosion of structures)	Model to predict/follow-up the effect of salt in reinforcement corrosion. Integration of sensors in asphalt to monitor salt filtration + other auscultation measures Produce more accurate very short-term icing-prediction models based in Temperature and Humidity	Implementation of networked sensors Decision support tool Common operational picture with other stakeholders

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
			meteorological predictions		in-time measurements. Accuracy in icing prediction can lead to significant savings (environmental and economic) due to optimization of salt use. Not to mention benefits in traffic management, and prevention of accidents and cuts. Advanced decision tool based in multi-hazard assessment Improved communication with police, traffic regulators	
time and load deterioration	Pavement	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		N/A	N/A	N/A	N/A	N/A
		Sync-Post Hazard: damage assessment				
		visual inspection, instrumental measurements	data processing, evaluation report by experts, rehabilitation proposal	traffic assessment for visual and instrumental inspection	special software, hardware for photographic data collection (high definition cameras on vehicle)	Photometry techniques

- **Communication procedures applied and requirements**

The Operational Procedure of Egnatia Odos SA for duties and responsibilities of Traffic Control Center Operators (TCC) under normal circumstances to deal with road incidents, are defined in the Operations Manuals of the Egnatia Motorway and in accordance with Emergency Plan (EP). This Operational Procedure applies to Egnatia Motorway and Vertical Axes, where a Traffic Control Center exists and within its competence.

The TCCs operators implement specific procedures for road and tunnel operation under normal conditions and under emergencies. In particular, the operating procedures for emergency incident management describe in detail the sequence of actions for each type of incident (e.g. accident, stopped vehicle, heavy snow etc.) during all stages: detection, confirmation, communications, traffic management, information provision, site management and clearance.

TCCs are not evenly distributed along the motorway. Three TTCs are located at the western part of the motorway, two are located at the central part and one at the eastern part. The specific characteristics of each road section (i.e. successive tunnels, geometry, etc.) were the main factors that mandated initially the establishment of a TCC.

Each local TCC monitors and manages dynamically the traffic in sections ranging from 30km up to 70km. These sections are under full surveillance through TMS software and field equipment (1,000 CCTV cameras, 700 SOS phones in tunnels, 100 VMS, several hundreds of Lane Control Signals, Variable Speed Limit Signs, 30 Road Weather Information Systems, 17 Public Address Systems in tunnels, etc).

Additionally to TCCs, all “Egnatia Odos” motorway sections are patrolled daily by 13 on-vehicle EP Units. When an incident occurs, TCC staff work closely with EP Units and, if needed, with other public rescue services, to ensure the safety of road users is maintained and traffic flow is properly directed and managed.

For the operation of the “Egnatia Odos” TMS, customized TMS software communicates and controls all traffic management electronic signs and devices installed along the motorway. The field equipment integrated into TMS, are:

- Variable Message Signs (VMS)
- Lane Control Signs (LCS)
- Variable Speed Limit Signs (VSLS)
- Traffic Lights
- Flashing Warning Signs
- Inductive Loops
- Over-Height Vehicle Detectors (OHVD)
- Road Weather Information System (RWIS)

The motorway has been divided in many short subsections (zones) taking into account the location of each one of the signs/devices and also the location of interchanges or emergency crossovers. Predefined traffic management scenarios, which are incident type and zone location specific, have been developed and are used when appropriate

The Emergency Plan is the systematic, planned and synchronized usage of people, services and equipment in order to reduce the duration and the effect of incidents, resulting in improved road users' safety and ensuring the safety of the maintenance staff.

For any non-frequent event that results either in the decrease of the road capacity or the increase of the traffic, which are mainly related to unexpected incidents such as accidents, stopped vehicles, bad or extreme weather conditions, entrance of animals on the road, work destructions (eg bridges), slow-moving vehicles, oversized vehicles, but to expected incidents, such as sports events.

Emergency Services means the Hellenic Police department (EL.AS) the Traffic Police department, the Fire department, the National Center for Emergency Assistance (EKAV), the General Secretariat for Civil Protection, and any other Public Service has been instructed, or authorized by the Greek State to handle and manage emergency events.

The 4-digit emergency phone number (1077) can be called by road users, in case of emergency events or incidents, which is encountered by the Traffic Control Center Operators. The 4-digit phone number is known to users by vertical signs on the road or by web site, electronic message of the variable message sign (VMS).

Traffic Control Center Operators are responsible for the:

- Road Traffic Code - General Road Traffic Law
- Use of SCADA software and in particular the management of ventilation, lighting and fire systems
- Use of TMS software and in particular for traffic management systems (eg Traffic Signals, LCS, VMS, VSLS, etc.)
- Use of CCTV management software
- Use of emergency call (SOS) management software and calls to 1077
- Use of a radio management system and broadcast radio messages
- Use of a loudspeaker system
- Use of back-ups of databases and other files
- Proper use of information systems and use of anti-virus protection systems
- Personal data protection issues (eg processing, storage, transmission, etc.) according to the European Regulation (EU) 2016/679, the National Legislation and the operational procedure ΛΔ-ΕΟΑΕ-ΛΕΣ-420
- Issues relating to the passage of overweight and oversized vehicles
- Issues relating to the passage of vehicles transporting dangerous goods

- **Stakeholders involved**

Stakeholder	**Asset**	**Monitoring responsibility**	**Reporting responsibility (if yes, to whom)**	**Maintenance responsibility (financial, operational)**
Farmers/ landowners	Soil, slopes	No	No	No
Egnatia Odos SA	Road Management	Yes	Yes	Yes
Police/ Civil Protection	Traffic	Yes (traffic)	Yes (traffic)	No
Fire Department	Asset on fire	No	No	No

Power supply company	Transmission power lines	Yes (power lines)	Yes (power lines)	Yes (power lines)
Emergency telephone 1077	Traffic	Yes	Yes, to whom it may concern (police, fire department, civil protection, Egnatia Odos SA)	No
Drivers	None	No	No	No

5.3 Comparison of ACCIONA and Egnatia Odos needs

This subsection deals with the analysis of the main differences between the needs of the two end-users of the project, which could be interpreted as local adaptation needs, and the similarities, which could be understood as general needs of road operators.

The differences between ACCIONA and Egnatia Odos radicate in the specific characteristics and local environment of the networks they manage:

- **In term of ITS implementation**, whereas Egnatia Odos manages a network with high degree of ITC: provided with sensing devices in all bridges and tunnels of the section, and even maintenance plan for bridges based on seismic vulnerability analysis of bridges[66]; the Spanish network is in their infancy with regard to ITC, automatization and data processing for DSS. Therefore, the needs of ACCIONA for their road corridor are more demanding than Egnatias': from installation of ground and remote sensors to automatization of processes (including alarms and communication), and data modelling to adapt maintenance operations.
- **In terms of hazards exposure,** it obviously depends on the location: in the Greek site the strong seismic loads predominates over the rest of the threats. The potential impact of seismic loads in infrastructure can be aggravated by extreme meteorological events such as heavy rain (causing erosion). Consequently, Egnatia Odos cares about Geotechnical and Structural Analysis tools and RWIS integrated systems. With regard to the Spanish site, the predominating threats to mobility are snow/icing conditions and landslide risk. Therefore, ACCIONA requirements focus on supporting winter operations by using advanced RWIS systems, and monitoring of slopes and embankments to prevent landslides.

Similarities between the two road operators, and then general needs, are listed below:

- They both propose the **implementation of computer vision/ advanced photometry for asphalt inspection**. The road surface is one of the assets that requires more maintenance, and therefore involve more resources. A smart tool applied to Road Management should always consider the operations related with the keep-up of the road surface. The technology requirements expressed by the end-users show that there is a need for shitting from man-made/visual inspections of road surface to automatic detection of damages in road surface based on image analysis and machine learning.

- Not only in the road surface, but also in other **infrastructure such as tunnels and bridges, there is a need to implement computer vision and machine learning techniques in daily inspection,** for **automatic detection of damages**.
- There is an evident preference for using **drone technology** instead of traditional vehicle based technologies, in inspection operations, because of its advantages in terms of time, safety and traffic mobility.
- Mobility is a very important indicator in the concession contracts. Problems with traffic mobility can lead to economic penalties for road operators. Therefore, road operators needs to maximize resilience in adverse conditions. There is a general need for a **resilience assessment tool**: first detect risk as soon as possible the risks (**forecasting models and alarms**), second mapping the adverse event evolution (**evolution of risk maps**), and overall have a **decision support** tool that uses real data and models based on historical data to support decision making.
- It is also a common need for all road agencies the **implementation of RWIS tool to predict and manage different meteorological conditions** (depending on the weather conditions of the specific site). The more concerning meteorological events look to be strong precipitation (flood) and fog.
- **In locations exposed to icing/snow frequent events, the** road operators consider as crucial the integration of **smart tools using RWIS and climatic models to support decisions in winter operations**. The salt gritting operations represent high cost for road agencies, not to mention the cost of traffic collapse, or vehicle accidents, very likely in icing conditions. A system supporting resilience of roads and optimization of operational costs under snow conditions seems to be a vital need for road agencies.
- **Need for multi-risks models**, coupling different nature database: for example crossing traffic management models with costs optimization, and weather forecasting.
- **There is a common interest in testing SAR technologies for monitoring slopes and ground deformations**. It is a very promising technology for the precision of the measurements (in the mm scale) not reachable by any other technologies, and the friendly use (not involving sensing devices, not affecting traffic).
- Need to **favor collaborative work among stakeholder through a common visualization tool** involved in road operations, specially under emergency operations.

5.4 Complementary needs provided by external organizations to PANOPTIS project

As explained above, the needs and high-level requirements provided by the end-users of the project have been complemented with some inputs from external end-users, contacted by some partners of the PANOPTIS consortium.

It is important to remark that, at this early stage of the project, it was difficult to collect inputs from external respondents, since most of them were only slightly aware of the technologies included in the project. What is more, in some cases, the respondents did not even have extensive knowledge on all fields of monitoring and maintenance management. Therefore, the needs and requirements reported in this subsection are more general than the ones reported by Egnatia Odos and ACCIONA, and in most cases, do not propose solutions based on the specific technologies of PANOPTIS.

However, as the project advances, the contributions from external end-users are expected to keep growing. The strategy of the project is to create a “PANOPTIS” community, formed by experts along the Transport Infrastructure value chain. This experts’ community, covering different roles and responsibilities, will be engaged throughout the project, and especially in the design stage. For instance, two end-user’s workshops are planned within the WP2 in order to disseminate the information about the technologies of PANOPTIS and allow multi-profile stakeholders to contribute with additional requirements.

5.4.1 Rijkswaterstaat[xxx, xxxi] needs and high level requirements

Rijkswaterstaat is a Dutch infrastructure operator, and therefore their profile would be equivalent to that of ACCIONA and Egnatia Odos.

Table 16 Rijkswaterstaat needs and high level requirements to PANOPTIS system.

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
Extreme precipitation ***Frost/Thaw cycle*** ***Prolonged high temperatures*** ***Increased (freight) traffic*** ***Calamities (traffic accidents)***	Bridges, Overpasses, Tunnels, ZOAB , Asphalt (Zeer Open Asfalt Beton; Road Safety and Drain Asphalt)	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		- Slip prevention monitoring system: measures temperatures in asphalt and on the surface of the asphalt. Additionally it measures temperatures and air moisture content of berms directly adjacent to the road. - Measurement of expansion and shrinkage movement of critical assets (bridges, joints) -Yearly monitoring of road deck to detect signs of:	- Slip prevention monitoring system measures continuously in winter. -In winter, sensors may have a downtime of maximum 48 hours. - Immediate intervention is taken when shortcomings are detected by maintenance contractors or Rijkswaterstaat	- In summer no continuous temperature measurements are taken. - Daily inspection by maintenance contractors or Rijkswaterstaat employees is key to early damage detection.	- Continuous temperature measurements in summer. - A monitoring system that would detect signs of ravelling is desired.	-Need for more information about PANOPTIS technologies to propose requirements

[xxx] Rijkswaterstaat is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands (https://www.rijkswaterstaat.nl/english)

[xxxi] The role of the respondent was Senior Advisor Maintenance Main Road Network. Main expertise is asphalt maintenance.

Hazard	Affected Critical infrastructures	Current detection mode/ monitored parameters	Current protocol applied	Problem/Gaps	End user needs	Technology requirements
		rigidity, lateral and longitudinal flatness, rutting, cracking and ravelling. -Bridges, tunnels and overpasses are monitored every 6 years. -Daily visual inspection of maintenance contractor. -Main road network is traversed daily by Rijkswaterstaat employees.	employees.			
	Sync-Post Hazard: damage assessment					
		There is no monitoring protocol unique for post-hazard events.		The daily inspection of roads may be intensified during or after extreme events		-Need for more information about PANOPTIS technologies to make proposals

5.4.2 French road police (Gendarmerie) needs and high level requirements

A very interesting complement are the needs expressed by the French Road police, because they represent a new point of view: the point of view of a new kind of stakeholder, dealing with security of drivers; in comparison with the Road agencies interviewed previously, responsible for operating and maintaining infrastructure.

Table 17 French road police (Gendarmerie) needs and high-level requirements to PANOPTIS system.

Situations of interest within the PANOPTIS system
1. Forecast weather, 2. Infrastructure risks (vulnerability of bridges, structures), 3. Alarms (imminent climatic events in zones where there are important vulnerabilities and 4. Post-event situation with damages (including an icing on the cake, which is the module of decision-making aid for Re-router the traffic, to repair, etc).
Objects/events to see in priority on these situations
• Group Date/Hour • Times before release of event weather - foreseeable Place of weather events - Levels of alert for the weather • Main and secondary axes, number of ways - service areas - petrol stations - turn pike - structures (bridge, tunnel) • Railway Networks and related areas • Relief exits and deviations • Town halls, municipal meeting rooms • Airports, aerodromes, heliports, stadiums, landing areas • Telephone relays • Intelligent Transport System relays(SCOOPF@) • Evaluation of the number of immobilized vehicles - length of the column of immobilized vehicles - nature of the immobilized vehicles - evaluation of the number of people in immobilized vehicles • Geolocalisation of the motorway, fixed services (Exploitation Command Posts) and mobiles (patrol) • Site and identification of the radars • Localization of the camera-equipped vehicles (LAPI for the plates reading) - Localization of the exploitation cameras - localization of the security/safety cameras • First-aid services • Security/public services: police (gendarmerie, CRS in France)

- Services of maintenance of roadway systems (snow dispersion vehicles, sand spreader, etc.)
- Military assets
- Population data: where, when, measures taken: alarm, evacuation, setting with the shelters, etc.; modes of transport

Building sites

Functional needs

- Each event will have to be associated with a descriptive file (for the monitoring and the follow-on).
- Historisation is necessary (events and associated actions).
  Digitized maps of situation that can be printed under current format (pdf type), are essential.
- It would be relevant to be able to create and manage book of complaints.
- A search engine by keyword would be very interesting
- ACCESS: It is preferable to access to information via a PANOPTIS service web rather than a terminal of the system. The service web will imply the opening of access accounts for the territorial command levels of the gendarmerie, with thus the supply of ad hoc identifiers.
- Linux is the software operating system.
- A mobile access mobility on NEOGEND terminals (Gendarmerie "smart phones") could be interesting.
- The cyber risk must be controlled.
- If the system generates personal data, the laws concerning data processing and freedoms (GDPR) will have to be respected

6 Conclusions

In general terms, the end-users needs can be summarised as follows:

- Substitution of visual inspections by remote sensing technologies
- Predictive models for meteorological events
  - Short term, to improve driver's safety and plan daily maintenance operations
  - Long term, for better planning of resources for Road operations, and better estimation of tenders
- Risk and vulnerability assessment of critical infrastructure to help operators to fine-tune the nature and extent of their preventive measures, and the time of their implementation, and adjust the life cycle costs models.

- Monitoring and control of asset's health, using sensor technologies (instead of man-based), in a continuous basis, to be able to create a data base that can be processed and analysed to produce models and alerts.
- Applying remote sensing techniques (SAR satellite, drone) to monitor stability of geotechnical infrastructure.
- Do more frequent inspections to detect possible earlier and thus to minimize the repair costs through a more preventive maintenance.
- Integration of early warning alarms for different events, (especially imminent climatic events in zones where there are important vulnerabilities)
- Integrate sensor techniques and weather forecasting tools into winter operations to optimize decision-making about gritting actions and traffic re-routing (if needed).
- Use mapping techniques in maintenance operations (integrating multi-range sensors, visual, LiDAR, thermographic)
- Use drones in daily maintenance operations and incident management
- Use of SAR (synthetic aperture radar) data to detect small displacements in embankments/cuts/slopes
- Integrate all data into one unique Smart road tool to help operators in the decision making process
- Digitized maps of risks situation
- Streamline communication with other stakeholders (civil protection, Administration, National Department of Traffic, National police), by using a common operational picture (COP) system limiting Access to information.
- Integrate automatization in communications (communication between different end-users of the tool, but also communication with drivers through variable message signs)
- Post and sync-event situation with damages update
- Traffic management tools: Evaluation of the number of immobilized vehicles, length of the column of immobilized vehicles, nature of the immobilized vehicles, evaluation of the number of people in immobilized vehicles
- Geolocalisation of the motorway assets (all kind, from infrastructure, road signs, ITS devices, RWIS, transfer areas, SOS post, etc) and services (Exploitation Command Posts) and mobiles (patrol)

Regarding functional requirements:

- Create History log
- Search engine by keyword
- Easy Access via website
- Connection to smartphones
- Ad-hoc access permits.

- Pay attention to cyber risk and personal privacy

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