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

D6.3: D6.3 Business Continuity Models and Adaptation Strategies assessment report

Work package	WP6: Risk Assessment, Data Fusion, DSS and Enhanced Visualization Interface
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Document Control Sheet

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0.2	17/12/2020	Added scenarios and weight for qualitative resilience assessment	ACCI, EGNATIA, IFS
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1.0	31/01/2021	Revised version according to internal review	*Submitted version*

Legal Disclaimer

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Abbreviation List

Abbreviation	Definition
PDCA	Plan-Do-Check-Act
BCMS	Business Continuity Management System
GCT	Guardia Civil de Tráfico
RI	Road Infrastructure
TTC	Traffic Control Center
EP	Emergency Plan
RAT	Resilience Assessment Tool
HRAP	Holistic risk assessment platform
IMS	Incident Management System
DSS	Decision Support System
MHVM	Multi-Hazard Vulnerability Modules

Executive Summary

Main concepts of business continuity according to ISO 22301 to mitigating impacts in case of disruption of system service are used as reference to develop procedures and strategies to ensure the continuity of the road infrastructure service. Existing best practices and operating principles adopted by end-users in the event of disruption have been identified. Then, the most recurrent outage and service disruption scenarios associated to hazards encountered in the Spanish and Greek demo-sites were identified to elaborate targeted procedures and measures. Adaptation and mitigation procedures to be used in PANOPTIS are then based on the main strategies of risk management (avoidance, sharing, elimination, reduction and control, transfer) combined with the identified existing best practices and operation procedures. Adaptation strategies are implemented and assessed in HRAP platform through the RAT tool assigning scores to defined indicators associated with resilience capacities.

1 Introduction

1.1 Purpose of the Document

The report is the outcome of Task 6.2 “Assessing Business Continuity Models and Adaptation Strategies”. It aims to identify the best practices of transport sector to minimise service disruptions to road infrastructures under different hazards pressures in the perspective of business continuity according to main concepts defined by ISO 22301:2019 Security and resilience-Business continuity management systems-Requirements.

In agreement with the end-user partners, ACCIONA e EGNATIA, recurrent scenarios of service disruption and critical functionalities associated with the main hazards addressed in PANOPTIS have been identified, taking into account the scenarios already identified in WP2 and the risk exposure of the two demo-sites analysed in D2.5.

Adaptation strategies framework, consisting of operational measures and procedures, to minimise service disruption is defined in this report by laying the main risk management strategies which are combined with existing best practices and operational principles adopted by end-users.

Adaptation framework is supported by the HRAP platform, which allows an evaluation of different strategies according to selected scenarios through the qualitative assessment of resilience carried out by implemented RAT tool.

1.2 Intended audience

D6.3 is public, thus it will be reachable by any interested stakeholder of PANOPTIS system.

2 Regulatory aspects of business continuity and organizational resilience

Security and resilience is treated within the ISO22300, in particular EN ISO 22301: Security and resilience - Business continuity management systems – Requirements [1] and EN ISO 22313: Security and resilience - Business continuity management systems - Guidance on the use of ISO 22301[2].

The definition of the structure and requirements for implementing and maintaining a business continuity management system (BCMS) are given, namely:

a) a policy;
b) competent people with defined responsibilities;
c) management processes relating to the planning, the policy, the implementation, the performance assessment;
d) documented information supporting operational control and enabling performance evaluation.

This has to be done with a Plan-Do-Check-Act (PDCA) cycle, where the cycle connects the Plan (establish), Do (implement and operate), Check (monitor and review) and Act (maintain and improve).

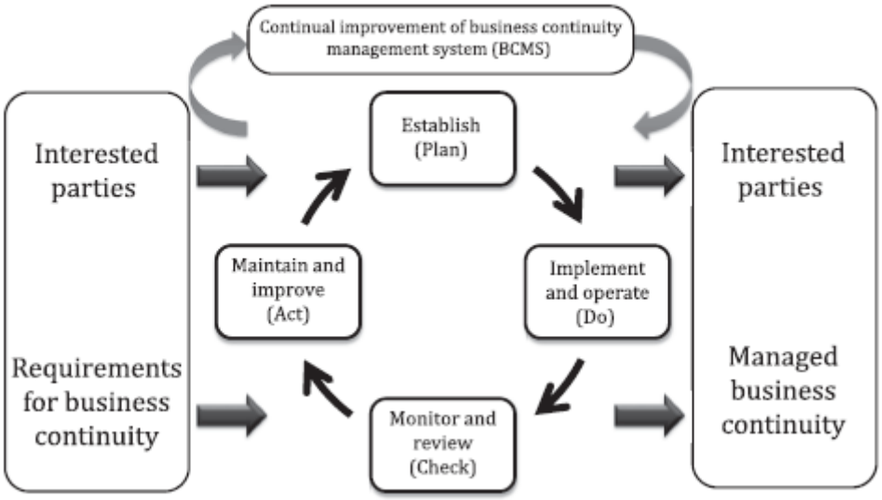


Figure 1: PDCA cycle applied to BCMS processes, extracted from [2].

It should be noted that these standards illustrate conceptually how business continuity can be effective in mitigating impacts from sudden disruption and for gradual disruption.

3 Best practices and operating principles

Road Infrastructure (RI) are a critical support system for the smooth operation of our societies and economies that can be compromised by the occurrence of hazard events causing disruptions on critical sections of the RI network, delay or stop in transport flows, etc. With regard to this, RI resilience refers also to system's capacity to remain operational under different hazard pressures. According to ISO 22301 [1], one can refer to:

- *business continuity* as the capability of an organization to continue to delivery of products and services within acceptable time frames at predefined capacity during a disruption,

- *business continuity plan* as documented information that guides an organization to respond to a disruption and resume, recover and restore the delivery of products and services consistent with its business continuity objectives.

In order to improve RI resilience, a business continuity plan by providing transport services to minimise RI service disruption is required, comprised of a set of adaptation strategies developed according to stakeholders like infrastructure managers, operators or regulating authorities in the transport sector.

For transport service, the main measures are often determined by legislators at the different levels of administration, it is then up to the different actors in the transport sector according to their interests to implement adaptation strategies and rules. Table 1 shows the interests of public and private service and infrastructure providers (RI operators) and their possible approaches in terms of adaptation according to a study by European Environment Agency [3].

Table 1 Adaptation approaches for transport private and public providers.

Actors	Interest in transport	Existing and potential adaptation approaches
Private and public providers — service operation	• Business continuity by providing transport services • Provide transport services as a basic service for society	• Adapt operation procedures; • Request climate-proof infrastructures and vehicles/equipment • Change to other infrastructure and equipment providers if that is an option • Accept interruptions if the related costs are lower for the company than adapting (cost–benefit analysis for the company)
Private and public providers — infrastructure	• Business continuity by providing transport infrastructures to operators • Provide transport infrastructures to operators to ensure a well-functioning transport system	• Proper maintenance of the infrastructure • Making infrastructure climate-resilient • Provide alternative routes (redundancies), if the related costs are lower for the company than adapting (cost-benefit analysis for the company) • Otherwise accept interruptions and repair the affected infrastructure after a disaster • insure against potential damages

For RI operators, main business continuity objectives can be intended as the interest of providing and ensuring the functionality of the infrastructure and related service through adaptation strategies in order to ensure a minimum level of functionality or minimising disruption. With reference to this, the business continuity plan should provide for strategies and measures:

- what will be done,
- what resources will be required,
- who will be responsible,
- when it will be completed,
- how the results will be evaluated.

This last point related to evaluation will be developed with the resilience assessment tool (RAT) that takes into account adaptation measures and strategies according to specific indicators, as will be explained in section 5.

3.1 Existing operating principles and best practices

Given the approaches listed above, operating principles and best practices that are currently adopted by ACCIONA and EGNATIA in relation to events that cause disruption to the normal functionality of RI are identified below. The described procedures and measures are described considering the actions to be done, the resources, the RI people in charge and time.

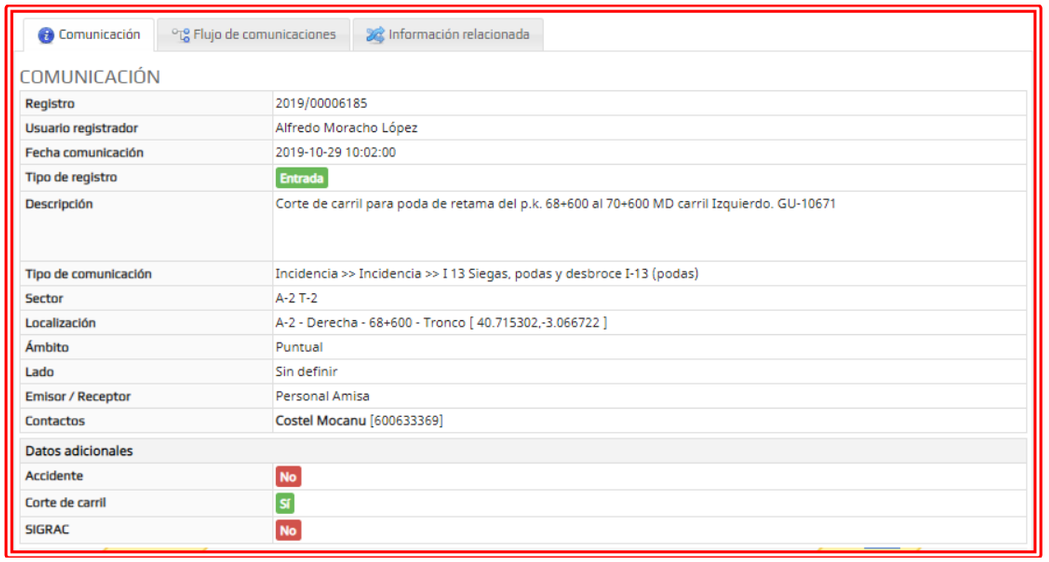
3.1.1 ACCIONA

In case of disruptive events, A2 operators (ACCIONA) are only responsible for:

- signposting the accident,
- notify the accident to other agents (usually Guardia Civil, Spanish police in charge of traffic),
- notifying the Ministry (specific contact) if needed.

The Ministry of Transport (owner of the motorway) collaborates with two organisations: ACCIONA (Concession for conservation and operation) to look after the infrastructure and maintain it and ensure is drivable and secure; and Guardia Civil for managing the traffic.

All communications are managed by the Communications Service, whose main task is to manage any type of communication regarding accidents and therefore the operation of the motorway, communicate in relation to this with the technical staff concerned and about the intervention work resulting from these service interruptions. All incoming and outgoing phone calls from the communications service must be listed in the SmartRoads tool.


Comunicación | Flujo de comunicaciones | Información relacionada

COMUNICACIÓN

Registro	2019/00006185
Usuario registrador	Alfredo Moracho López
Fecha comunicación	2019-10-29 10:02:00
Tipo de registro	Entrada
Descripción	Corte de carril para poda de retama del p.k. 68+600 al 70+600 MD carril Izquierdo. GU-10671
Tipo de comunicación	Incidencia >> Incidencia >> I 13 Siegas, podas y desbroce I-13 (podas)
Sector	A-2 T-2
Localización	A-2 - Derecha - 68+600 - Tronco [40.715302,-3.066722]
Ámbito	Puntual
Lado	Sin definir
Emisor / Receptor	Personal Amisa
Contactos	Costel Mocanu [600633369]
Datos adicionales	
Accidente	No
Corte de carril	Sí
SIGRAC	No

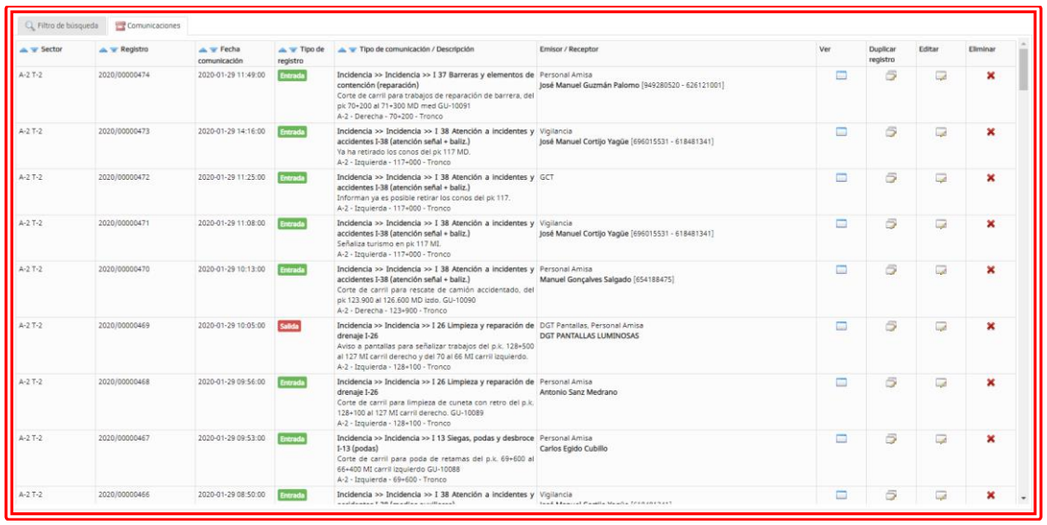


Figure 2: Example of listing phone call communications in SmartRoads Tool.

Operating procedures for traffic viability and accidents

The communication service is active 24 hours a day, every day of the year. In addition to the main task of providing information on motorway incidents, the communications service staffs provides information on the operation of the motorway section managed.
Below is a description of the situations for which actions are envisaged by the communications service and related procedures.

Ordinary Situations

Every Friday afternoon, the competent authorities (Guardia Civil de Tráfico GCT-manager of Traffic, and Guadalajara's Unidad de Carreteras- owners of the infrastructure) receive a detailed planning of the activities scheduled by ACCIONA for the following week.
In addition, every day, early in the morning, between 8 and 9 am, the competent authorities (Guardia Civil de Tráfico GCT and Guadalajara's Unidad de Carreteras) must receive all the information related to the road conditions as well as the works which can affect the traffic via email. The absence of traffic disturbances must also be reported.
The procedure is as follows:

- all information regarding exploitative conditions of the highway along with works which affect the traffic must be registered in SmartRoads tool,
- the conditions should be notified to Dirección General de Tráfico DGT (https://reno.dgt.es/reno/index.xhtml) and to the Ministry of Transport (http://www.inforuta-rce.es/).
- after informing all competent authorities, DGT's centre of the screen should be notified in order to correctly show the information in the variable message panels.

Figure 3 Example of listing incidents and related details in SmartRoads tool.

In the event of network failure, each detail of the incident must be notified via phone communication to the competent authorities pending the confirming via network.

Extraordinary Situations

All those incidents not expected or not informed in advance, which cause an alteration in the traffic conditions or in any case, when the closure of a lane is required for more than 15 minutes or the closure causes traffic jam, must be registered in SmartRoads Tool, InfoRuta and Reno.

Serious Accidents-SICRAG (Rapid Communication System for Serious Accidents)

In addition, operators (ACCIONA) use SICRAG as an application that generates a report for rapid communication of serious accidents in a specific number of cases under special circumstances as follows:

- 3 or more fatalities involved,
- 4 or more vehicles involved,
- vehicles transporting hazardous goods involved,
- heavy vehicles or buses involved,
- school vehicles involved,
- accidents inside a tunnel,
- high-profile personalities involved (with impact in media) or personnel from the Ministry involved,
- fire on the main road or roadsides,
- severe damage in infrastructure,
- the accident is consequence of public disorder,
- any accident with potential impact in media,
- simulations that affect traffic.

All the accidents out of the circumstances listed above are reported only via InfoRuta. But the accidents under the circumstances on the list are reported first via InfoRuta under the title “SICRAG communication” and then via the application of SICRAG. The application of SICRAG has different recipients: the template generated by the application SICRAG is sent to Madrid (Central Management of the Ministry). In addition, the report generated by SICRAG is sent to 2 specific emails and also there is contact for telephone call.

Winter Serviceability

During Winter Serviceability, preventive treatments must be carried out when the air temperature is below 3º C.

Daily before at 8:30 a.m. and, in the case of snow alert at 8:30 p.m., the communications service must register all the treatments carried out for the maintenance of the road in the Winter Serviceability’s web site (http://www.fomento-vi.es/Inicio.aspx). The reported information Kms treated with preventive and curative treatments, tons of brine used, plates of the vehicles used. In addition, whenever an incident resulting from winter weather events disrupts the road traffic, the related notification should be registered in the mentioned web site besides notifying it to the competent authorities via email. If the situation goes worse, the operators can also ask the competent authorities (Guardia Civil) to apply measures as the use of snow chains/winter tires for light vehicles and the interruption of heavy traffic.

Furthermore, it is important to keep up continuous communication with the adjacent sectors to the highway stretch in case of necessary preventive intervention.

Annual Monitoring of Winter Serviceability's Alerts

As the road owner required, ACCIONA should keep track of the days AEMET (Spanish national meteorological agency) alerts for snow and should indicate whether the removal of snow from the road was needed.

Breakdown Vehicles

Whenever there are operation/conservation car or machinery breakdowns, the corresponding insurance company must be notified. All the necessary data have to be requested from the operator who reports the breakdown in order to report to the insurer. When machinery fails, the Regional Department of the Ministry must be informed. All the information is registered in the Smart Roads tool.

Indicators

Road safety: actions on high accident concentration sections (TCA in Spanish from Tramos de Concentración de Accidentes).

The sections with high accident concentration (TCA) are estimated every year according to the working procedures distributed by the General Directorate of Highways (DGC in Spanish) attached to the Ministry using updated data of the year.

Required response: All the TCAs must be improved/ fixed/ corrected

Response time: 4 months. This period covers: redaction, approval and execution of new projects if needed. There is a possibility of extension to 8 months if the works needed are significant works or requires expropriations.

Penalties: there are tabulated monetary penalties to the operators if not solved

Road safety: accidental danger index (IP from Spanish Índice de Peligrosidad)

The aim of this indicator is to assess the effectiveness of the safety measures adopted by the operators (currently ACCIONA) to diminish the number of traffic accidents with victims. It is estimated using data from the 4 previous years according to the following equation:

Current IP (%)=100*(IP4-IP)/IP4.

Being IP: Accidental danger Index equal to nº of accidents involving victims*10e8/(Length of section*ADT*365) – ADT is Average Daily Traffic.

IP4: average IP (accidental danger Index) from previous 4 years.

Frequency of measurement: Ministry procedures-1 year. ACCIONA procedures-every 6 months

Penalty: no monetary penalty.

Winter road maintenance

Winter road maintenance must comply with the following threshold values and response times. If the threshold values or response times are exceeded a penalty is applied.

Indicator	Threshold value	Response time
Total traffic cut or traffic blockage occurs as consequence of snow, with no previous request/warning of traffic restriction to the competent traffic authorities by the operators according to procedures.	0 (none is accepted)	Cleaning and treatment with melting salts of road surface: duration of snowstorm >45 minutes Cleaning of roadsides: duration of snowstorm > 2 hours
Total traffic cut or traffic blockage occurs as consequence of heavy vehicle(s) accident(s), with no previous request/warning of traffic restriction to the competent traffic authorities by the operators according to procedures.	0 (none is accepted)	
Preventive traffic closure for heavy vehicles as consequence of snow	Maximum duration = duration of snow storm > 45 min	
Light vehicles driving without winter tires/ snow chains with no previous request/warning by operators according to procedures	0 (none is accepted)	
Presence of ice-sheets on the road	0 (none is accepted)	
% of road length with preventive treatment applied (deicing salts) below 2ºC of ambient temperature (current or forecast)	100%	

Storage of melting salts	To respond to annual average consumption under adverse meteorological conditions. Need for strategic location	

Penalty: tabulated monetary penalties, or even termination of contract in case of very severe fault by operators.

Security Surveillance (Patrolling)

It refers to the permanent patrolling of the road conditions every day and every hour of duration of the contract with the aim of ensuring safe driving conditions. The minimum length coverage is the total kilometres on both lanes every day. At night, during adverse meteorological conditions and during periods of high traffic intensity, the patrolling team must be composed of at least 2 people. During adverse meteorological conditions and high traffic intensity, the service must be uninterrupted. All the patrolling vehicles must be equipped with GPS to report the position. The GPS records are downloaded at the end of the day in the Smart Roads tools. Monthly reports of statistics are generated using these data

Penalty: there are tabulated monetary penalties if any of the rules are not respected.

3.1.2 EGNATIA

Egnatia Odos refers to Operations Manuals for duties and responsibilities of Traffic Control Center (TCC) operators under normal circumstances to deal with road incidents in accordance with Emergency Plan (EP) [4].

The EP is the systematic, planned and synchronized usage of people, services and equipment in order to reduce the duration and the effect of incidents, resulting improved road users' safety and ensuring the safety of the maintenance staff. Emergency Services means the Hellenic Police department (ELAS), 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.

In case of emergency events or incidents, an emergency phone number can be called by road users which is encountered by Traffic Control Center Operators.

Moreover, the TCCs operators implement specific procedures for road and tunnel operation under normal conditions and for emergency incident management describing the sequence of actions for each type of incident (e.g. accident, stopped vehicle, heavy snow, etc.) during all steps: detection, confirmation, communications, traffic management, information provision, site management and clearance. Predefined traffic management scenarios, which are incident type and subsections location specific, have been developed.

TCC, established at selected points of road subsections, locally monitor and dynamically manage the traffic through TMS software and field equipment (CCTV cameras, SOS phones in tunnels, VMS, lane control signals, variable speed limit signs, road weather information systems, etc.).

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.

4 Adaptation strategies

Risks related to climate change have an impact on RI that are concretely reflected in short-term delays and interruptions but also long-term interruptions and detouring needs in the event of destroyed infrastructure. Traffic disruptions or disservice in the RI can be the effects of to the high connectedness of the transport system itself and with other sectors, such as the fuel or electricity supply network

In this section, the hazards affecting the two demo-sites of the project have been identified and different scenarios that may occur have been associated with them, reported in Table 2. This analysis then allows which are the typical situations that influence the functionality i.e. the continuity of service in the RI sections, which can be classified in three main cases:

- traffic disruption, disservice or reduction,
- damage to structural RI assets,
- damage to non-structural RI assets.

Table 2 Hazards and associated scenarios affecting PANOPTIS demo sites.

HAZARD	SCENARIO	Demo-site concerned
Storm surge, heavy rain, flood	1. Traffic **disservice** or reduction on the road section or geographical area affected by the hazard event for a short duration 2. Damage to **drainage** components or to **cutting slopes**, required **soft** interventions	ACCIONA, EGNATIA
Strong wind and storms	1. Traffic reduction on the road section **due to fallen trees and plants or disruption if heavy vehicles are affected** 2. Damage to non-structural RI components/**light structures (such as gantries, even pedestrian bridge)**	ACCIONA, EGNATIA
Precipitation intensity (hail)	1. Traffic disruption or **disservice** in the geographical area affected by the hazard event for a	ACCIONA, EGNATIA

	short duration	
Extreme cold&increase freeze/thaw cycles	1. Damage to RI component **(specially to the pavement)**, required structural intervention and long-term alteration of the road viability	ACCIONA, EGNATIA
Ice-Snow	1. Traffic disruption/**disservice** or reduction on the road section or geographical area affected by the hazard event for a short duration	ACCIONA, EGNATIA
Fog	1. Traffic disruption or **disservice** in the geographical area affected by the hazard event for a short duration	ACCIONA, EGNATIA
Landslides	1. Traffic disruption or reduction on the road section or geographical area affected by the hazard event for a short duration 2. Damage to RI component, required structural intervention and long-term alteration of the road viability	EGNATIA
Earthquake	1. Traffic disruption or reduction on the road section or geographical area affected by the hazard event for a short duration 2. Damage to RI component, required structural intervention and long-term alteration of the road viability	EGNATIA
Traffic accident	1. Traffic disruption or reduction in the road section by the hazard event for a short duration	ACCIONA, EGNATIA

	2. Damage to **road surface and accessory** components	
Fire	1. Traffic **disservice because of poor visibility** or reduction on the road section or geographical area affected by the hazard event for a short duration 2. Damage to RI component, **(unlikely)** required structural intervention and long-term alteration of the road viability	ACCIONA, EGNATIA
Power outage	1. Damage to RI monitoring system 2. Damage to RI monitoring component **(usual battery operation)**	ACCIONA, EGNATIA
Wild animals	1. Traffic disruption**/disservice** or reduction on the road section	ACCIONA, EGNATIA
Corrosion of the rebar in reinforced concrete structures/ steel structures	1. Damage to infrastructures **(speci ally to the bridges in case of RC)**, required structural intervention and long-term alteration of the road viability 2. In a very severe scenario, corrosion can lead to collapse of the infrastructure (e.g. bridge), meaning in the worst case total close of the road for a long period or even human fatalities.	ACCIONA, EGNATIA

In relation to the scenarios defined above, one can then identify strategies and measures that can be adopted by RI end-users so that core functionalities of RI are ensured in case the identified scenarios occur until the return to the normal situation.
It is useful to distinguish two different approaches to mitigating the effects of these scenarios, the first being a proactive management approach and the second a reactive one

which are taken into account for the PANOPTIS system. The first involves measures and actions that can act on the causes of that scenario, while the second involves measures and actions that reduce the effects of the scenario by providing alternatives to the previous measures [5][6][7].
The proactive approach concerns risk response strategies to prevent the risks that can be eliminated and minimize those that are impossible to avoid, according to four techniques:

Risk Avoidance
Risk avoidance is the first technique that can be used to eliminate a risk and its effects. The risks identified for road infrastructure cannot be avoided, as it is not possible to remove all events caused by climate change. What can be done is to avoid the risk by acting on the affected RI assets, i.e. to avoid their exposure to that particular risk.

Risk Sharing
Risk sharing is a technique that involves accepting the risk but sharing it and its effects with another party. It also involves sharing and then working together to implement measures and actions to reduce a risk. For example, procedures involving competent bodies such as the Ministry of Transport, regional and local authorities, RI operators and owners can be envisaged.

Risk elimination
This strategy includes all measures that can be implemented to eliminate the risk to which the assets are exposed. These include, for example, all those countermeasures that involve stabilising areas affected by landslides and repairing damaged structural elements.

Risk reduction and control
Risk reduction deals with risks taking measures and actions to minimize the impact or the probability of the risk to an acceptable level, such as monitoring structures against particular risk exposures such as corrosion of reinforced concrete bridges or metal structures, or the removal of dry shrub and bush cover near the highway to reduce fire hazard, improving de-icing and fog procedures through the use of alerts sensors.

Risk transfer
Risk transfer is a method to reduce the risk through shifting it to another party, e.g. the purchase of insurance provided against repair action and business interruption.

The reactive approach, on which the business continuity models are based, follows the same strategies but proposes alternative solutions in response to occurred scenarios associated with the risks, already minimised by the actions and procedures of the proactive approach.

The set of measures and procedures foreseen by the different approaches constitute the adaptation strategies protecting against negative impacts of disruptive scenario, but also building resilience in order to constitute a circle of continuity of RI service, from the scenario of disruption or interruption to the “back to normal” scenario.

In the PANOPTIS system this set of measures within the risk reduction and control strategy are implemented through an early warning system consisting of the different sensors managed by the HRAP platform and the IMS and DSS according to the different hazard-related scenarios. In fact, it is possible to set up a system of constant monitoring such as the corrosion monitoring system that follows the evolution of the phenomenon degrading the structures and to intervene when selected parameters exceed the acceptable risk threshold. Another possible way of monitoring is targeted monitoring such as drone

inspections to detect the effects of corrosion and then take action, or in post-damage scenarios to survey and estimate damages after the event occurring.

PANOPTIS system through HRAP also improves the ability and rapidity of intervention by motorway operators, who can benefit from real-time control that allows them to anticipate the action to be taken in relation to disruptive events. In addition, the possibility of using analysis and calculation tools, i.e. MHVM modules for the assessment of structural vulnerability, allows operators to implement measures and actions to avoid or eliminate the related risk according to consequence estimations.

Key component of the PANOPTIS system, i.e. the RI infrastructure monitoring framework in routine and post-event situations adds to the existing operational procedures and best practices already adopted by end-users.

5 Assessment of adaptation strategies in RAT Tool

In this section reference is made to what has already been introduced in D4.4.1 PANOPTIS resilience framework-V1, i.e. the assessment of RI resilience in qualitative terms through the use of indicators that are associated with resilience capacities.
For the qualitative estimation, as declared in the above mentioned report, end-users' interviews were required in order to determine the weight to be associated to the resilience capacities and to the respective indicators according to end-users' experience, reported in Table 3.
A qualitative assessment of resilience is then proposed considering the different scenarios that have been previously identified to show the influence of adaptation strategies discussed in the previous section. In a first assessment, defined as a baseline, only existing procedures and measures will be taken into account, while a second assessment defined as adapted, will take into account the adaptation measures proposed in the framework of the PANOPTIS system.
This allows us to assess the feasibility of the proposed adaptation measures taking into account typical scenarios that end-users are constantly confronted with in order to match the policy targets and optimal adaptation measures in agreement with general conditions of the Member States, regional and local authorities. It also allows to understand the impact of the measures on the functionality of the road infrastructure and demonstrates how they are integrated into a procedure that is the qualitative assessment using the RAT tool included in HRAP.

Table 3 Weights associated to resilience capacities, indicators and categories/subcategories for the resilience qualitative assessment.

Resilience Capacities	Resilience capacity weights	Resilience Indicators	Indicator weight	Resilience Categories / Subcategories	Weights
1. Anticipatory	0.1	1.1. Quality / extent of mitigating features	0.2	**1.1.1. Equipment and procedures for hazard mitigation exist**	**0.8**
				1.1.1.1. Procedures are documented	0.4
				1.1.1.2. Procedures are regularly revised	0.6
				1.1.2. Early warning system exists	**0.2**
				1.1.2.1. System is tested	0.3
				1.1.2.2. System is up to date	0.3
				1.1.2.3. How many hazards it covers	0.2
				1.1.2.4. How many assets it covers	0.2
		1.2. Quality / extent of monitoring system	0.2	**1.2.1. Equipment and procedures for operational monitoring**	**0.8**
				1.2.1.1. Procedures are documented	0.4
				1.2.1.2. Procedures are regularly revised	0.6
				1.2.2. Early warning system exists	**0.2**
				1.2.2.1. System is tested	0.3
				1.2.2.2. System is up to date	0.3
				1.2.2.3. How many hazards it covers	0.2
				1.2.2.4. How many assets it covers	0.2
		1.3. Quality of disturbance planning / response	0.1	**1.3.1. Operational response plans exist**	**1.0**
				1.3.1.1. Plans are tested	0.3
				1.3.1.2. Plans are used for training	0.4
				1.3.1.3. Plans are up to date	0.3
		1.4. Communication Systems / Information sharing	0.2	**1.4.1. Plans of communication and information sharing exist**	**0.7**
				1.4.1.1. Plans are tested	0.4
				1.4.1.2. Plans are up to date	0.6
				1.4.2. Communication system exist	**0.2**
				1.4.2.1. System is tested	1.0
				1.4.3. Backup of communication system exist	**0.1**
		1.5. Learnability / Training	0.3	**1.5.1. Training system exist**	**0.5**
				1.5.1.1. How many hazards are covered by training	0.3
				1.5.1.2. Hours of training	0.2
				1.5.1.3. Training program is tested	0.2
				1.5.1.4. Training program is up to date	0.2
				1.5.1.5. Last training was within a year	0.1
				1.5.2. Ratio of trained people	**0.4**
				1.5.3. Training with other CI exists	**0.1**
2. Absorption	0.2	2.1. System failure (integrity of CI affected)	0.2	**2.1.1. Number of assets fully damaged (beyond reparability)**	**0.2**
				2.1.2. Number of assets partially damaged	**0.2**
				2.1.3. Number of assets with a [over] certain percentage(%) or range of damages	**0.2**

				2.1.4. Time that CI is not able to serve its intended function	**0.2**
				2.1.5. Costs of damaged assets	**0.2**
		2.2. Severity of failure (services of the CI affected)	0.2	**2.2.1. Loss for certain hazards level**	**0.2**
				2.2.2. Reduced network capacity	**0.2**
				2.2.2.1. Connectivity Loss (CL)	0.7
				2.2.2.2. Service Flow Reduction (SFR)	0.3
				2.2.3. Number of assets fail	**0.2**
				2.2.4. Number of assets fully damaged (beyond reparability)	**0.2**
				2.2.5. Number of assets partially damaged	**0.2**
				2.2.6. Number of assets with a [over] certain percentage(%) or range of damages	**0.0**
				2.2.7. Loss of income as a result of not servicing demand	**0.0**
		2.3. Resistance	0.6	**2.3.1. Probability of failure**	**0.2**
				2.3.2. Failure > 50% for certain hazards level	**0.2**
				2.3.3. Aging of CI	**0.2**
				2.3.4. Maintenance is regular	**0.4**
				2.3.4.1. Maintenance plan exists	0.3
				2.3.4.2. Maintenance plan is in line with the Construction project	0.3
				2.3.4.3. Maintenance is performed according to the plan	0.2
				2.3.4.4. Maintenance is documented	0.1
				2.3.4.5. Critical infrastructure is fully operational according to specification	0.1
3. Coping	0.2	3.1 Redundancy	0.2	**3.1.1. How many assets have backup**	**0.3**
				3.1.2. After how much time backup is available	**0.3**
				3.1.3. How long backup is available	**0.4**
		3.2. Resourcefulness	0.2	**3.2.1. Availability of interconnected assets (provide reserve services, could be different CI)**	**1.0**
		3.3. Response	0.2	**3.3.1. Special response plan exist**	**0.2**
				3.3.1.1. Plans are tested	0.3
				3.3.1.2. Plans are used for training	0.4
				3.3.1.3. Plans are up to date	0.3
				3.3.2. Time needed to respond	**0.2**
				3.3.3. Emergency plans under Climate Hazards (in the context of climate change) exists	**0.2**
				3.3.3.1. Plans are tested	0.3
				3.3.3.2. Plans are used for training	0.4
				3.3.3.3. Plans are up to date	0.3
				3.3.4. Business continuity plans under Climate Hazards (in the context of climate change) exists	**0.4**
				3.3.4.1. Plans are tested	0.3
				3.3.4.2. Plans are used for training	0.4
				3.3.4.3. Plans are up to date	0.3
		3.4. Economics of response	0.2	**3.4.1. Cost of response (for CI only)**	**0.2**

				3.4.2. Costs for replacements of services	**0.3**
				3.4.3. Backup cost	**0.5**
		3.5. Interoperability with public sector	0.2	**3.5.1. Procedures exist**	**0.5**
				3.5.2. Communication system exist	**0.2**
				3.5.3. Joint action plans exist	**0.3**
				3.5.3.1. Plans are tested	0.3
				3.5.3.2. Plans are used for training	0.4
				3.5.3.3. Plans are up to date	0.3
4. Restoration	0.4	4.1. Post-event damage assessment	0.33	**4.1.1. Equipment and procedures for post-event monitoring**	**1.0**
				4.1.1.1. Procedures are documented	0.3
				4.1.1.2. Procedures are regularly revised	0.3
				4.1.1.3. Information exchange to vulnerability assessment components	0.4
		4.2. Recovery time	0.33	**4.2.1. Special recovery plan exist**	**0.2**
				4.2.1.1. How many hazards it covers	0.4
				4.2.1.2. How many assets it covers	0.6
				4.2.2. Time needed for recovery	**0.8**
		4.3. Economics of restoration	0.33	**4.3.1. Cost of restoration**	**0.2**
				4.3.2. Loss of income during restoration	**0.1**
				4.3.3. Loss due to possible penalties from violating service level agreements with buyers	**0.3**
				4.3.4. Costs for replacements of services	**0.2**
				4.3.5. Maintenance costs after hazard	**0.1**
				4.3.6. Cost of reputation	**0.1**
				4.3.7. Insurance costs	**0.0**
5. Adaptation	0.1	5.1. Substitutability	0.33	**5.1.1. Replacement of asset is possible**	**0.8**
				5.1.1.1. Technically possible	0.3
				5.1.1.2. Financially possible	0.7
				5.1.2. Replacement of service is possible	**0.2**
				5.1.2.1. Technically possible	0.3
				5.1.2.2. Financially possible	0.7
		5.2. Adaptability and flexibility	0.33	**5.2.1. Adaptation plan exist**	**1.0**
				5.2.1.1. How many hazards it covers	0.3
				5.2.1.2. How many assets it covers	0.7
		5.3. Economics of adaptation	0.33	**5.3.1. New investments take consider a climate change**	**0.8**
				5.3.2. Reputation is increased by implementing climate change adaptation options	**0.2**

For the scenarios identified in Table 2 and in relation to the indicators, Table 4 briefly identifies the countermeasures taken for the baseline assessment by ACCIONA for the concerned scenarios.

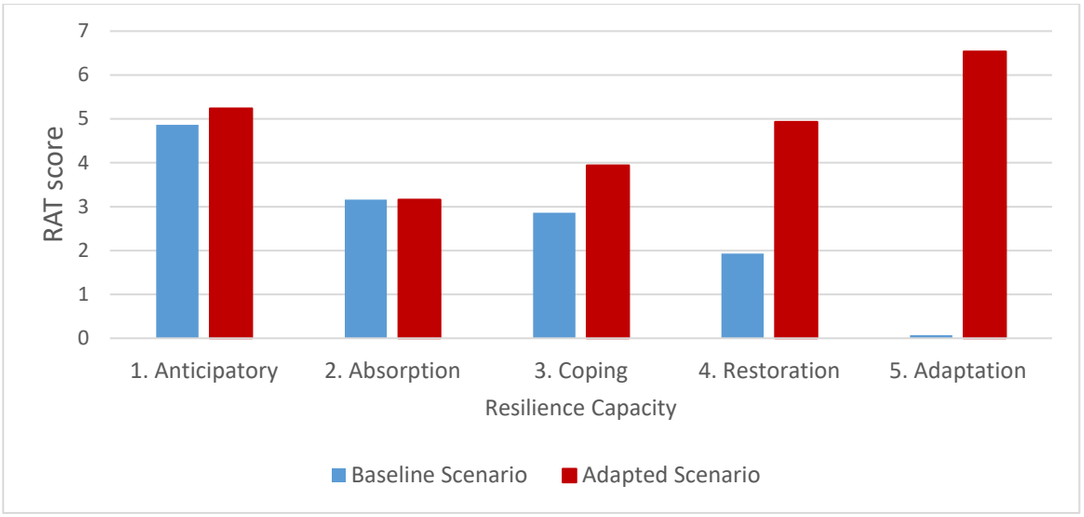
Table 4 Countermeasures adopted by ACCIONA for the hazard-related scenarios.

HAZARD	SCENARIO	ACCIONA COUNTERMEASURES
Storm surge, heavy rain, flood	1. Traffic **disservice** or reduction on the road section or geographical area affected by the hazard event for a short duration	Operating procedure carried out by Guardia Civil (Traffic Police); Road Operator - Traffic management
	2. Damage to **drainage** components or to **cutting slopes**, required **soft** interventions	Intervention by Road Operator
Strong wind and storms	1. Traffic reduction on the road section **due to fallen trees and plants or disruption if heavy vehicles are affected**	Operating procedure carried out by Road Operator - Traffic Management according to procedures
	2. Damage to non-structural RI components/**light structures (such as gantries, even pedestrian bridge)**	Intervention by Road Operator
Precipitation intensity (hail)	1. Traffic disruption or **disservice** in the geographical area affected by the hazard event for a short duration	Operating procedure carried out by Road Operator - Snowplough
Extreme cold&increase freeze/thaw cycles	1. Damage to RI component **(specially to the pavement)**, required structural intervention and long-term alteration of the road viability	Programmed follow-up. Reparation if needed (re-pavement)
Ice-Snow	1. Traffic disruption**/disservice** or reduction on the road section or geographical area affected by the hazard event for a short duration	Intervention by Road Operator: - anticipation, application of preventive treatment (brine) to road surface; - if snow, snowplough and curative treatment to road surface. Guardia Civil (Spanish Traffic Police) manages the traffic. ACCIONA only takes care of road surface.
Fog	1. Traffic disruption or **disservice** in the geographical area affected by the hazard event for a short duration	Warning and directional light panels
Traffic accident	1. Traffic disruption or reduction in the road section by the hazard event for a short duration	Operating procedure for traffic accident: Road Operator cuts the lane, traffic management by Guardia Civil and Ministry of transport

	2. Damage to **road surface and accessory** components	Road Operator - superficial (and temporary) intervention
Fire	1. Traffic **disservice because of poor visibility** or reduction on the road section or geographical area affected by the hazard event for a short duration 2. Damage to RI component, **(unlikely)** required structural intervention and long-term alteration of the road viability	Notification; caution message due to smoke in variable message panels; intervention
Power outage	1. Damage to RI monitoring system 2. Damage to RI monitoring component **(usual battery operation)**	Intervention by supply concessionary company
Wild animals	1. Traffic disruption**/disservice** or reduction on the road section	Operating procedure carried out by Guardia Civil (specific department for wild nature protection-SEPRONA); Road Operator - Traffic management

The results following reported in Figure 4, are related to the resilience qualitative assessment using the RAT tool for one of the scenarios in Table 2, namely the scenario associated to the ice-snow hazard for ACCIONA. The analysis carried out concerns the evaluation of the adaptation strategies for the selected scenario in order to show with the aim of highlighting the influence of adaptation measures that are taken in PANOPTIS. Accordingly only indicators with an evaluation related to these strategies are considered in this analysis, which are found to be: Quality / extent of monitoring system indicator for anticipatory capacity, Response and Interoperability with public sector indicators for coping capacity, Recovery time for restoration capacity and all the indicators for anticipatory capacity.

The global resilience indexes in the two configurations, baseline and adapted for the selected scenario are respectively 2.47 and 4.57, as outcome of resilience capacities combination. In the adapted scenario, as mentioned above, the countermeasures already in place to ensure service continuity of the highway section are considered joint to the proactive and reactive strategies of PANOPTIS system. Thus, in this case, as shown in Figure 4, the adapted strategies improves the global resilience index through a risk reduction and control measures, i.e. the already existing maintenance and operation procedures in ACCIONA for winter serviceability combined with the monitoring system implemented in PANOPTIS and its alert system. The resilience capabilities of RI network that benefit from this contribution are those of anticipation and adaptation.



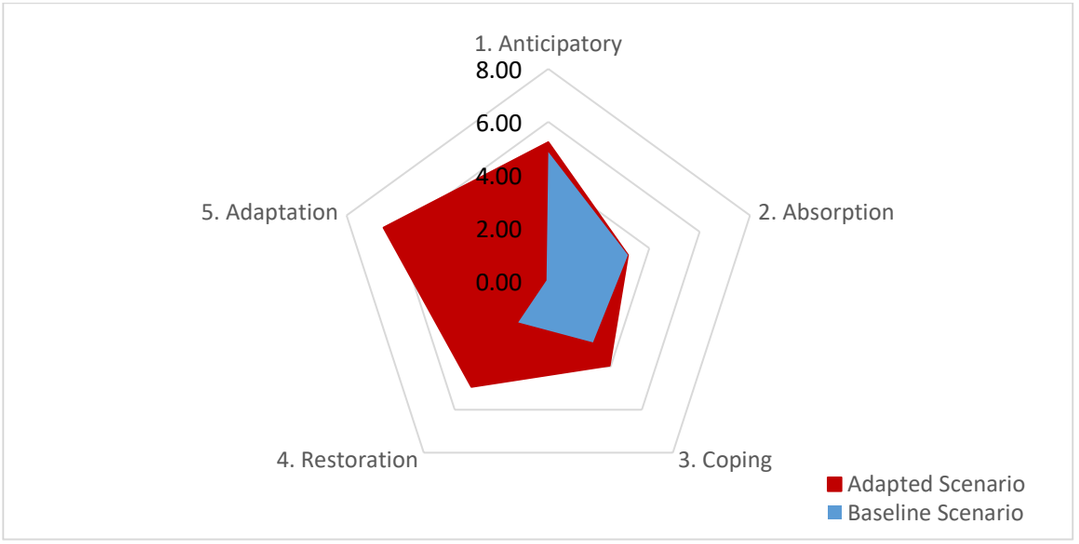


Figure 4 Results of resilience qualitative assessment through RAT tool for the ice-snow hazard scenarios, baseline and adapted, for ACCIONA demo-site.

6 Conclusions

RI network plays a critical role for the operation of societies and economies. In particular, ensuring its functioning, i.e. its continuity of service against events that may cause interruptions or disruptions related to environmental and climate-change related hazard, means improving the resilience of the RI and the of the society. To this end, reference has been made to the several standards such as ISO 223000, ISO 22301 and ISO 22313 that define the principles and procedures for a business continuity management for security and resilience of system. In accordance with these, adaptation strategies have been defined, which are based on the main concepts of risk management, taking into account existing operational procedures and best practices in the RI sector and combining them with the tools and technologies integrated in PANOPTIS system. In particular, recurring scenarios associated with the risks analysed in PANOPTIS have been identified for each pilot site, for which adaptation procedures are established to ensure continuity of service. Adaptation strategies are then evaluated through a qualitative estimation using the RAT tool, assessing their influence through the resilience indices of the different resilience capacities, according to selected indicators to which scores are attributed. This tool and thus the assessment of adaptation strategies are included in HRAP.

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