- FORESEE -

Future proofing strategies FOr RESilient transport networks against Extreme Events

– Deliverable 6.4 –

SP Case Study #3 Montabliz Viaduct & A-67.

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1 INTRODUCTION

This deliverable will consist in the test and validation (in the Montabliz Viaduct, Spain) of the project outcomes in order to select and design the best technical solutions for preventive maintenance, to provide ground and road control (hazards assessment), to ensure user's safety (notices and events management), to plan future maintenance interventions and to set up of procedures for events management (Task 6.1)[1].

2 CASE STUDY #3

2.1 DESCRIPTION

The highway A67, it is a dual carriageway land route, which is part of the radial system of motorways of Spain, owned by the Ministry of Development of the Government of Spain, which connects the port of Santander with Madrid capital of Spain, its route runs through the Cantabrian mountain range with specific risks.

This case study has two well-defined areas in which specific hazards occur throughout their life cycle.

- **Montabliz Viaduct**, is studied in the Design and Construction phase, this viaduct saves the big valley formed by a river in Cantabria Spain. It has a length of 721 m distributed in 5 spans (11 + 155 + 175 + 155 + 126), maximum light 175.00 m, radius of curvature in plant 700 m. Continuous board, formed by a monocellular drawer of prestressed concrete of variable edge between 4.30 and 11.00 m supported on single pile. The maximum height of the pile is 128.60 m, the highest in Spain and among the 6 largest in Europe (year 2008). The board has been built by the voussoirs system concreted "in situ" by cantilevered forward[2].
- In addition, **A67 Corrales de Buelna**, is studied in the Operation and Maintenance phase, stretch of highway that runs halfway, parallel to the River Besaya and the village of Corrales de Buelna.

Figure 1. Location and high pile CS#3.

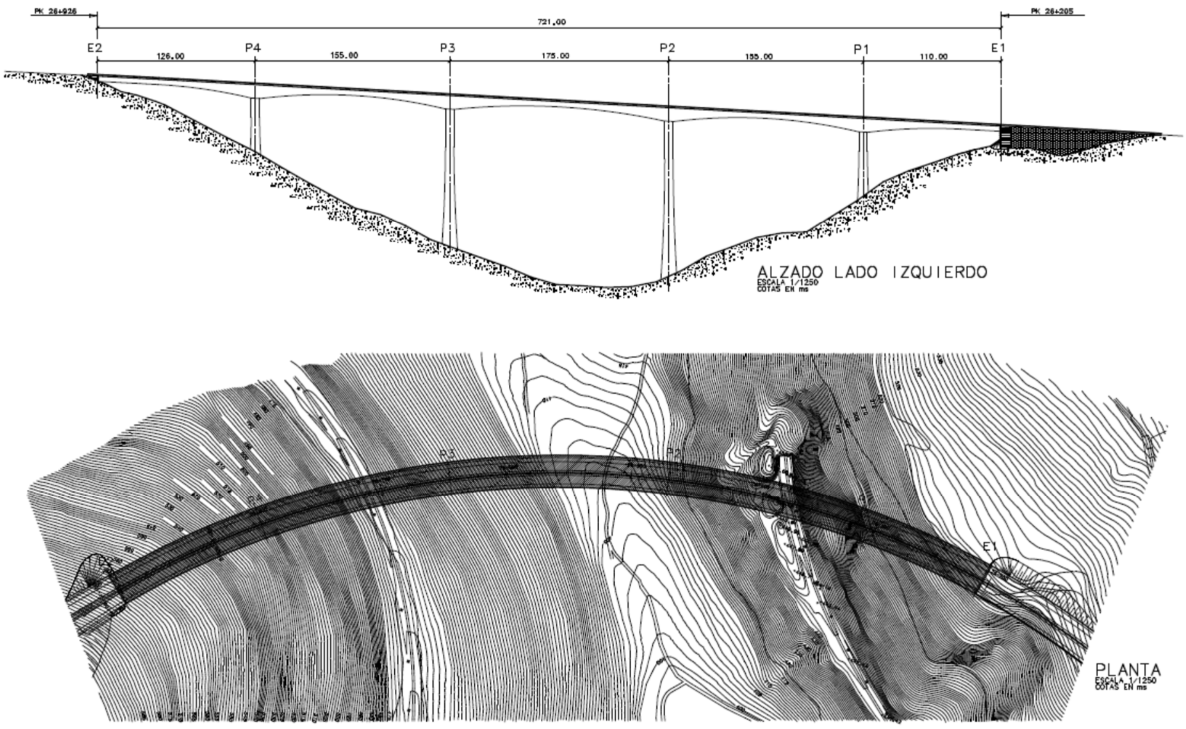


Figure 2. Elevation and Plan Cs#3.

2.2 HAZARDS

The specific hazards affecting this infrastructure are:

CASE STUDY #3 Hazards	
HAZARDS	Wind, **W**
	Snowfall, **S**
	Flooding, **F**
	Man-Made, **M**
POSSIBLE HAZARDS	Fog, **f**
	Landslide, **L**

Table 1. Hazards CS#3.

Wind and **Snowfall** are the main hazards that affect this infrastructure, since they are repeated annually in winter throughout its life cycle.

The **fog** is a hazard that appears continuously throughout the life cycle, due to the height of the infrastructure, impossible to mitigate by design, except to pre-notice its existence.
While **Flooding** is hazard, which can affect throughout the life cycle, with different return periods.
And **Landslide**, is probably in some areas of the A-67 already designed for this hazard, but that would be susceptible to improvement.

3 SCENARIO CARD & VALIDATION CONDITIONS

3.1 SCENARIO CARD FOR CASE STUDY#3 MONTABLIZ VIADUCT & A67

The case study of Montabliz Viaduct has been studied in two different scenarios, corresponding to two phases of the life cycle.

- **Evaluation & Decision, E phase** definition of main hazards that affect this region.
- **Design & Construction**, **D phase** definition of the design resilient to the specific hazard, wind.
- **Operation & Maintenance**, **M phase** definition of flood zones on the A-67 motorway, for avenues with different return periods.

CASE STUDY #3 **Scenario**			
phase	**Evaluation & Decision, E**	**Design & Construction, D**	**Operation & Maintenance, M**
hazards	Wind, **W**	Wind, **W**	
	Snowfall, **S**	Snowfall, **S**	
	Fog, **f**		
	Flooding, **F**		Flooding, **F**
	Man-Made, **M**		
	Landslide, **L**		
transport	Road, **R**		
scale	National, **N**		
	Autonomic, **A**		
location	Spain, **S**		
	*risk (**W** risk (**F,M**), transport (**R**), scale (**N,A**), location (**S**),**S,M**), transport (**R**), scale (**N,A**), location (**S**)*		

Table 2. CS#3 SCENARIO.

3.2 VALIDATION METHODOLOGY AND PROCEDURE & POSSIBLE CONNECTION WITH THE PREVIOUS KRI

The FORESEE tools selected to improve the resilience by KRI-KTI, of this infrastructure are:

TOOL	Name	Developer	KPI-KRI connection	CASE STUDY #3		
				SCENARIO		
				Evaluation & Decision, E	Design & Construction, D	Operation & Maintenance, M
D 1.1	Resilience Guidelines to measure Level of Service & Resilience	ETHZ	√	√	√	√
D 1.2	Set Targets	ETHZ	√	√	√	√
T 1.3	Governance Module	UC			√	
T 2.2	Risk Mapping	UC	NO	√		
T 2.4	Virtual modelling Platform	UEDIN				
T 2.5	Alerting SAS platform	TVUK				
T 3.4.1	Traffic Module	WSP				1
T 3.4.2	Fragility and Vulnerability Analysis & Decision Support Module	RINA-C				
T 4.1	Flooding Methodology	IH	NO			√
T 4.4	Hybrid Data Fusion Framework	ETH				
T 5.5	Command and Control Center	FRA	√			√
T 7.1	Definition of framework: use cases, risk scenarios and analysis of impact	CEM	√		√	√
T 7.2	Design, construction and remediation plans	CEM				
T 7.3	Operational and maintenance plans	TEC				
T 7.4	Management and contingency plans	ICC				
Solutions Catalogue						
T 4.2	Earthquake Platform	CEM				
T 3.3	Sustainable Drainage System	CEM	NO			√
T 4.3	Development of algorithms for the selection and definition of efficient and optimal actions	ETH/CEM				
D 3.5	New Family of PA-pavements	UC	NO			√
D 3.6	Smart & Integral slope stabilization system	UC	NO			√
D 4.4	SHM Algorithms	TEC				

Table 3. Validation Methodology by KRI-KTI, CS#3.

[1] The model for the traffic module has been defined but because adequate traffic data is not available, it has not been possible to obtain solutions for this case study #3.

4 SYSTEM VALIDATION IN CASE STUDY #3 BY LEADER.

- In the current state the management of the infrastructure leader CS#3 Montabliz Viaduct, is carried out based on expert knowledge and lessons learned, with the aim of making the infrastructure robust, facing specifics hazards.
- With the use of Foresee tools, management becomes objective, transparent, automatic and from the point of view of resilience and robustness, in addition to taking into account qualitative and reputational aspects of the leader.

	CASE STUDY#3			
	LEADER		***FORESEE TOOLKIT***	
HAZARDS DEFINITION	- EXPERTS	- Subjective	- RISK MAPPING	- Predictive & Objective
	- Lessons Learned	- Manually		- Transparency
			- FLOODING METHODOLOGY	- Automated
		- Robustness quality		- Resilience & Robustness quality
			- COMMAND AND CONTROL CENTER	- Qualitative & Reputational Aspects
MAKING DECISION	- EXPERTS	- Subjective	- GOVERNANCE MODULE	- Objective
	- Lessons Learned	- NO Transparency		- Transparency
		- Manually		- Automated
		- Robustness quality		- Resilience & Robustness quality
				- Qualitative & Reputational Aspects

Table 4. Comparison Leader & FORESEE Tools.

5 OUTPUTS COMING FROM THE VALIDATION PHASE

The application of the FORESEE tools to CS#3, have the sole purpose of developing the Operation and Maintenance Plan of the infrastructure defined in CS#3, based on its most resilient definition from the Design and Construction phase.

	Case Study #3	OUTPUTS	PHASE
FORESEE TOOL	**RISK MAPPING**	Hazard maps and risk maps of the infrastructure's area to identify the risks prior to the more accurate and local scale quantification, wind and snowfall.	Evaluation & Decision, E
	GOVERNANCE MODULE	Making design decisions, to mitigate specific infrastructure hazards, wind.	Design & Construction, D
	FLOODING METHODOLOGY	Flood Map different return period.	Operation & Maintenance, M
Solutions Catalogue	Sustainable Drainage System	sustainable drainage solution	Operation & Maintenance, M
	New Family of PA-pavements	sustainable pavements solution	Operation & Maintenance, M
	Smart & Integral slope stabilization system	sustainable slope stabilitation solution	Operation & Maintenance, M

Table 5. Outputs by Phase Foresee Tool & Solutions Catalogue CS#3.

5.1 FORESEE TOOLS

5.1.1 RISK MAPPING

5.1.1.1 Methodology

The Risk Mapping tool developed in T2.2 of the FORESEE project is aimed at the early large scale identification of the risks to extreme natural desasters to which road infrastructures are exposed as well as to approach the vulnerability of these infrastructures. This application is to be employed at early phases of the project design, when the relevance of risks potentially involved can be initially estimated, and prior to a more detailed data collection and analysis for a given impending regional or local extreme natural event. Two main outcomes can be obtained from running the tool: hazard and risk maps at a European scale.

The methodology for risk mapping follows and empirical approach as it is based on a series of past real extreme natural events occurred all over Europe in the last years. For assessing the risk of occurrence of the three most significant natural disasters -floods, landslides and earthquakes-, regression models have been developed that made use of the catalogue of past real events as the response variable and a series of geo-referenced databases as factors or predictor variables. Those factors with the highest level of significance were finally used for the modelling of the hazard maps.

Vulnerability refers to the group of individuals or goods potentially exposed to the action of hazards. For the purpose of this tool, vulnerability of roads concentrated the greatest effort. In this sense, for the vulnerability assessment of the different types of roads (motorways, primary, secondary and tertiary roads) a MCDM analysis was carried out that made use of different criteria: traffic, length, costs and accidents rate. As the vulnerability of transport infrastructures is also related to the people living around them, potential personal damage must have an impact on the vulnerability factors defined. Therefore, population density was set to weight the general vulnerability factors. A synoptic diagram of the process followed for the risk mapping is in Figure 3.

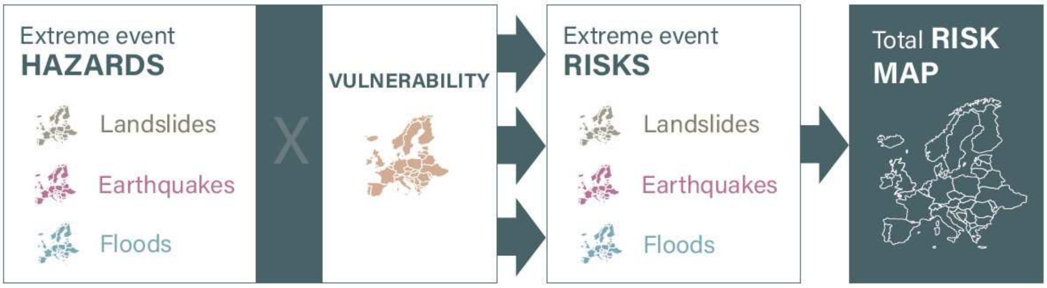


Figure 3. Synoptic diagram of the risk maps generation.

5.1.1.2 Results

As for the study case here referred, some of the maps generated in the context of the analysis of the Montabliz Viaduct are shown at different scales.

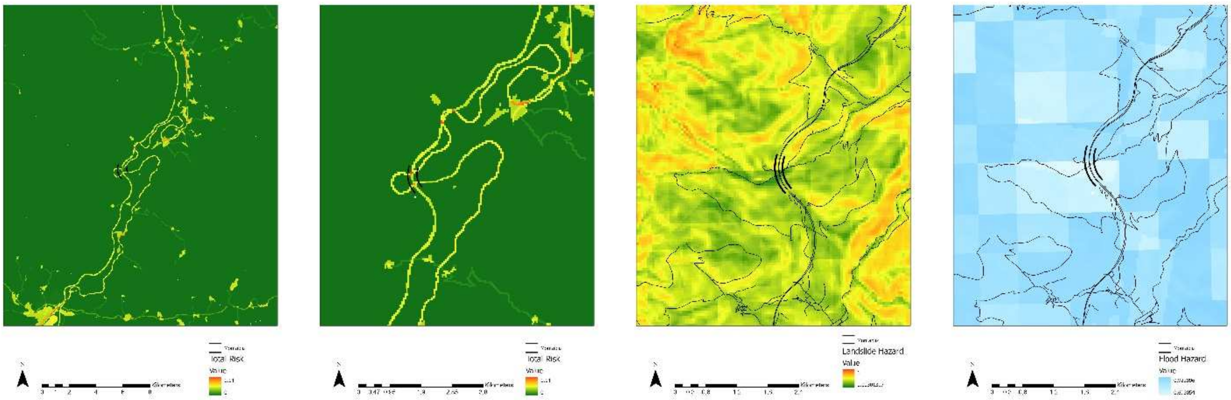


Figure 4. CS#3 Risk Mapping Result.

5.1.2 GOVERNANCE MODULE

5.1.2.1 Methodology.

When planning, designing and executing a new project (infrastructure), the owner and contractors based on hazards, KPIs and KRTs, make decisions with the aim of mitigating risks, maintaining stable service level and obtaining maximum profitability. This decision-making is carried out automatically and transparently, through the Governance module.

1. Thus, the owner defines the KRI and the KRT, depending on the specific hazards of the infrastructure.
2. Subsequently and prior to each of the phases, the owner selects through the governance module and depending on the hazards, both the type of contract and the most appropriate contractor for its execution. The interested contractors apply for the tender and declare their abilities to carry out the works, by completing the KPIs and KRTs defined by the owner.

3. Once the selection is made, both the contractor and the owner use the governance module for the selection of the different governance, technical and financial issues to define the infrastructure, based on the KRIs and KRTs, with the basic objective of mitigating the hazards in the different phases of Evaluation & Decision, Project and Construction and Operation and Maintenance.

5.1.2.2 Results.

In the CS#3 Montabliz Viaduct, the Governance Module is used:
• ***Phase: Design & Construction:***
In the selection of the Typology of the most appropriate structure according to the hazards.

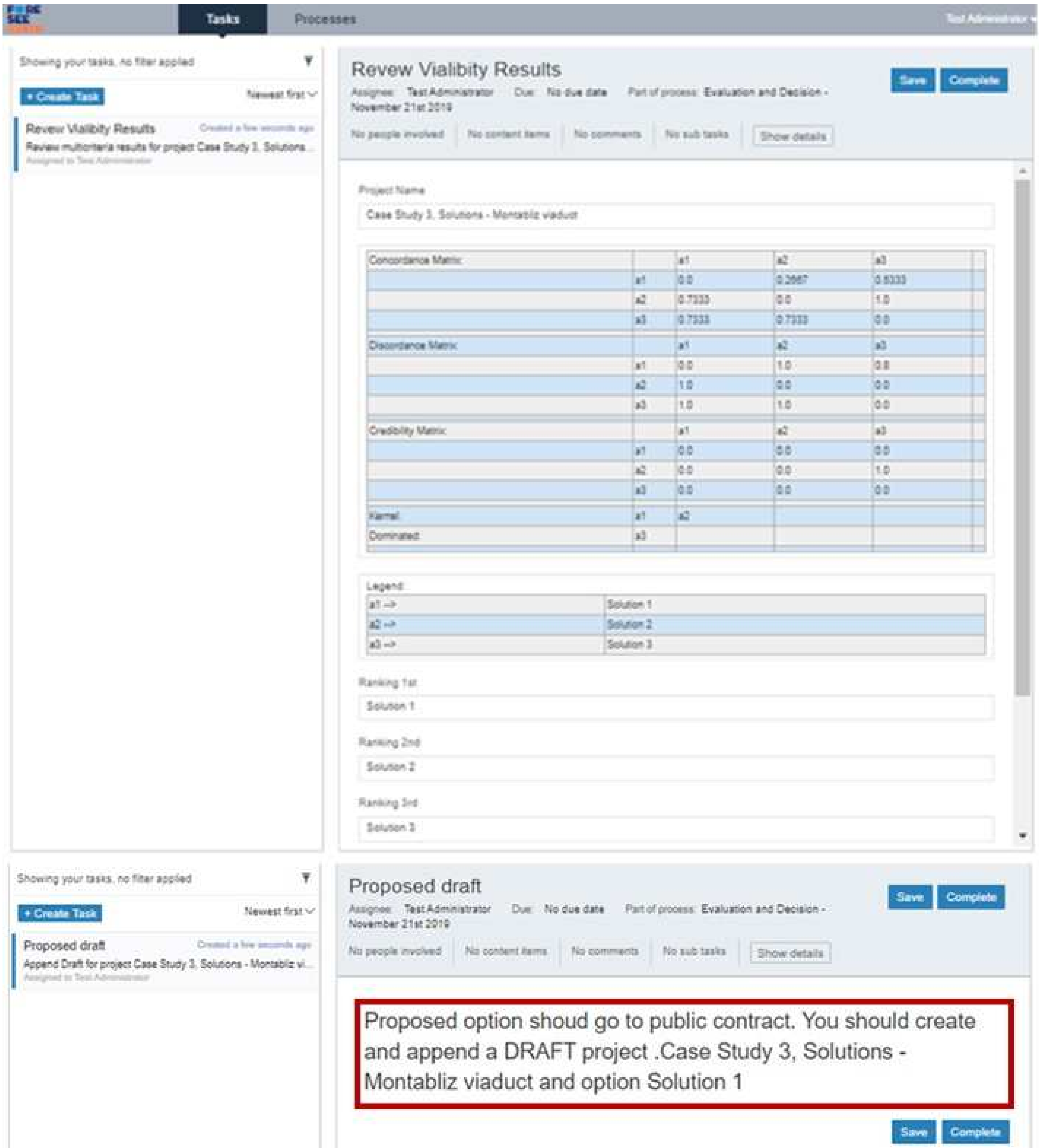


Figure 5. Design & Construction Definition.

- ✓ Study: Excellent results to selection, alternatives of solution, typology of viaduct, to the better design in front of the hazards, in the Design & Construction phase and select the expert contract to developer the Plan of Operation & Maintenance.

✓ Proposal: GUI recommendations, Economical units.

5.1.3 FLOODING METHODOLOGY

5.1.3.1 Methodology

Most often, to obtain the flood risk associated with some return period, the associated floods are obtained from the hyetographs corresponding to each return period and, by means of hydrological modeling, obtain the associated flood hydrograph that allows by hydraulic modeling to determine flood depths. In short, the extreme regime is obtained for precipitation and then, this extreme regime is assigned to every other derived variable, that is, it is normally assumed that the 100-years return period rainfall induces the 100-years return period flood. However, in this study a new methodology is proposed in which the precipitation series of the existing rain gauges are taken as starting data, which allow by means of hydrological simulation to obtain flow series, from which the events that exceed a certain threshold beyond which flooding occurs are selected. Once the events have been selected, thousands of years of flow events are generated synthetically through a copula model (Ben Alaya et al., 2014). Due to the need to simulate hydrology and subsequently the use of a hydraulic model, it is necessary to select a reduced number of synthetic events using data mining methods (Camus et al., 2011). To calculate the threat produced for a certain return period, the extreme statistics are computing for the flood depth and speed, not for the precipitation as in the traditional methodology. The proposed approach assumes explicit consideration of flood statistics, including some of the uncertainty that other methods overlook.

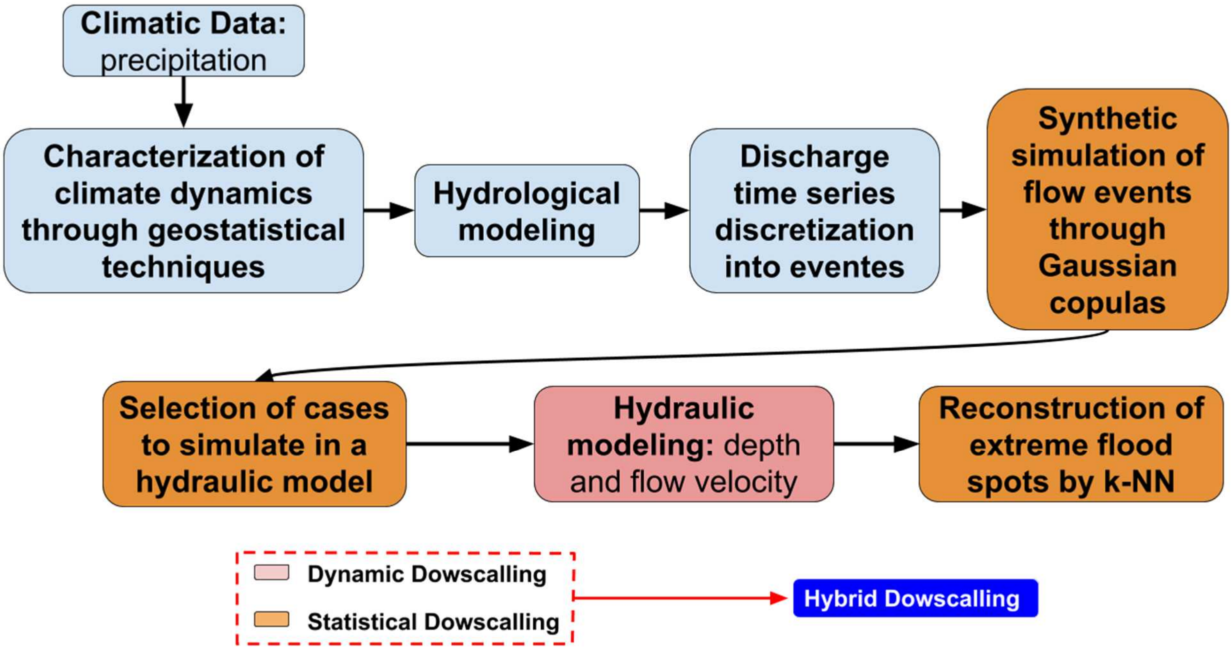


Figure 6. Methodological scheme

There is another variant to this methodology, which is to synthetically generate precipitation events from the separation of time series events of this meteorological variable and subsequently follow the same process. But in this case, there is the limitation that long series with an hourly time resolution are needed, which are occasionally not available.

5.1.3.2 Results

In the results obtained from the hydrological model, the reduction in maximum flow rates that occurs in the simulated series can be observed. This reduction is around 50% -60% as can be seen in Figure 7. For this reason, the generation of synthetic events through copulations is essential to cover the range of maximum flows that is not reflected in the result of the hydrological model.

The use of Gaussian copulas allows to obtain events with maximum flow rates like those of the real series, which are those that directly influence the magnitude of the flood.
The floods obtained with the proposed methodology have a greater extension than those generated with the usual methodology for the same return period, which allows to remain on the side of security. This difference is mainly due to the low density of rain gauges and the short length of the precipitation series used to obtain the rainfall intensities corresponding to each return period using the usual methodology, in addition to not including explanatory variables such as the form of the hydrograph of flood events and the spatial distribution of precipitation.

For this reason, the applied statistics do not fully include the possible dynamics of the river, giving rise to reduced flood spots. However, in the proposed methodology, all possible dynamics are collected when performing the synthetic reconstruction, generating larger stains and therefore areas with a higher risk of flooding.

It is very interesting to observe how the spot generated for a return period of 10 years coincides with the floodplain of the Besaya River in 1946. In this way it is shown that the generated flood is probable.

In Figure 7 the comparison between the results shown by the usual methodology and arises.

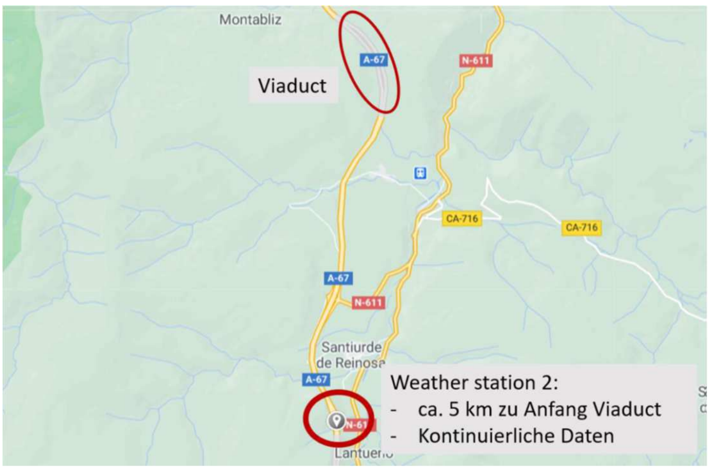
a) Risk map associated with a return period of 500 years obtained using the usual methodology

b) Risk map associated with a 500-year return period obtained using the proposed methodology

Figure 7. Comparison in the results of the risk maps obtained using the proposed methodology and the usual methodology.

5.1.4 COMMAND AND CONTROL CENTER

5.1.4.1 Data CS#3



Weather station: approx. 5 km away from Viaduct.
Weather station near by Viaduct (EM)
Problem: too many data gaps (approx. 50% or more missing data in required time range)
Only used numeric data (no graphical data, no text-data…)

Figure 8. Weather satation CS#3

Sensors at Viaduct:
- 2 Sensors for wind strength and direction
- 8 Extensometers
- 37 Temperature-sensors

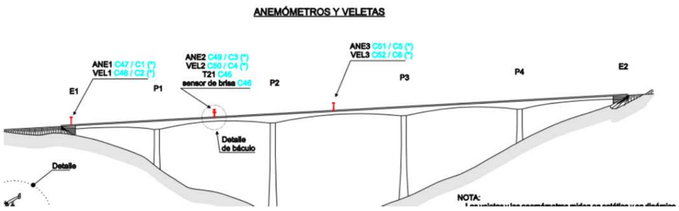


Figure 9. Sensors CS#3

Format: Excel-table as provided

	A	B	C	D	E	F	G	H	
1	DATA	DATE	TIME		C1	C2	C3	C4	(
2	Column1	Column2	Column3	(	Column5	Column6	Column7	Column8	Colur
89314	89312	16.01.2020	12:00:00		9,471743	10,21259	10,71373	13,3325	1C
89315	89313	16.01.2020	12:05:00		9,47322	10,21379	10,71926	13,35852	1
89316	89314	16.01.2020	12:10:00		9,483365	10,21511	10,72503	13,38344	
89317	89315	16.01.2020	12:15:00		9,492522	10,22016	10,72914	13,40508	1C
89318	89316	16.01.2020	12:20:00		9,508095	10,22314	10,73302	13,4298	1C
89319	89317	16.01.2020	12:25:00		9,523552	10,22515	10,73622	13,45125	1C
89320	89318	16.01.2020	12:30:00		9,533568	10,23226	10,7423	13,47809	1C
89321	89319	16.01.2020	12:35:00		9,539806	10,23259	10,74781	13,50205	1C
89322	89320	16.01.2020	12:40:00		9,547194	10,23742	10,75137	13,53922	1C
89323	89321	16.01.2020	12:45:00		9,558205	10,2404	10,7548	13,59972	1C
89324	89322	16.01.2020	12:50:00		9,574641	10,24167	10,76315	13,6429	1

Table 6. Data Sensors CS#3

5.1.4.2 Results CS#3

```
Analysis of:  2019-05-30 13:15:00

An anomaly was detected by the network:  No
Predicted anomaly Score:  1.36

Stations/Sensors measurements:
  pressure    humidity    rain gauge    dew point
----------  ----------  ------------  -----------
     944.3          87             0         8.23
```

5.2 SOLUTIONS CATALOGUE

5.2.1 Sustainable Drainage System

The sustainable drainage is a strategies for adapting current drainage designs to the sustainable drainage concept and to the new needs of linear infrastructures due to the effects of climate change. As presented in the following sections, these strategies have been developed covering two different perspectives: the hydrological point of view, related to the precipitation patterns, and the SDS point of view, related to the study of SDS feasibility. The strategies here developed include the use of novel techniques based on statistical methodologies and data analytics, and Geographical Information Systems (GIS), in order to improve the reliability of drainage solutions.

Possible implementation in the drainage of A-67, as improve and accommodation to the climate change.

5.2.2 New Family of PA-pavements

New porous asphalt mixtures with improved infiltration capacities able to manage extreme rainfall events, reducing risks and users´ risk perception in wet weather conditions. These fibre-reinforced porous asphalt mixtures have a higher air void content that allows a higher volume of water to be drained. The use of fibres to reinforce the mortar ensure the mechanical performance is not compromised.

These new mixtures are able to improve the resilience of the road pavement due to their ability to quickly remove the water accumulating on the road surface, thus preventing tire spray and hydroplaning, as well as improving the visibility during an extreme rainfall event. In the same way, the lower risk and lower risk's perception directly contributes to prevent the increase in travel time during and after the extreme event.
On the other hand, the new porous asphalt mixtures present a higher clogging resistance than conventional porous asphalt mixtures, thus contributing to maintain the infrastructure in a good condition state longer.

Possible implementation in the renovation of asphalt mixtures, to benefit of traffic and drainage of A-67, as improve and accommodation to the climate change.

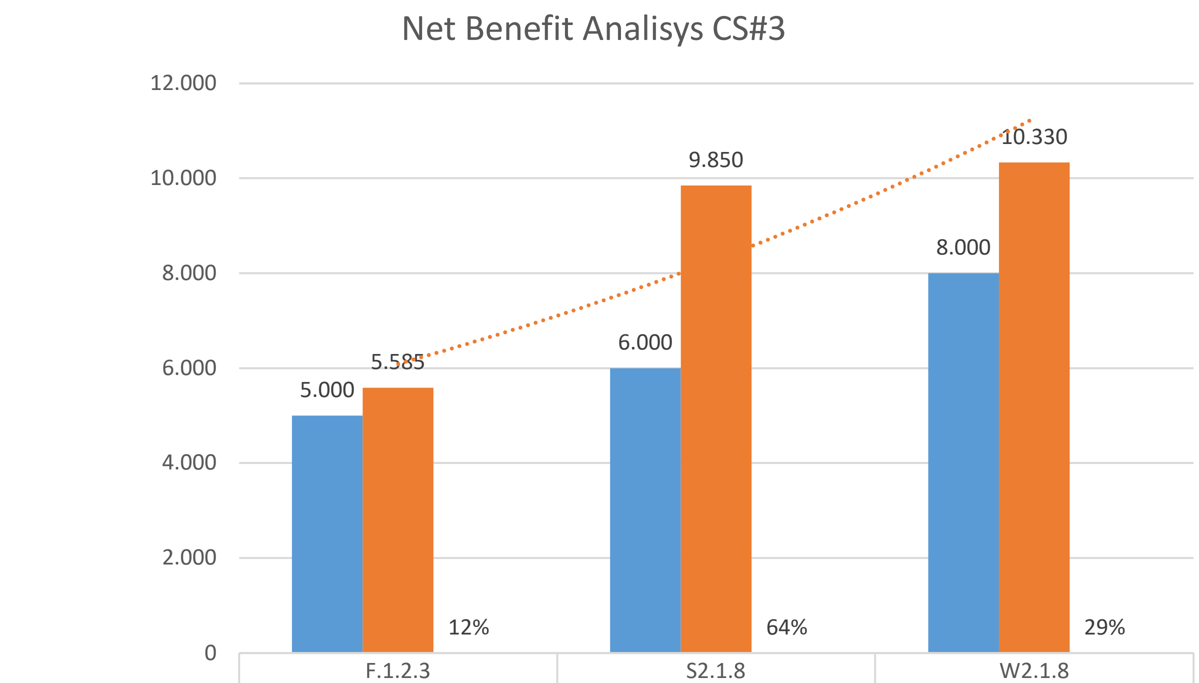
5.2.3 Smart & Integral slope stabilization system

Flexible systems anchored to the ground are low visual impact alternatives to be used in slope protection. With the aim of reducing their installation time and costs the mechanical union between layers of membranes is proposed to be done in warehouses instead of independent installations on site. The most appropriate component selection and linking method is selected using multi-criteria decision analysis, specifically using AHP, WASPAS and TOPSIS techniques. The criteria considered in order to take the decision are cost of materials, ease of sewing, transport and installation of the system, biodegradability of the secondary mat and its hydroseeding retention capacity that stimulates the revegetation. Due to the uncertainty on the data of biodegradability, four scenarios were analysed. The results indicate that the most suitable secondary membrane in all cases is the coconut fibre mesh and should be connected to the main membrane using a cable tie machine.

Possible improvement of the slope stabilization networks currently existing on the A-67.

6 ASSESSMENT OF THE RESILIENCE LEVEL OF THE INFRASTRUCTURE AND IMPROVEMENT AFTER THE USE OF FORESEE TOOLS.

6.1 NET BENEFIT ANALYSIS CS#3

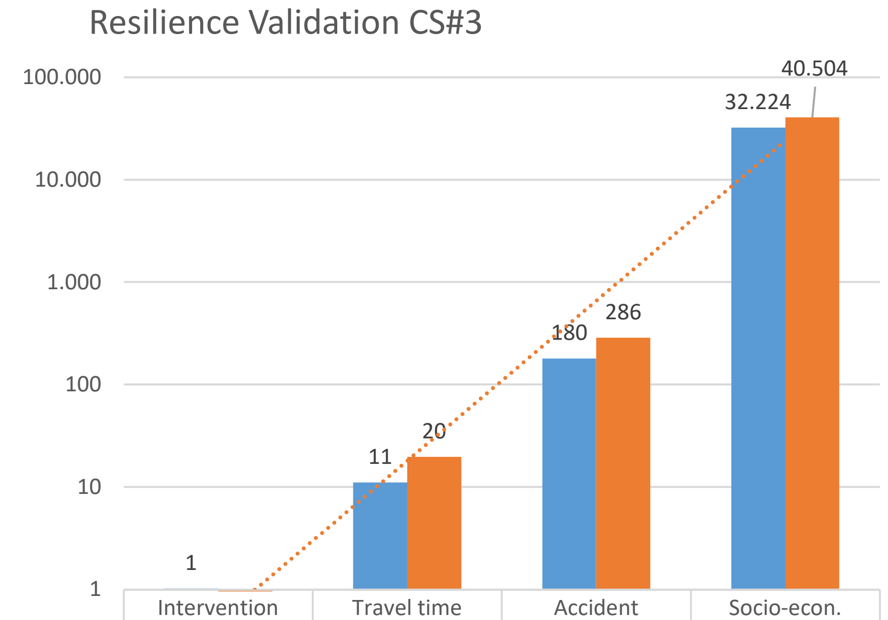


	F.1.2.3	S2.1.8	W2.1.8
Net Benefit (Actual)	5.000	6.000	8.000
Net Benefit (Target)	5.585	9.850	10.330
Increase	12%	64%	29%

Figure 10. CS#3, Net benefit analysis [IVE].

Figure 10 demonstrates that the net benefit of LoS costs and thus the resilience of the infrastructure to hazards can be increased by a minimum of **35%** in total compared to the current state if the set resilience targets are fulfilled.

6.2 RESILIENCE VALIDATION CS#3



	Intervention	Travel time	Accident	Socio-econ.
Total wihtout FORESEE Resilience Tools	1	11	180	32.224
Total With FORESEE Resilience Tools	1	20	286	40.504

Figure 11. Effect on the resilience of the use case#3 applying FORESEE Tools[2].

Finally, and as a check of the method proposed by FORESEE, to improve the resilience of the infrastructure studied in CS#3.

In this case a notable improvement in resilience is obtained as shown the exposed graph according to the application of the FORESEE tools.

6.3 RAMSSHEEP AND RESILIENCE PRINCIPLES FOR CS#4

RAMSSHEEP is a risk-driven maintenance concept developed by the Ministry of Infrastructure and the Environment of The Netherlands and Rijkswaterstaat (RWS).

The idea of introducing this concept here is for the identification of weak points in the system. Sometimes these weak points are related to the reliability, or sometimes are related to the maintainability so a common approach for the harmonization of the tools performance and their suitability in different use cases is necessary.

- R: Reliability—indicates the failure probability of the validated tools in which its functions cannot be fulfilled.
- A: Availability—indicates the time duration in which the tools are functional and their functions can be fulfilled.

[2] Logarithm Scale, due to the difference in values between components.

- M: Maintainability—the ease in which the tools can be maintained over time.
- S: Safety—the absence of human injuries during using or maintaining the system.
- S: Security—a safe system with respect to vandalism, terrorism and human errors.
- H: Health—the objective argument of good health with respect to the physical, mental and societal views.
- E: Environment—influence of the system on its direct physical environment.
- E: Economics—a serious reflection in terms of costs versus benefits (as well as direct and indirect) to provide more insight for an economical responsible choice.
- P: Politics—a rational decision on all the previous aspects.

Case Study#3 FORESEE TOOL	*OUTPUT*												
	RAMSHEEP									RESILIENCE PRINCIPLES			
	R	A	M	S	S	H	E	E	P	*Robustnes*	*Resoucesfulness*	*Rapid-Recovery*	*Adaptability*
RISK MAPPING	+	-	++	+++	-	-	-	-	-	√	√		
GOVERNANCE MODULE	+	-	++	+++	-	-	+	+	-	√	√	√	√
FLOODING METHODOLOGY	+	-	++	+++	-	-	+	+	+	√	√		√

Table 7. CS#3, RAMSHEEP & Resilience Principles

7 ROUTE ASSET PLAN UPDATING. COMPARISON WITH CURRENT MANAGEMENT PLAN

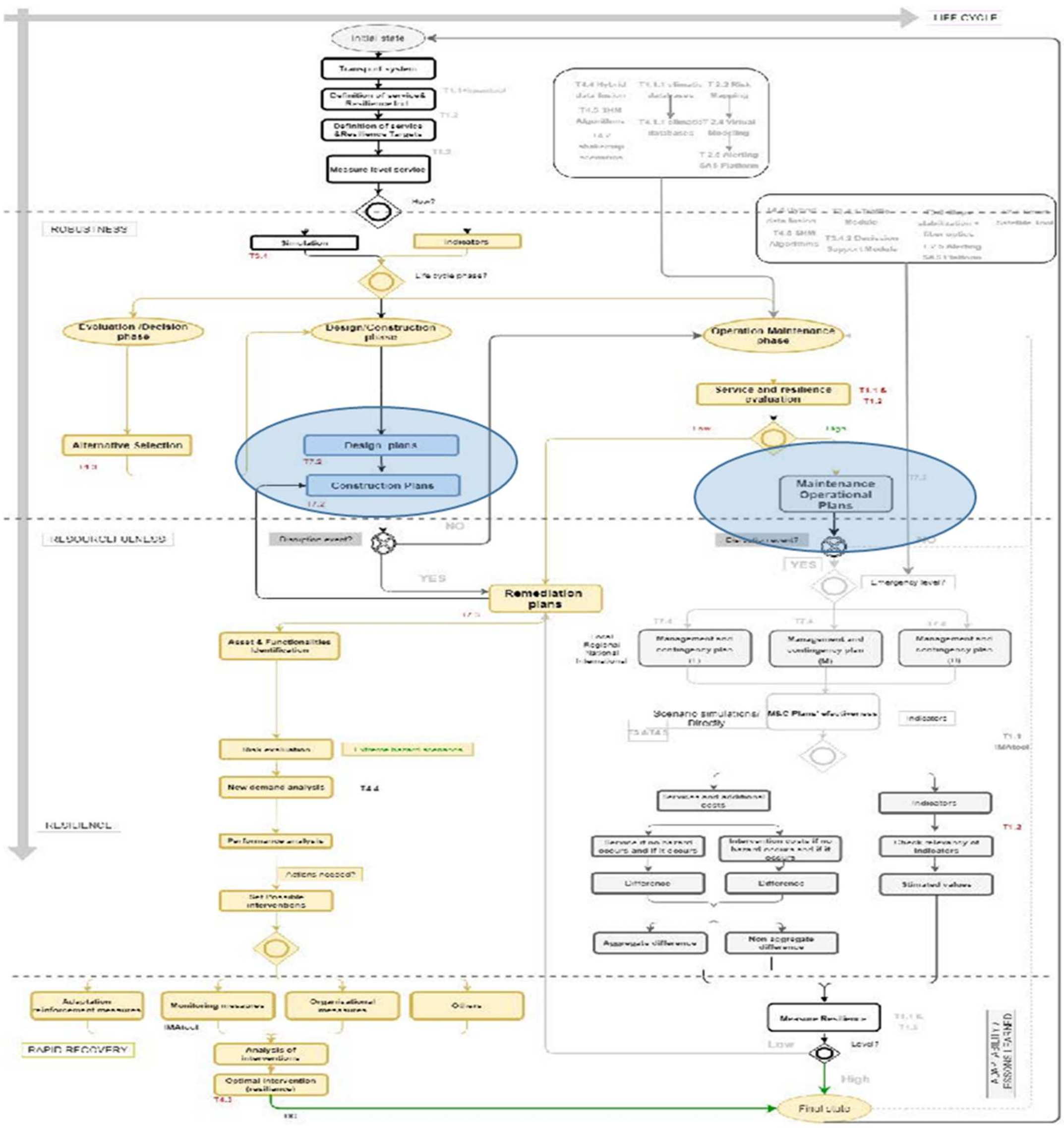


Figure 12. Route Asset Plan Updtaing CS3#

The updating used in the route asset plan for CS#3, corresponds to:

- In the Phase Design and Construction is selected the resilience typology of infrastructure along specific hazards, wind and snowfall, to include on Operation & Maintenance Plan.
- And, in the Phase Operation & Maintenance Plan based on Resilience Design.

VALIDATION EVALUATION & DECISION CS#3 1. KPI-KRT 2. Command and Control Center 3. Definition of framev risk scenarios and ana 4. Risk Mapping	VALIDATION DESIGN & CONSTRUCTION CS#3 1. KPI-KRT 2. Command and Control Center 3. Definition of framev risk scenarios and ana 4. Risk Mapping 5. Governance Module 6. DESIGN & CONSTRUCTION	VALIDATION OPERATION & MAINTENANCE CS#3 1. KPI-KRT 2. Command and Control Center 3. Definition of framewor scenarios and analysi 4. Flooding Methodology 5. OPERATION & MAINTENANCE PLAN
1. The infrastructure is digitized through Indicators, KPI and thresholds KRT. 2. The Tool Command and Control Center represents graphically the indicators and the thresholds. 3. The Tool Definition of framework: use cases, hazards scenarios and analysis of impact, defines the potentials hazards. 4. The Tool Risk Mapping analyzes the real hazards graphic.	1. The infrastructure is digitized through Indicators, KPI and thresholds KRT. 2. The Tool Command and Control Center represents graphically the indicators and the thresholds. 3. The Tool Definition of framework: use cases, hazards scenarios and analysis of impact, defines the potentials hazards. 4. The Tool Risk Mapping analyzes the real hazards graphic. 5. The Tool Governance Module, select design to mitigate specifics hazards. 6. Definition structural Typology.	1. The infrastructure is digitized through Indicators, KPI and thresholds KRT. 2. The Tool Command and Control Center represents graphically the indicators and the thresholds. 3. The Tool Definition of framework: use cases, hazards scenarios and analysis of impact, defines the potentials hazards. 4. The Flooding Methodology defined the flood zone. 5. The Operation & Maintenance Plan, along resilient definition.

Table 8. Validation FORESEE TOOL CS#3.

8 POTENTIAL IMPROVEMENTS OF THE TOOLKIT FOR REAL COMMERCIALISATION

A series of improvements are proposed to be implemented in the FORESEE TOOL, in view of the results obtained for the CS#3.

- Improvement of technical indicators, in the Design & Construction phase, **D**.
- Express the results of decision-making in economic terms to achieve a better integration of the Resilience Plan with the Asset Management Plan.
- GUI output of the Tool, for a faster and easy understanding

Case Study #3		**REAL COMMERCIALISATION**
FORESEE TOOL	**RISK MAPPING**	√
	GOVERNANCE MODULE	√
	FLOODING METHODOLOGY	√
Solutions Catalogue	Sustainable Drainage System	√
	New Family of PA-pavements	√
	Smart & Integral slope stabilization system	√

Table 9. FORESEE Tool CS#3 COMMERCIALISATION

9 CONCLUSIONS

Applying the Foresee tools to the Case Study CS#3 provide the infrastructure leader.

- **CS#3 Evaluation & Decision, E Phase:**
- The Risks definition of study zone.
- The prediction risk of study zone.

- **CS#3 Design & Construction, D Phase:**

1. The Resilient, objective, transparent, automatic decision-making, encompassing all reputational qualities and aspects
2. The selection of the resilient infrastructure against its specific hazards, which complies with the Resilience Plan and subsequently, will be the resilient infrastructure for the Operation and Maintenance Plan.
3. The Path of Resilient Infrastructure Governance.

- **CS#3 Operation & Maintenance, M Phase:**

1. The definition of Operation & Maintenance Plan, based on a resilient design in front of specific hazards.
2. In addition, obtain a better benefit, introducing the FORESEE Tool, along of the life cycle of the infrastructure.

And, regarding **RESILIENCE**:

- The better resilience with the FORESEE Tool of CS#3, RISK MAPPING, GOVERNANCE MODULE and FLOODING METHODOLOGY, define the better resilient design, to posteriorly determined the **resilience** according to the concepts, travel time, accident and socioeconomic, proving thus the objective principally of **FORESEE Project**.

Annex 1 Identification of KRI and KRT

ID	INDICATOR	Target	Costs
WIND			
W1.1.1	Age / Age of replacement of the warning system	2	40.000
W1.1.2	Condition state of protective structures/systems	2	30.000
W1.2.1	The possibility of using another means to satisfy transport demand	3	80.000
W1.2.2	The number of possible existing alternative ways to deviate vehicles	2	70.000
W1.2.3	The presence of a warning system	1	1.000
W1.3.1	Adequacy of hazard effect reduction system (barriers to wind)	0	0
W2.1.8	Traffic	3	50.000
W2.1.9	Hazards goods traffic	2	5.000
W3.1.1	The presence of an emergency plan	1	10.000
W3.1.2	Practice of the emergency plan	0	0
W3.1.3	Review/update of the emergency plan	0	0
SNOWFALL			
S1.1.1	Age / Age of replacement of the warning system	2	40.000
S1.1.2	Condition state of protective structures/systems	4	50.000
S1.2.1	The possibility of using another means to satisfy transport demand	0	0
S1.2.2	The number of possible existing alternative ways to deviate vehicles	2	70.000
S1.2.3	The presence of a warning system	0	0
S1.3.1	Adequacy of hazard effect reduction system (barriers to snow)	2	50
S2.1.7	Traffic	3	50.000
S2.1.8	Hazards goods traffic	2	5.000
S3.1.1	The presence of a monitoring strategy	1	200
S3.1.1	The presence of a monitoring strategy	1	200
S3.1.1	The presence of a monitoring strategy	2	200
S3.1.1	The presence of a monitoring strategy	1	200
S3.1.2	The presence of an maintenance strategy	1	50
S3.1.2	The presence of an maintenance strategy	0	0
S3.1.2	The presence of an maintenance strategy	0	0
S3.1.2	The presence of an maintenance strategy	0	0
S3.1.2	The presence of an maintenance strategy	0	0
S3.1.2	The presence of an maintenance strategy	0	0
S3.1.2	The presence of an maintenance strategy	1	50
S3.1.3	The extent of interventions executed prior to the event	1	30

FLOODING			
F.1.1.1	Age / Age of replacement of safe shut down system	3	5.000
F.1.1.2	Condition state of infrastructure	3	3.000
F.1.1.3	Condition state of protective structures/systems	3	6.000
F.1.1.4	After-event condition state of infrastructure	3	250
F.1.1.5	After-event condition state of protective structures/systems	3	1.000
F.1.2.1	The possibility of using another means to satisfy transport demand	1	1.000
F.1.2.2	The number of possible existing alternative ways to deviate trains	1	1.000
F.1.2.3	The presence of a safe shutdown system	1	5.000
F.1.3.1	Compliance with the current flood design code	1	5.000
F.1.3.2	Strength of construction material used	3	5.000
F.1.3.6	Adequate systems to reduce flooding	1	3.000
F.2.1.1	Accessibility*	3	5.000
F.2.1.2	Extent of past damages due to hazards*	3	1.000
F.2.1.3	Hazard zone*	1	5.000
F.2.1.4	Duration of past down time due to hazards*	1	2.000
F.2.1.5	Budget availability	1	1.000
F.2.1.6	Traffic*	1	5.000
F.2.1.7	Hazards goods traffic*	1	1.000
F.3.1.1	The presence of a monitoring strategy	1	1.000
F.3.1.2	The presence of an maintenance strategy	1	1.000
F.3.1.3	The extent of interventions executed prior to the event	2	5.000
F.3.2.1	The presence of an emergency plan	1	1.000
F.3.2.2	Practice of the emergency plan	3	2.500
F.3.2.3	Review/update of the emergency plan	1	2.500
F.3.2.4	Expected time for tendering	3	5.000
F.3.2.5	Expected time for demolition	3	5.000
F.3.2.6	Expecetd time for construction	3	2.000

REFERENCES

[1] FORESEE testing strategy & plan.

[2] The Montabliz viaduct. (2006). Villegas, Roberto; Pantaleón, Marcos J.; Revilla, Roberto. Consejo Superior de Investigaciones Científicas (España)