

Future proofing strategies FOr RESilient transport networks against Extreme Events

H2020-MG-7-1-2017: Resilience to extreme (natural and man-made events)

Integration of Resilience in Transport Infrastructure Life-Cycle

Concepción Toribio Díaz

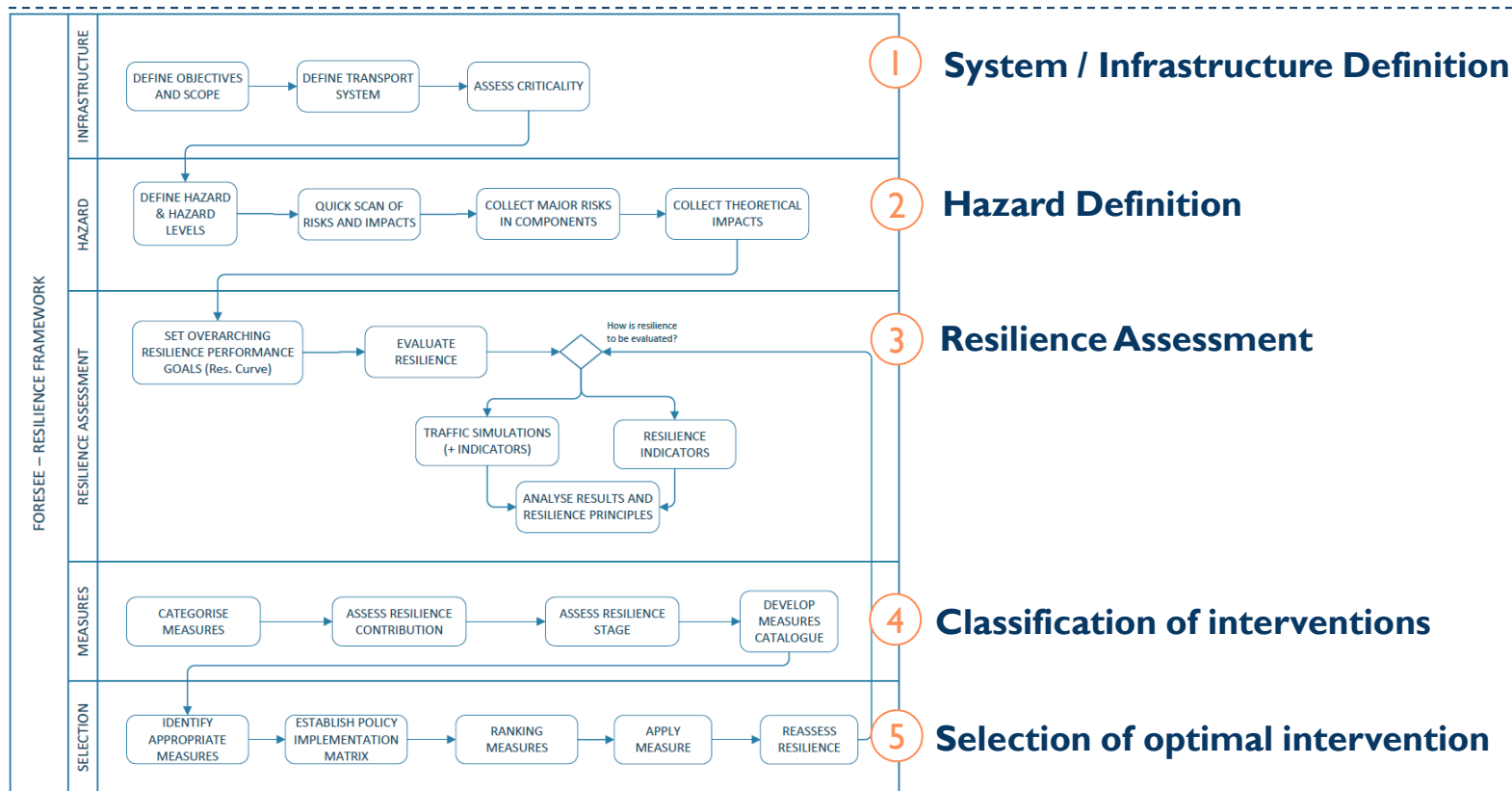


FORESEE Resilience Framework

- ▶ **FORESEE Resilience Framework** to systematically **integrate resilience** in **Transport Infrastructure Life Cycle**. Including procedures to:
 - ▶ System Definition.
 - ▶ Hazard Definition.
 - ▶ Resilience Assessment.
 - ▶ Classification of Interventions to build resilience.
 - ▶ Selection of resilience-enhancing interventions.
- ▶ **FORESEE portfolio** of solutions are included in the **Framework**, either:
 - ▶ As a resilience-enhancing solution or
 - ▶ As a tool that supports the implementation of some step of the framework.



FORESEE Resilience Framework



1 System / Infrastructure Definition

- ▶ **Criticality Assessment Tool:** identify those assets that are most critical to the functioning of the society. According to the **criticality category** obtained, resilience performance objective are established in terms of performance levels and recovery times associated under different risk scenarios.



2 Hazard Definition

- ▶ Definition and analysis of the hazard that may impact the system causing a disruption.

FORESEE Tools

GIS Risk analysis Platform

Fragility and Vulnerability Functions

New Flooding Methodology

New Shakemaps Methodology

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3 Resilience Assessment

FORESEE Procedures:

- ▶ Using traffic simulations.
- ▶ Using indicators:

I. Resilience Indicators

Resilience Indicators
(CWA 17819)

Relation of the indicator
to resilience principles

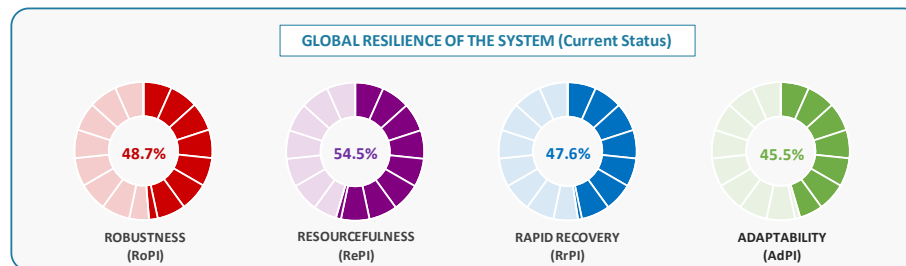
RESILIENCE INDICATORS		RESILIENCE PRINCIPLES SCORE			
ID	INDICATOR DESCRIPTION	ROBUS.	RESOU RCEF.	RAPID R.	ADAPT
1.1.1	Age / age of replacement of the warning system	3	0	2	0
1.1.2	Condition state of infrastructure pre-event	3	0	2	0
1.2.1	Possibility of building a temporary alternative route for vehicles	3	1	2	0



CASE STUDY #4: RAILWAY TRACK 6185 (OEBISFELDE - BERLIN SPANDAU)

II. Resilience-principles Performance Indicators

Global Performance Index for each resilience principle



4 Classification of interventions to build resilience

Procedure to systematically identify, categorize, and assess measures in terms of their contribution to the resilience:

► Classification of Interventions:

Eight resilient categories

1. Robust Design
2. Resilient Construction
3. Design Strategy

Phase
Planning & design

4. Monitoring
5. Maintenance & Management
6. Emergency Management

Phase
Operation

7. Legislation & Regulation
8. Research & Learning

Phase
All

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4 Classification of interventions to build resilience

Procedure to systematically identify, categorize, and assess measures in terms of their contribution to the resilience:

- ▶ **Classification of Interventions**
- ▶ **Resilience Performance:** Analyze interventions from a resilience perspective.

How the intervention contributes to the resilience principles:

- ✓ Robustness?
- ✓ Resourcefulness?
- ✓ Rapid Recovery?
- ✓ Adaptability?

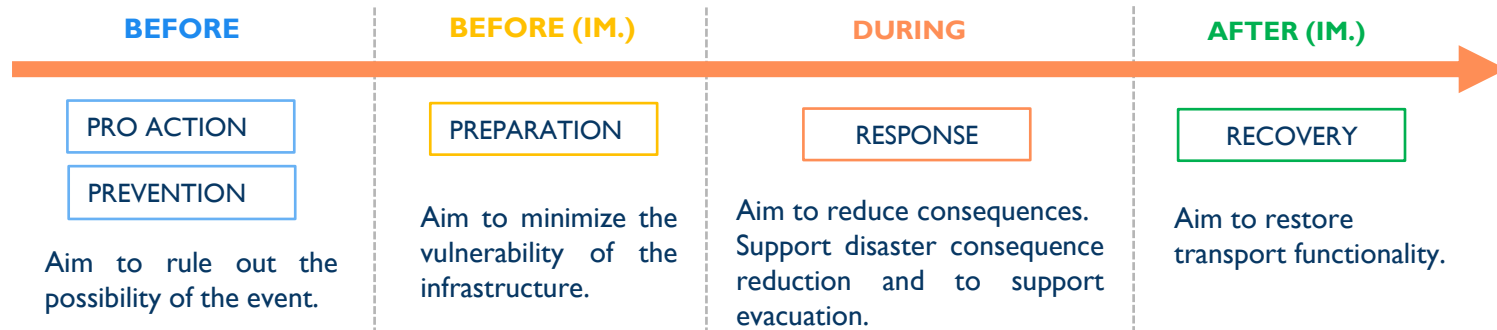
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4 Classification of interventions to build resilience

Procedure to systematically identify, categorize, and assess measures in terms of their contribution to the resilience:

- ▶ **Classification of Interventions**
- ▶ **Resilience Performance**
- ▶ **Resilience Stage:** phase of resilience in which the intervention is applied?



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Classification of FORESEE Tools

Foresee Task ID	MEASURE / TOOL	MAIN CHARACTERISTICS				LIFE CYCLE				RESILIENCE STAGE					RESILIENCE PRINCIPLE				SUMMARY SHEET
		HAZARD	CATEGORY	LOCATION	ASSET	PLANNING	DESIGN	CONSTRUCTION	OP&M	PRO-ACTION	PREVENTION	PREPARATION	RESPONSE	RECOVERY	ROBUSTNESS	RESOURCEF.	RAPID RECOV.	ADAPTABILITY	
T1.3	Governance Module	Any	Design Strategy	General	Infrastructure		✓	✓			✓				●	●	●	●	
T2.1	GIS Risk analysis platform	Flooding, Landslide, Earthquake	Research & Learning	On the infrastructure and surroundings	Infrastructure	✓				✓					●	●	●	●	
T2.4	Virtual Modelling platform	Landslide	Research & Learning	On the infrastructure and surroundings	Infrastructure				✓	✓	✓				●	●	●	●	
T2.5	SHM BIM Based alerting SAS platform	Landslide	Monitoring	On the infrastructure	Infrastructure				✓	✓	✓				●	●	●	●	
T3.1	Improved permeable asphalt pavement for extreme conditions	Flooding	Robust design	On the infrastructure	Pavement		✓			✓	✓				●	●	●	●	
T3.2	New slope stabilization-protection systems	Landslide	Robust design	On the infrastructure	Slopes		✓			✓	✓				●	●	●	●	
T3.3	Adaptation strategies toward sustainable drainage systems	Flooding	Design Strategy	Outside the infrastructure	Culverts and surroundings	✓	✓			✓	✓				●	●	●	●	
T3.4	Traffic Module	Any	Design Strategy	General	Infrastructure	✓	✓								●	●	●	●	
T3.4	Fragility and Vulnerability Functions and Decision Support Module	Earthquake	Design Strategy	General	All assets				✓	✓	✓	✓	✓		●	●	●	●	
T4.1	New flooding methodology	Flooding	Design Strategy	General	Infrastructure	✓	✓			✓					●	●	●	●	
T4.2	Shakemaps methodology	Earthquake	Research & Learning	Outside the infrastructure	Infrastructure	✓	✓			✓	✓				●	●	●	●	
T4.3.1	Algorithm to determine optimal restoration programs	Any	Maintenance & Management	General	Infrastructure		✓		✓				✓	✓	●	●	●	●	



Classification of FORESEE Tools

VIRTUAL MODELLING PLATFORM					
Task	T2.4	Leader	UEDIN	Deliverable(s)	D2.8
Name					
Virtual Modelling Platform					
Description					
A numerical model that ingests rainfall data, ground motion data, and topographic data and then calibrates a physics-based slope stability model based on these inputs.					
MAIN CHARACTERISTICS					
Category	Research and learning				
Location	On the infrastructure and surroundings				
Asset	The whole asset				
Hazard	Landslides				
Life-cycle phase	Operation and Maintenance				
RESILIENCE					
Resilience Stage					
Pro-action	Preventive	Preparation	Response	Recovery	
X	X	X			
Resilience-Principle Performance					
Performance Indicator Related			Score		
Robustness	2				
Resourcefulness	3				
Rapid Recovery	1				
Adaptability	1				
WP1 Resilience indicator related					
Indicator	Category		Part		
Condition state of the infrastructure (pre-event)	Condition State		Infrastructure		
Expected condition state of infrastructure (post event)	Condition State		Infrastructure		

FLOODING METHODOLOGY					
Task	T4.1	Leader	UC	Deliverable(s)	D4.10
Name					
FLOODING METHODOLOGY					
Description					
Novel methodology for the study of floods using advanced statistical techniques to improve the calculation of flood extent for different return periods through a better exploration of the space of extremes.					
MAIN CHARACTERISTICS					
Category	Design strategy				
Location	General				
Asset	Construction and infrastructure				
Hazard	Flooding				
Life-cycle phase	Planning				
RESILIENCE					
Resilience Stage					
Pro-action	Preventive	Preparation	Response	Recovery	
X					
Resilience-Principle Performance					
Performance Indicator Related			Score		
Robustness	3				
Resourcefulness	2				
Rapid Recovery	3				
Adaptability	2				
WP1 Resilience indicator related					
Indicator	Category		Part		
Compliance with the design code	Preventive measures		Infrastructure		
Hazard zone	Physical		Environment		



5 Selection of resilience-enhancing interventions

Methodology to support, at the **strategic level**, infrastructure managers and operators in decision-making processes for ranking resilience enhancing interventions taking into account current and target resilience level as measured through indicators.

Overview

- ▶ Based on Analytic Hierarchical Process (AHP) theory: systematic engineering method transforming qualitative analysis into quantitative analysis.
- ▶ Based on the construction of a **hierarchical model**: decision problem becomes hierarchical, and the complexity is decomposed

Result

Vector that shows the **weight of each intervention** considered in relation to the resilience of the system.



Methodology for prioritizing resilience-enhancing interventions

HIERARCHICAL MODEL

TOP LEVEL

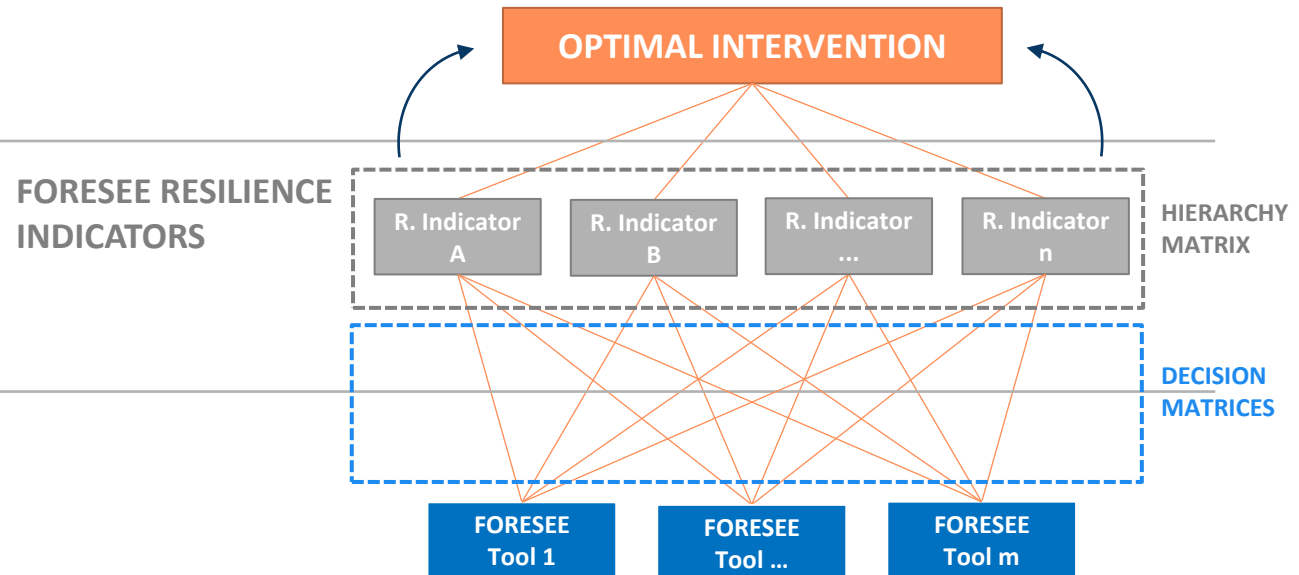
Overall goal: to determine the optimal interventions in terms of increased resilience.

MIDDLE LEVEL

Criteria that influence the goal and are used for evaluating alternatives (bottom level).

BOTTOM LEVEL

Alternatives to achieve the goal. In this case:



FORESEE TOOLS

Conclusions

- ▶ **FORESEE RESILIENCE FRAMEWORK provides procedures to:**
 - ▶ Assess the criticality of the transport system and set resilience goals accordingly.
 - ▶ Assess the resilience of the system using a wide variety of indicators.
 - ▶ Analyse, define and classify potential interventions from a resilience perspective.
 - ▶ Rank interventions in terms of increased resilience.
- ▶ **FORESEE provides a range of tools that contribute to enhancing the resilience:**
 - ▶ Design Strategies
 - ▶ Monitoring
 - ▶ Maintenance & Management
 - ▶ Research & Learning
 - ▶ Pro-action
 - ▶ Prevention
 - ▶ Preparation
 - ▶ Response
 - ▶ Recovery





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