

Assessing the impact of extreme weather events for single mode failures

- Climate Change and Weather Modelling Workshop
- TCD, Dublin, Ireland.
- 9th of November, 2015

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Outline

- Introduction
- Risk Assessment Framework- Technical Framework
 - Hazard Assessment
 - Vulnerability Assessment
 - Consequence Analysis
 - Risk Evaluation
- Risk Assessment Framework- Illustrative Example
 - Alpine Region Flash Flooding in 2003

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Introduction

- **Problem**
 - Europe is the 3rd most affected region in the world based on average 10 year **disaster costs** of €10 Billion



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Introduction

- **Solution**

- A systematic **R**isk **A**nalysis framework that explicitly considers **I**nfrastructure networks in response to extreme weather events and develops an optimization tool for series of mitigation strategies



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Introduction

- Risk arises from uncertainty of information
 - 100% certainty of information = $p_f=0.0$ or 1.0
- Uncertainty and variability of (random variables):
 - material properties
 - dimensions
 - environment
 - loads (and load combinations)
 - etc.
- Accuracy of predictive models
 - computer models, hazard scenarios, consequence models
- Inherent variabilities
 - natural hazards, weather, individual exposure to hazard

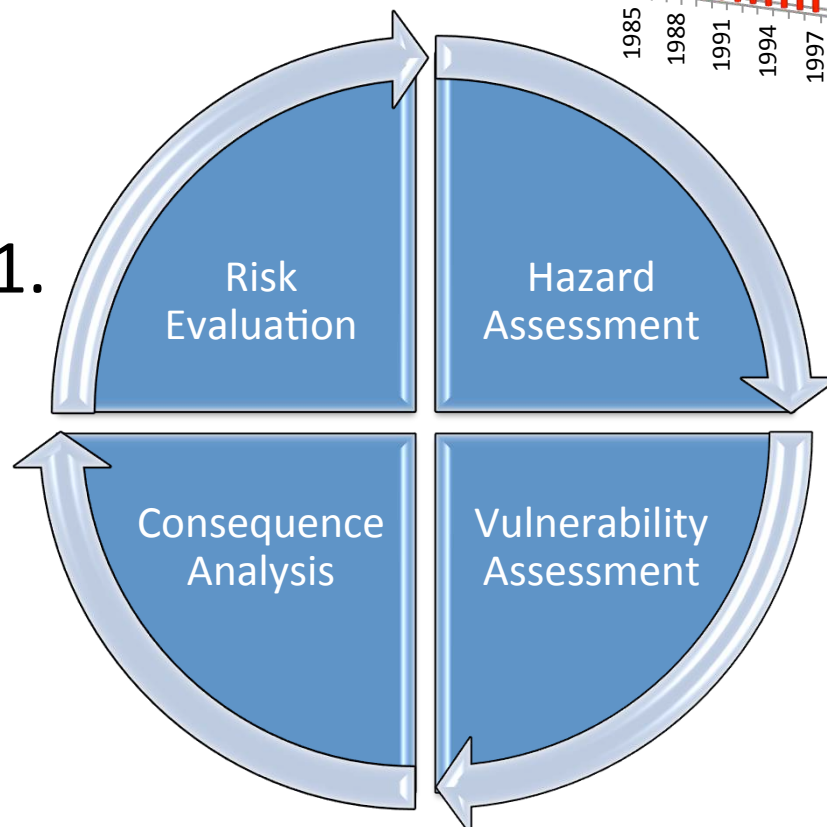
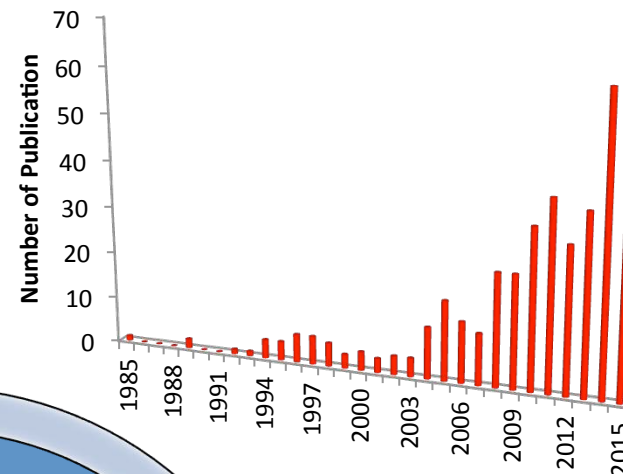


 **probabilistic modelling**

Introduction

- Available Risk Frameworks

- MATRIX
- UNDP
- EC-TIGRA
- ESPON 1.3.1.
- Armonia
- ...



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Introduction

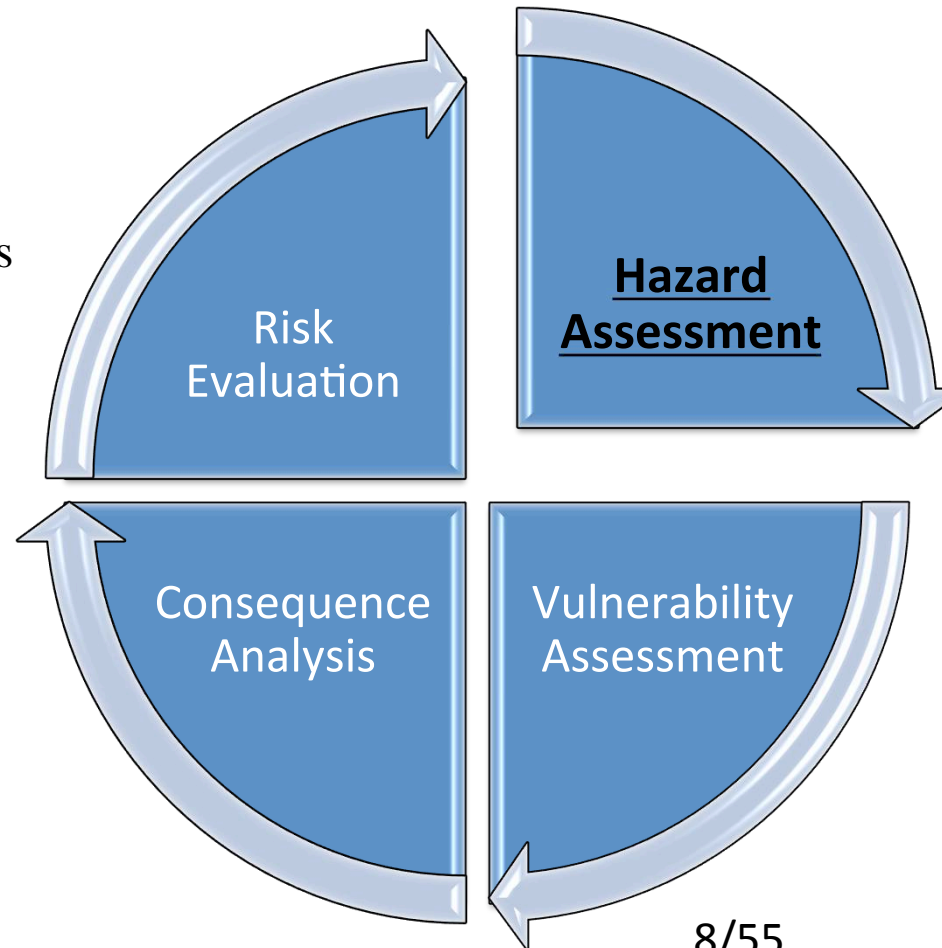
- **What is Different in RAIN?**
 - GIS-based Bayesian Probability Theory
 - Updating and optimising decisions and ranking Mitigation Strategies
 - Multi Hazard/Multi vulnerability using Markovian Networks
 - Cascading effects
 - (Inter)dependencies in Critical Infrastructure Network
 - System of system modelling
 - Graph Theory
 - Critical hotspots in network
 - Objective Ranking Tool
 - Similarity Judgement and Delphi Panel

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Risk Assessment Framework

- Identifying Extreme weather Events
- Thresholds of Extreme weather Events
- Probability of Extreme weather Event
- Projection of Climate change



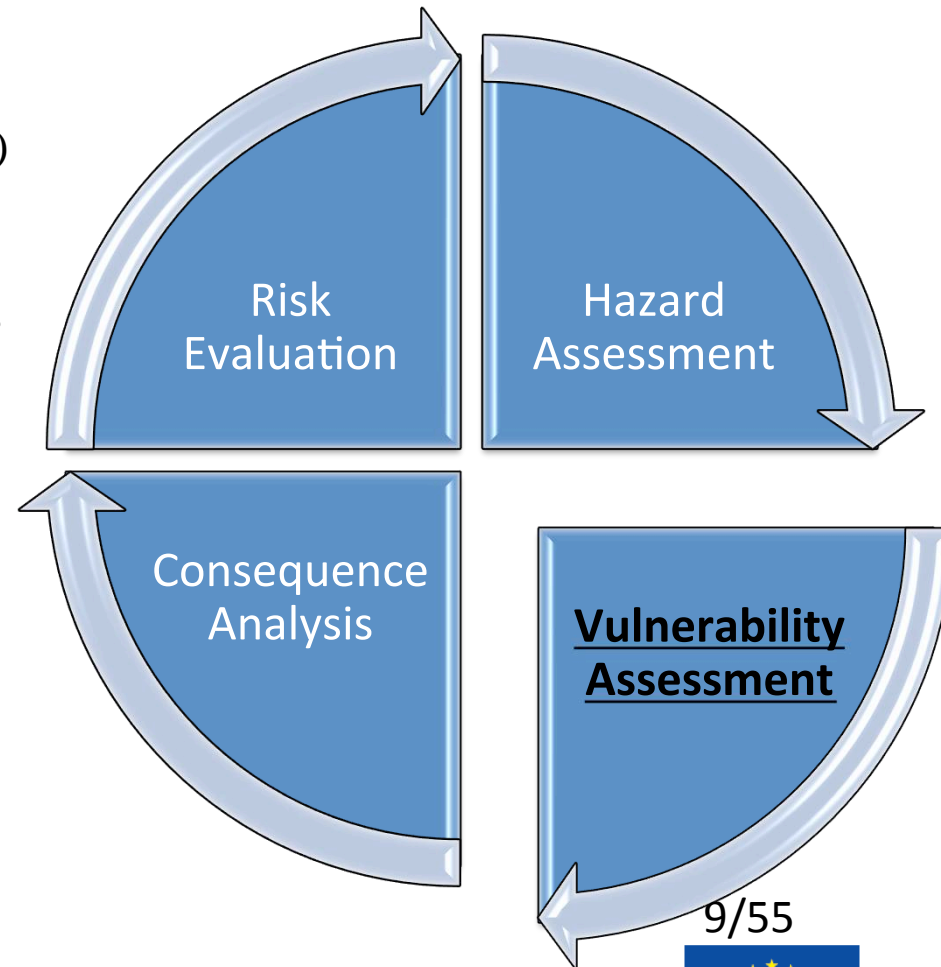
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Risk Assessment Framework

- Identifying Critical infrastructure (CI)
- Identifying (inter)dependencies
- Identifying risks associated with CIs
- Vulnerability Analysis of CIs



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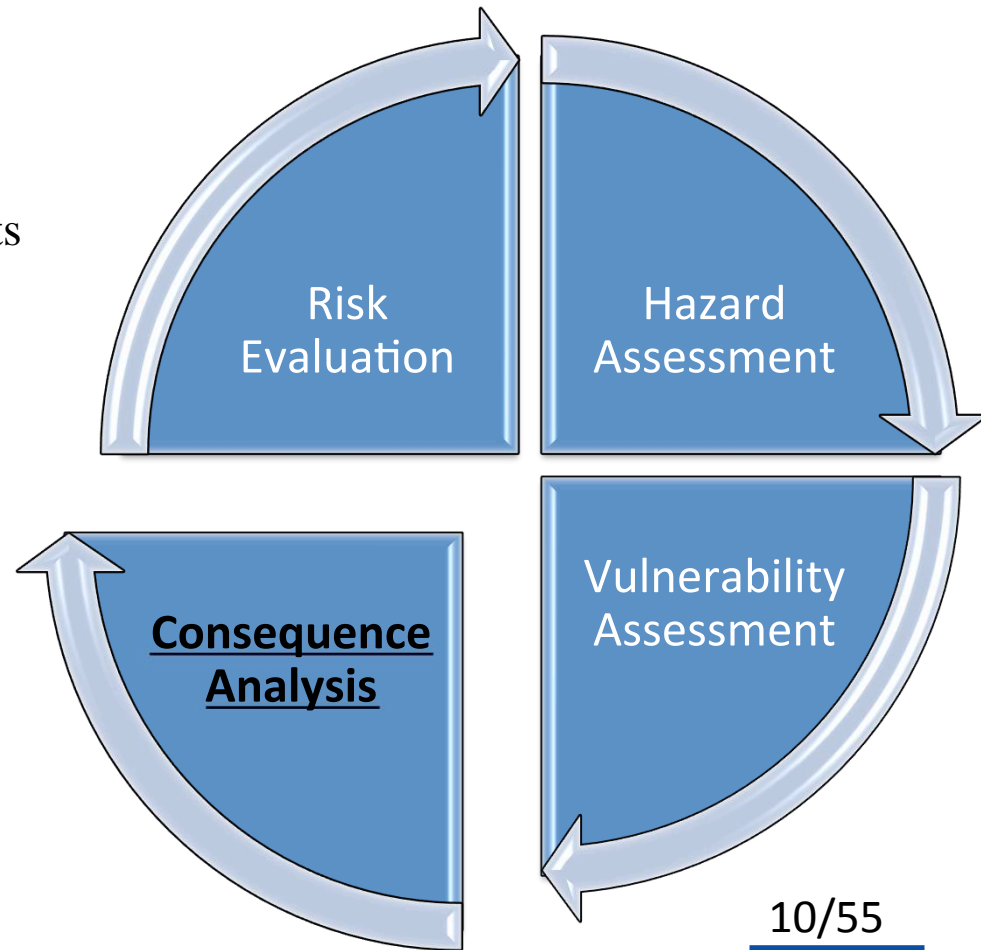


Risk Assessment Framework



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- Identifying Consequences
- Identifying key factors and weights
 - Objective Ranking Tool
- Consequence Quantification
 - F-N curves
 - Loss Exceedance Curve
 - Recovery time Analysis



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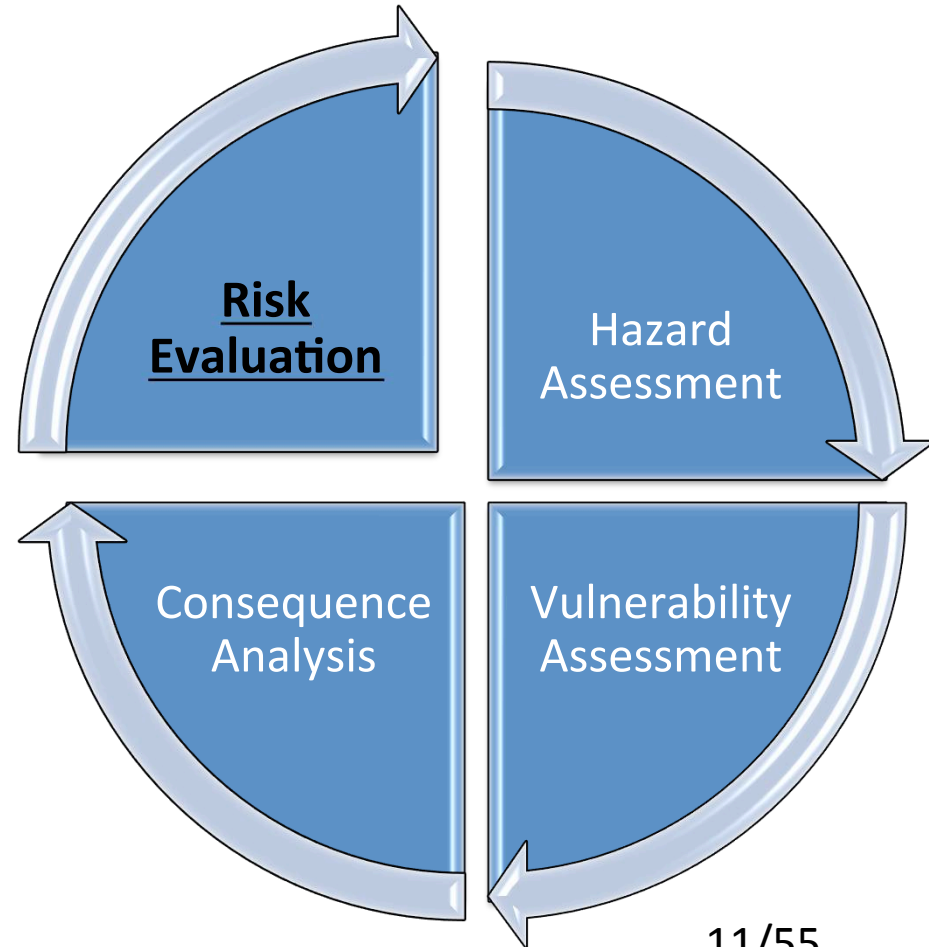
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Risk Assessment Framework



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- Identifying Risk Scenarios
 - Inference Network
- Quantifying Risks
 - Bayesian Probability Theory
 - Markovian Process
- Quantifying Benefits of Mitigation
 - Technical engineering solutions
 - Early warning systems



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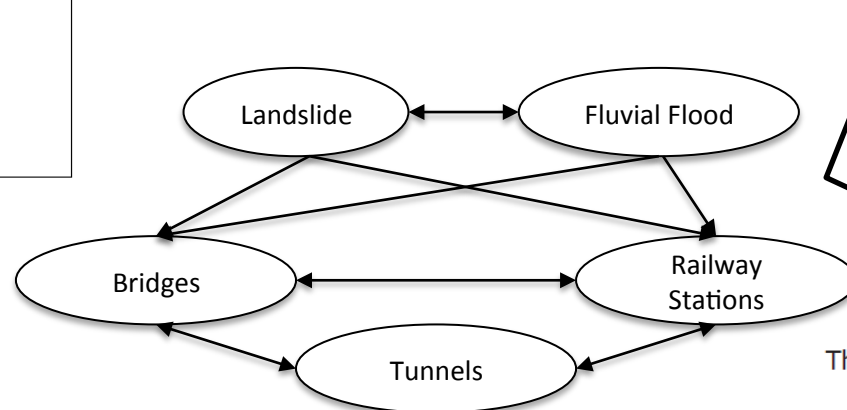
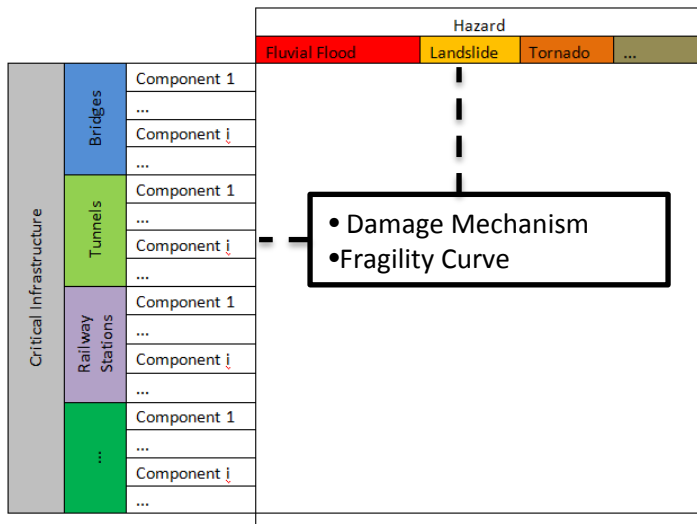
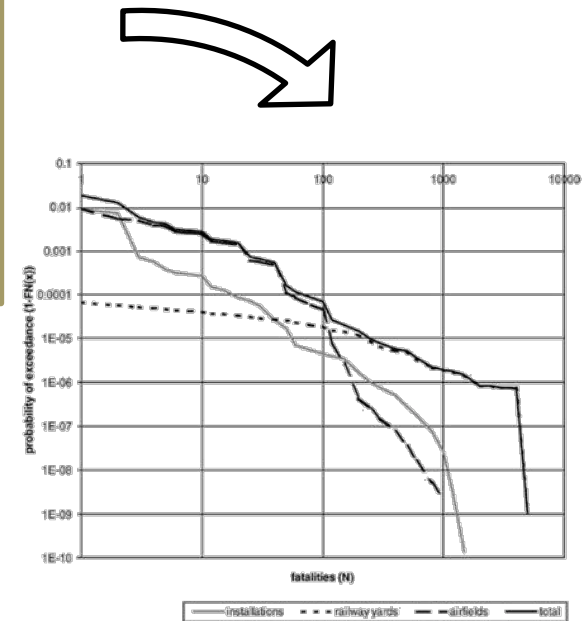
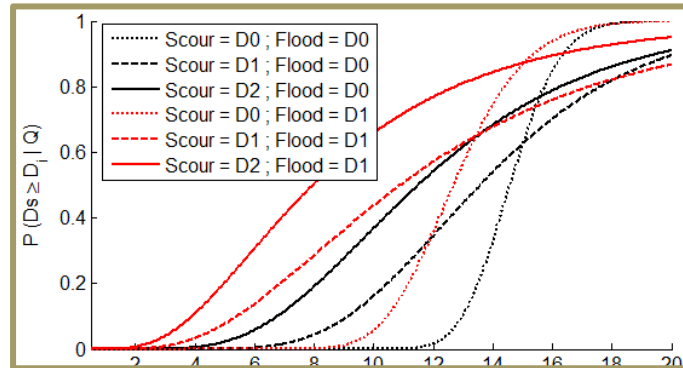


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Risk Assessment Framework



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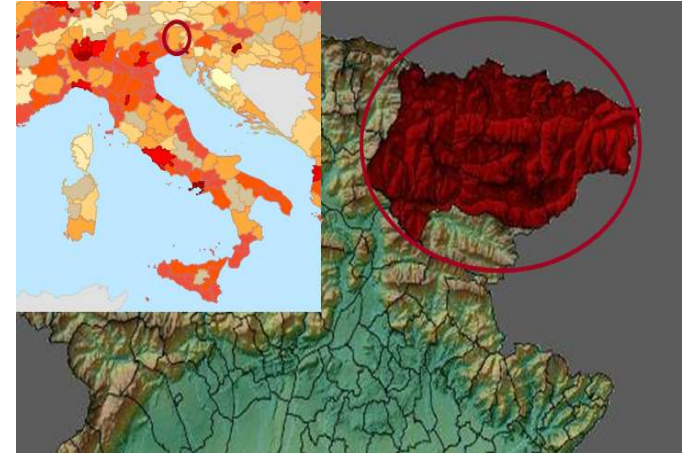


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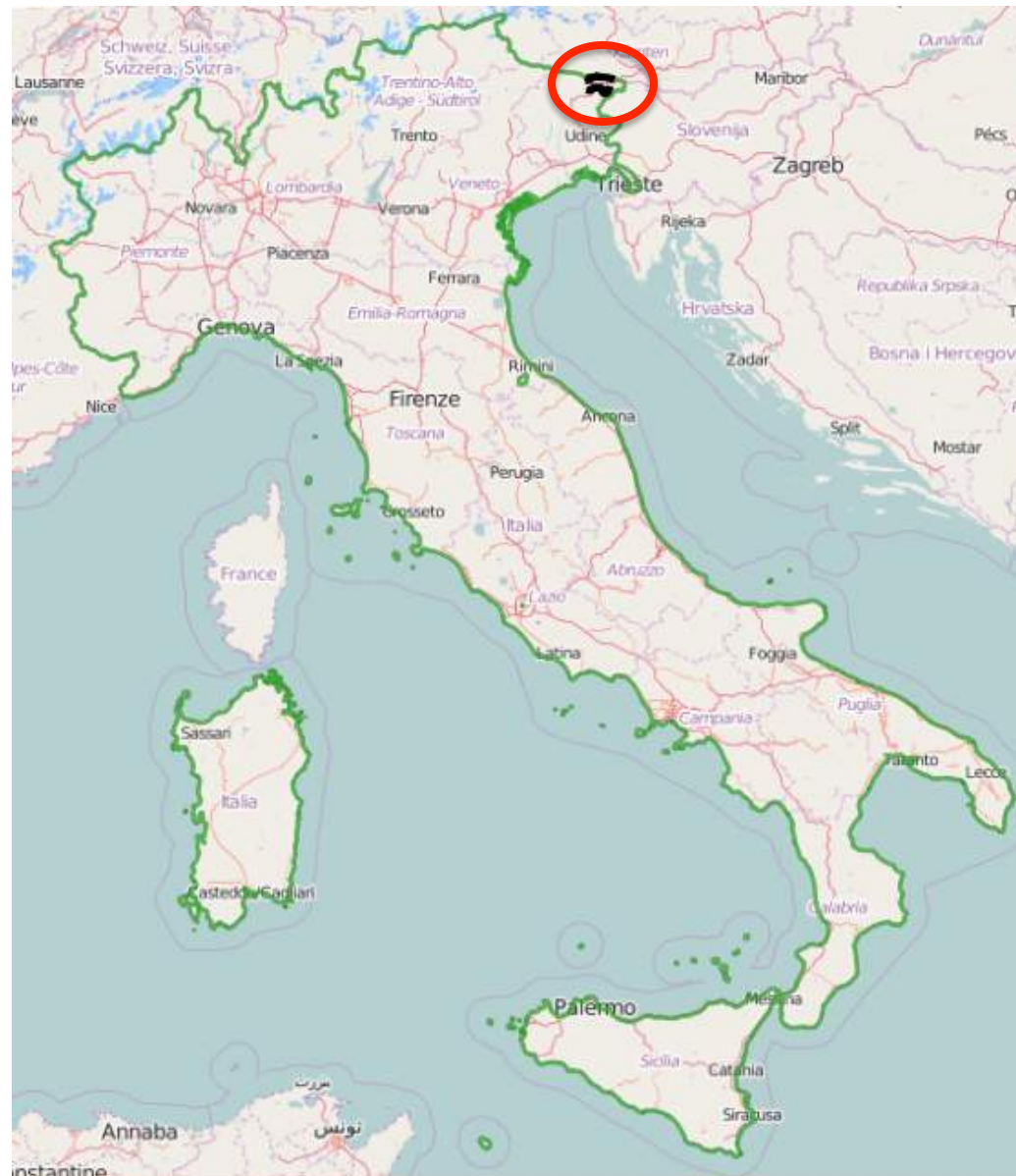
Example of Risk Assessment

Alpine Region

- Flash flooding in 2003
- 600 residents were evacuated
- Estimated damage of €190 million



Establishing the Context



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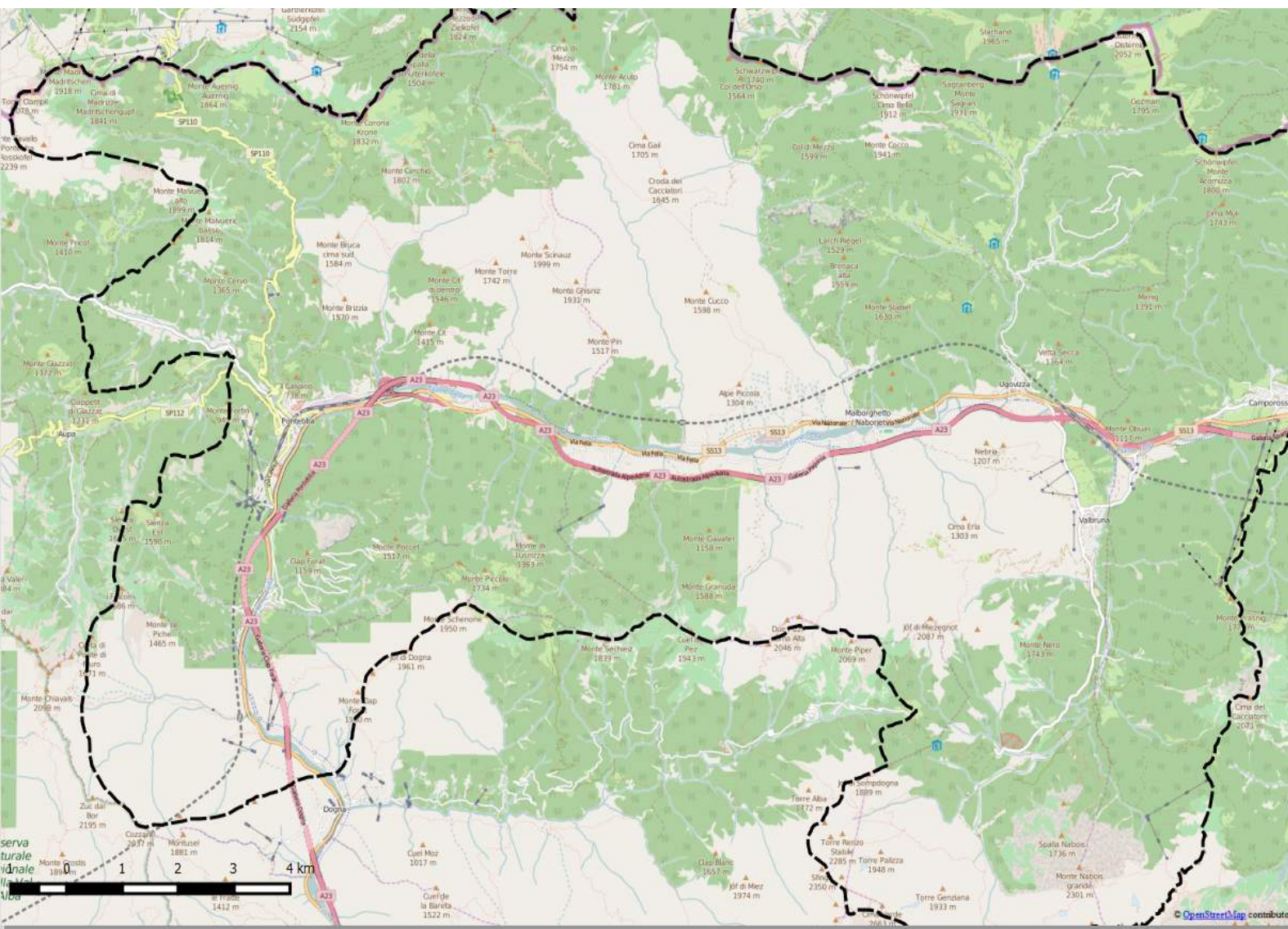


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Establishing the Context

Step 1- Isolating the Case Study Area



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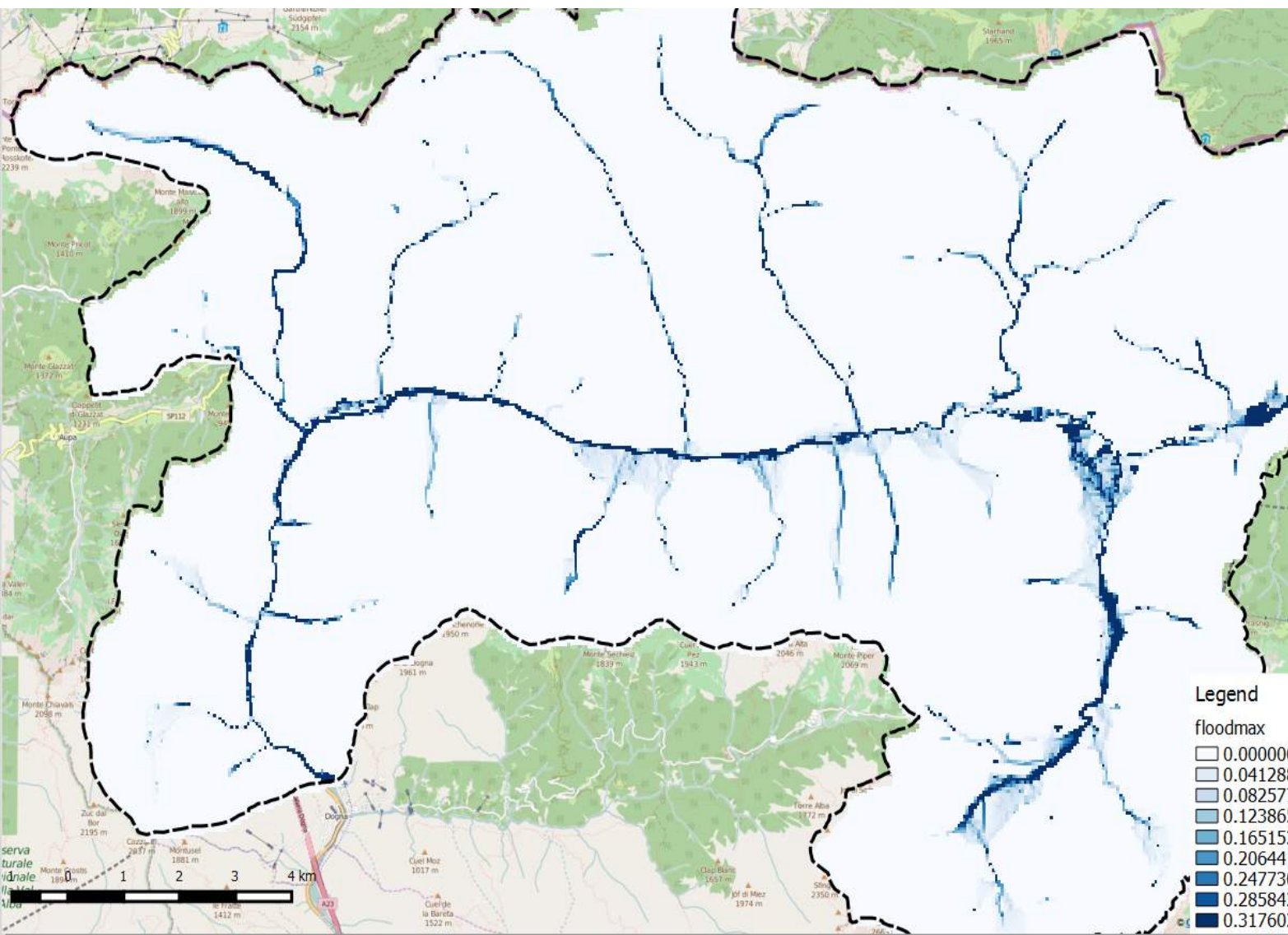


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Hazard Assessment

Step 2- Identifying hazards, thresholds and corresponding probabilities



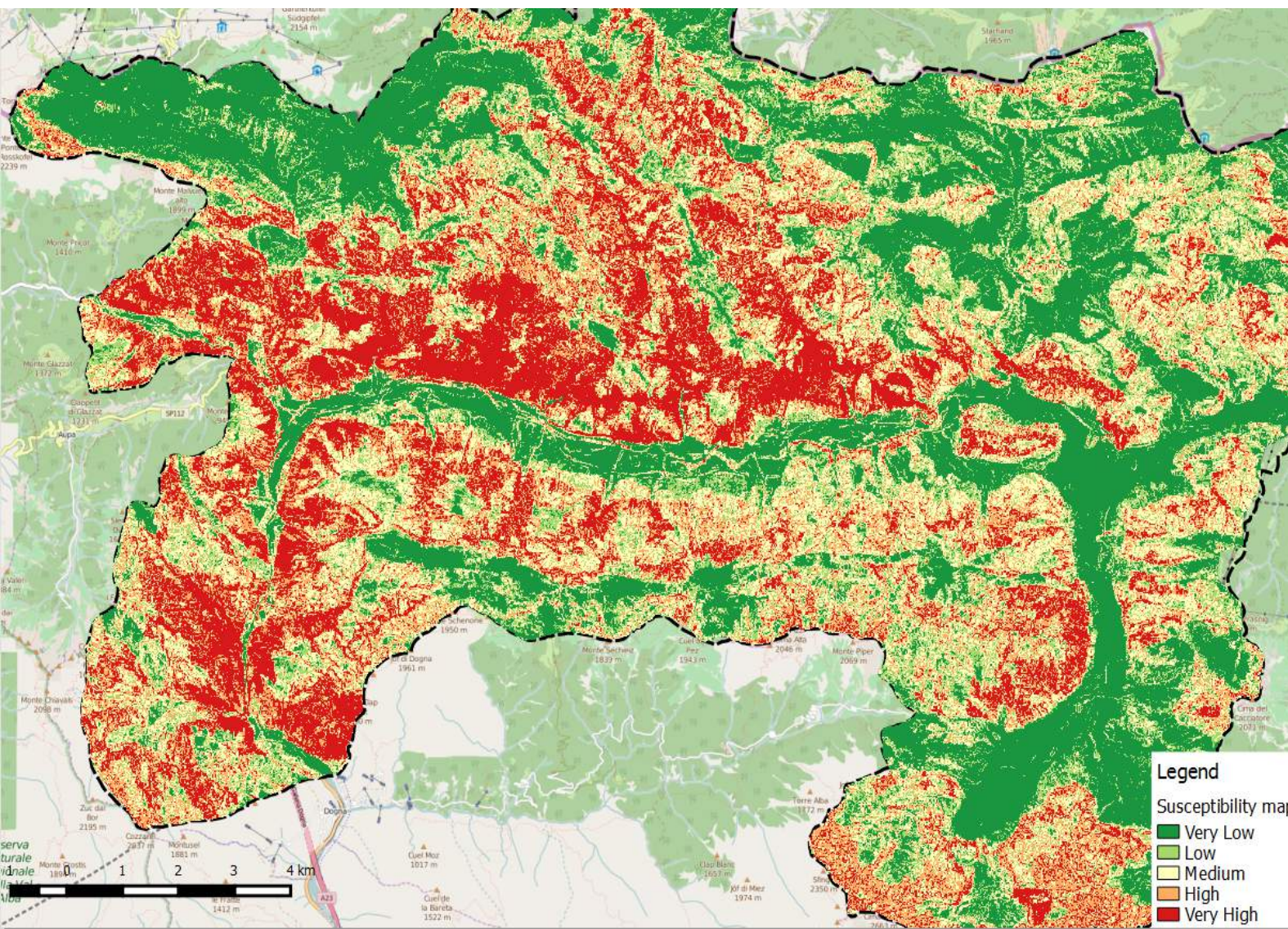
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Hazard Assessment

Step 2- Identifying hazards, thresholds and corresponding probabilities



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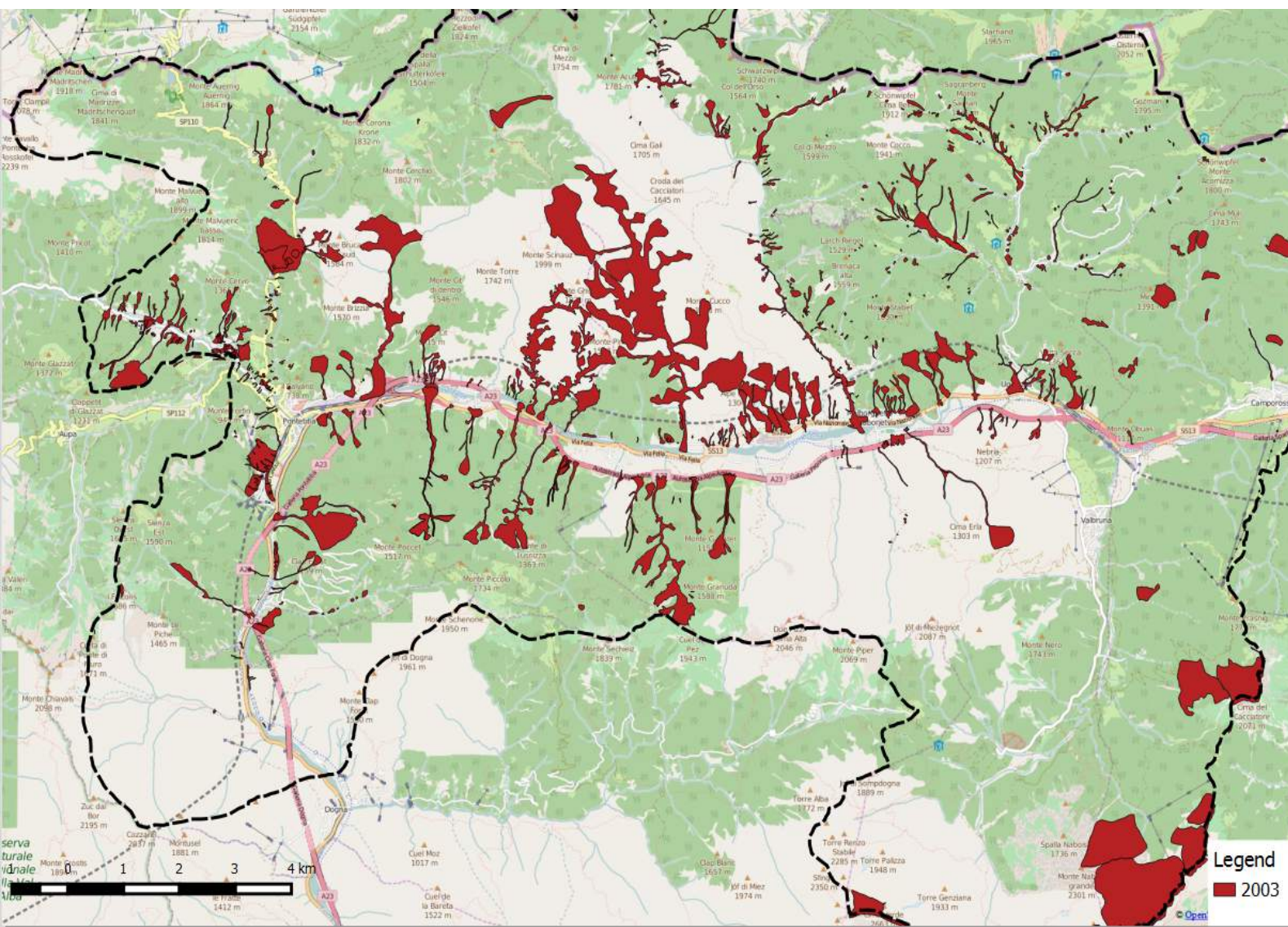


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Hazard Assessment

Step 2- Identifying hazards, thresholds



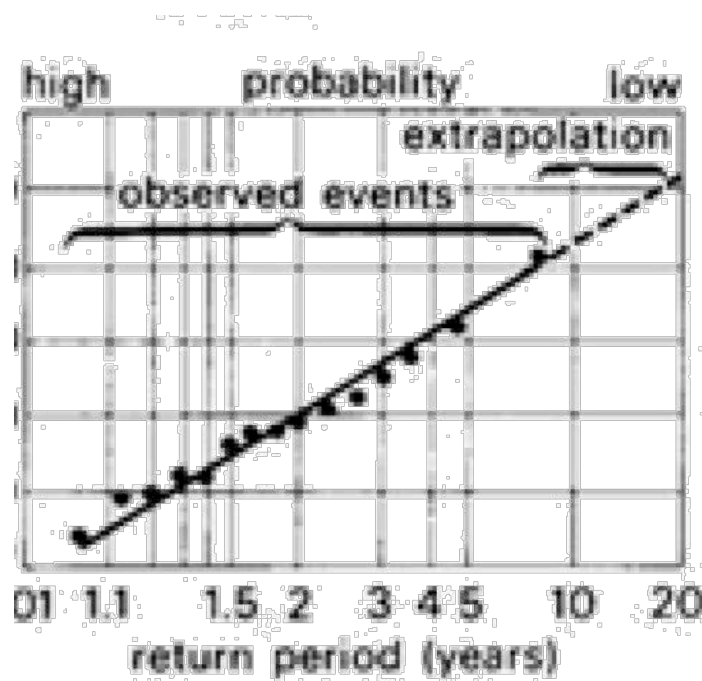
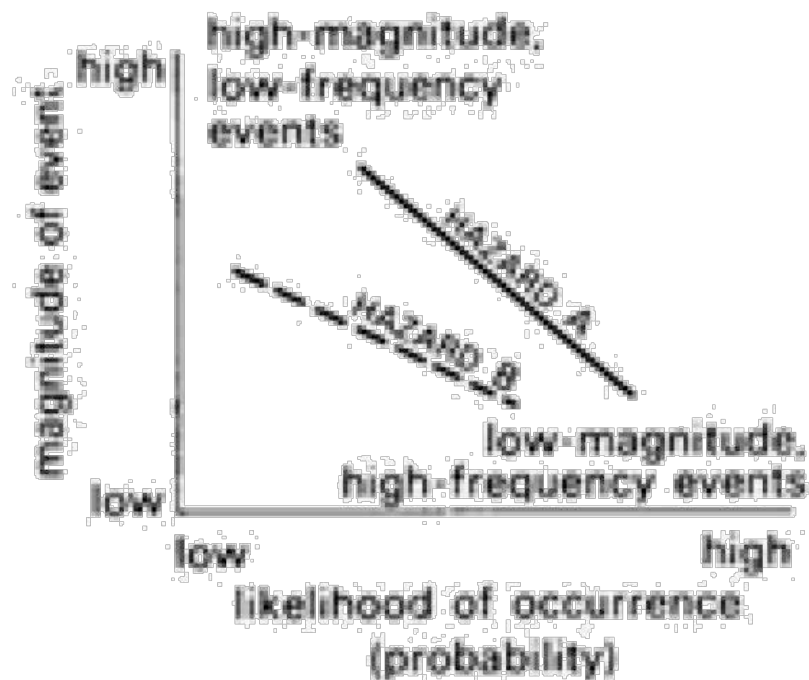
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Hazard Assessment

Step 3- Evaluation Probability of Extreme Weather Event



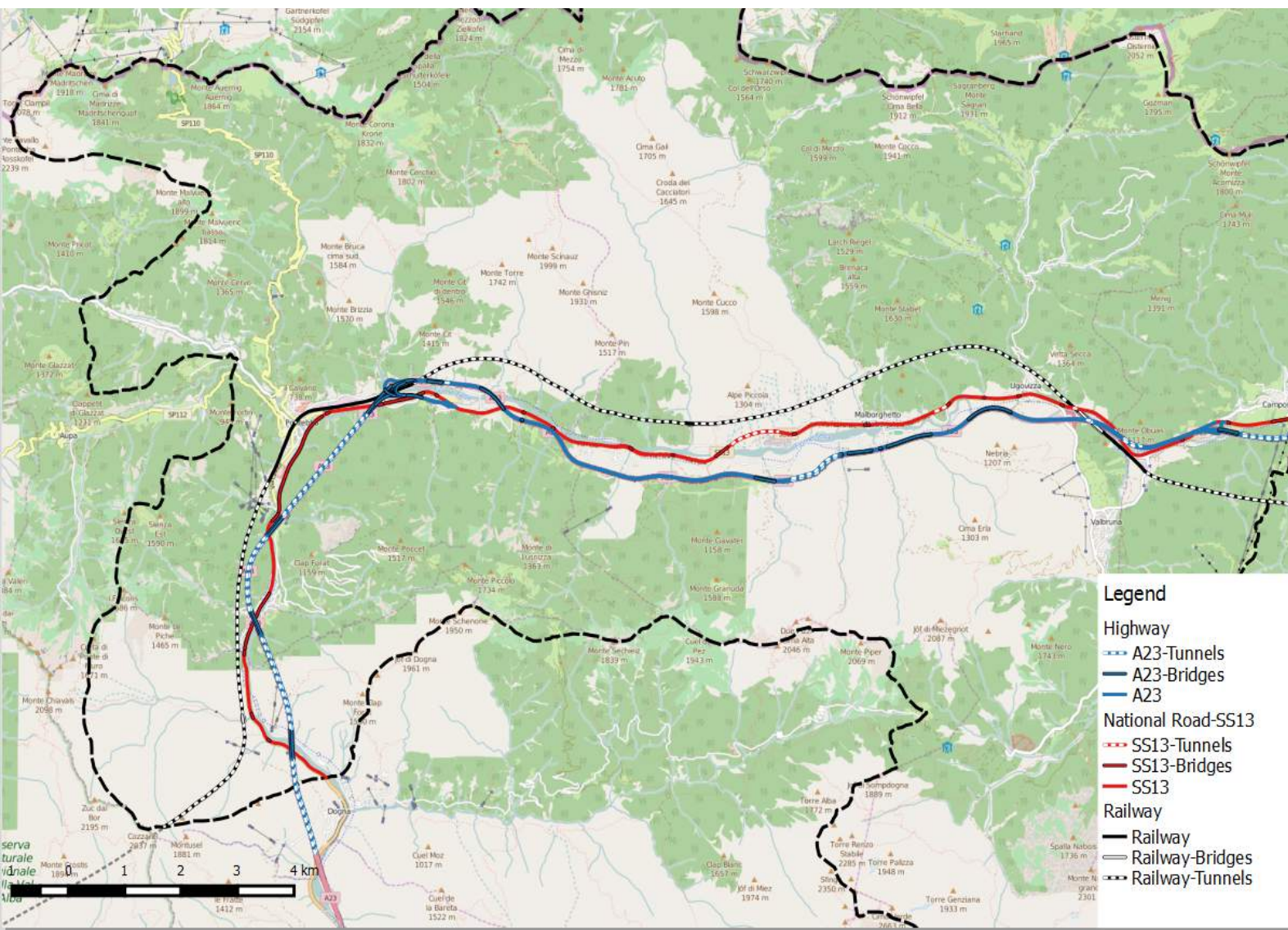
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Vulnerability Assessment

Step 4- Identifying vulnerable elements



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Vulnerability Assessment

Step 4- Identifying vulnerable elements



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Cable Stayed Bridge Wizard

Node Coordinates & Heights

Type

☒ Symmetric Bridge
☐ Asymmetric Bridge

	X(ft)	Z(ft)
A	0	100
B	400	360
C	1280	360
D	1680	100

	H1(ft)	H2(ft)
Height	360	360

☐ Depth of Deck (H3)

H3(ft)	0
--------	---

	...	Material	...	Section
Cable	1	1: Cable	1	1: Cable
Deck	2	2: Deck	2	2: Deck
Tower	3	3: Tower	3	3: Tower

Select Cable Element Type

☒ Truss
☐ Tension Only(Cable)

☐ Distance from Deck to Tower

	Dist(ft)		Dist(ft)
G1	0	G3	0
G2	0	G4	0

☐ Shape of Deck

Left Slope(%)	0
Arc Length(ft)	0
Right Slope(%)	0

Cable Distances & Heights

	Distance(ft)	Height(ft)
Left	12, 8@40, 56	4.8, 3@6, 3@8, 2@9, 180
Center	56, 9@40, 48, 9@40, 56	
Right	56, 8@40, 12	4.8, 3@6, 3@8, 2@9, 180

The diagram illustrates a symmetric cable-stayed bridge. It features two vertical towers, labeled B and C, supporting a horizontal deck. The bridge is anchored at nodes A and D. Cables connect the towers to the deck at various points. Key dimensions are labeled: H1 and H2 for tower heights, H3 for deck depth, and various distances (G1, G2, G3, G4) and heights (G1, G2, G3, G4) for the cable stays. The deck is divided into Left, Center, and Right sections. The diagram also shows the overall bridge height and the distance from the deck to the towers.

☐ Node No.
☐ Member No.

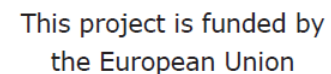
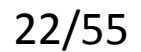
View option

☒ Bitmap
☐ Drawing

Update & Draw

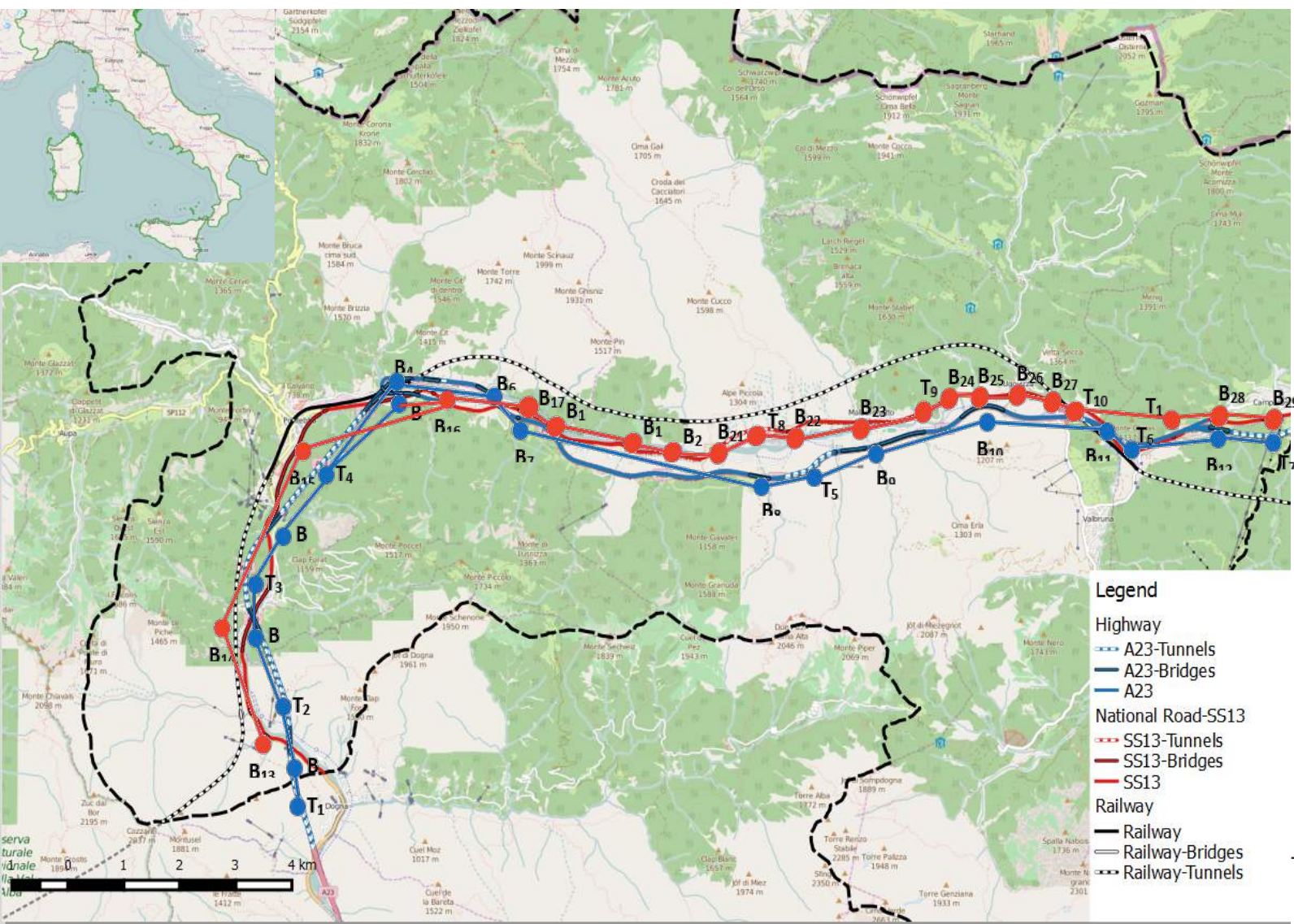
OK

Close



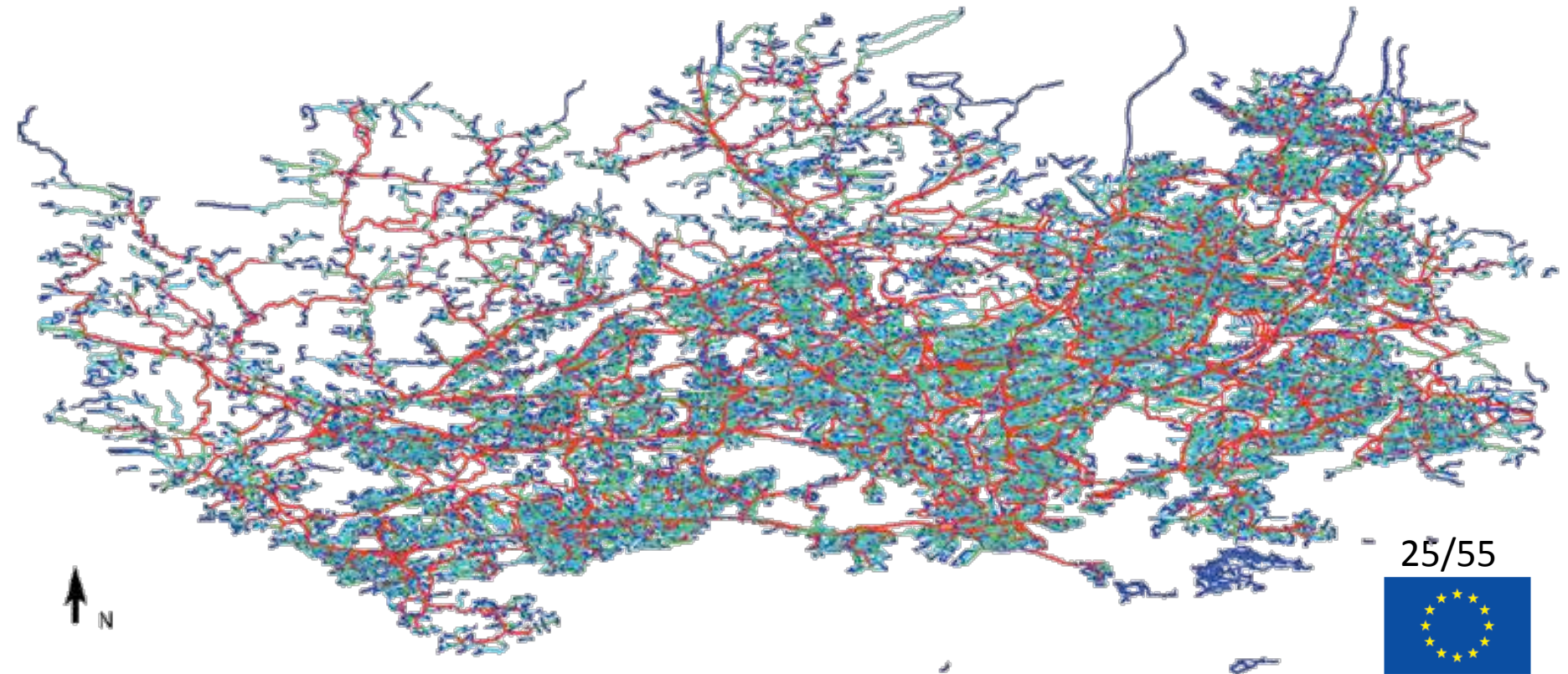
Vulnerability Assessment

Step 5- Identifying critical locations



Vulnerability Assessment

Step 5- Identifying critical locations



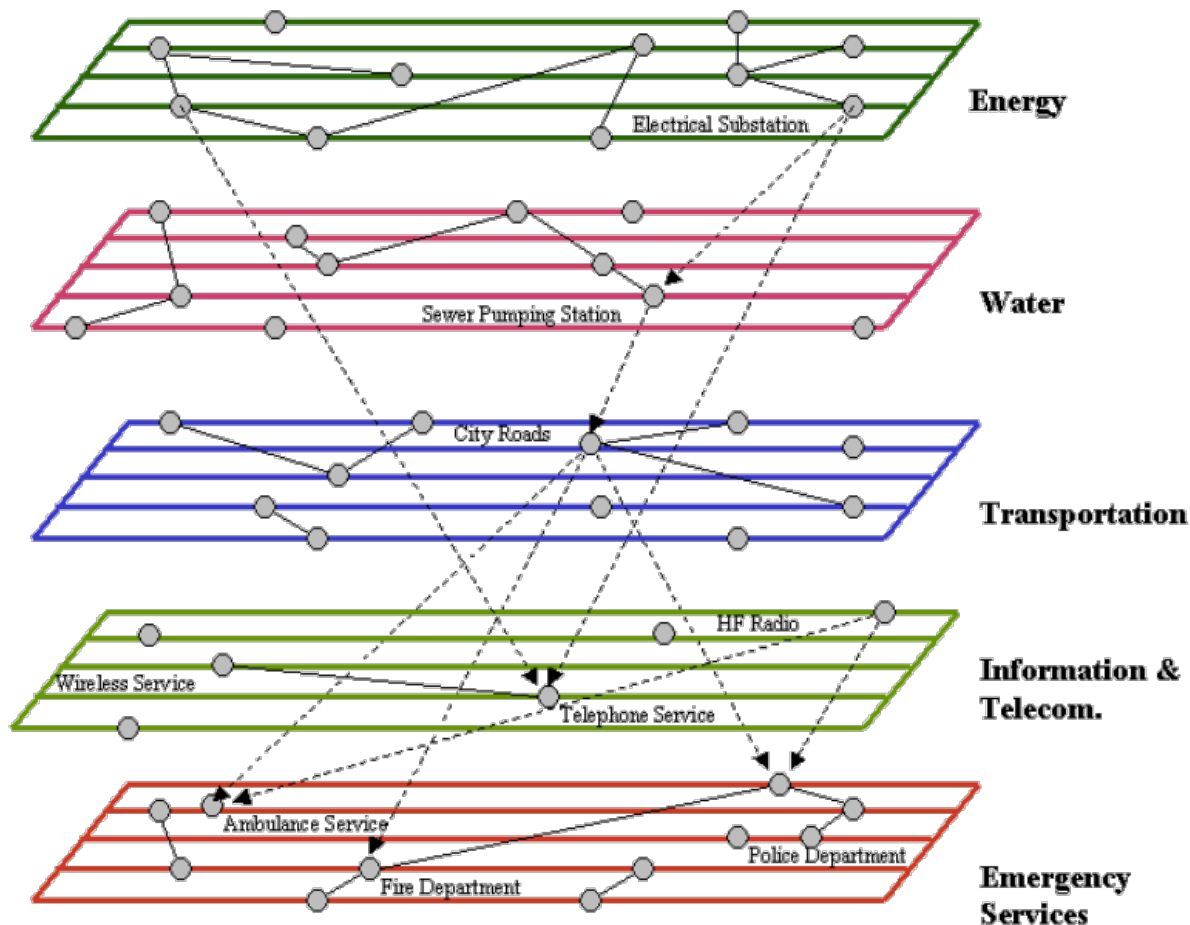
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Vulnerability Assessment

Step 6- Identifying (inter)dependencies



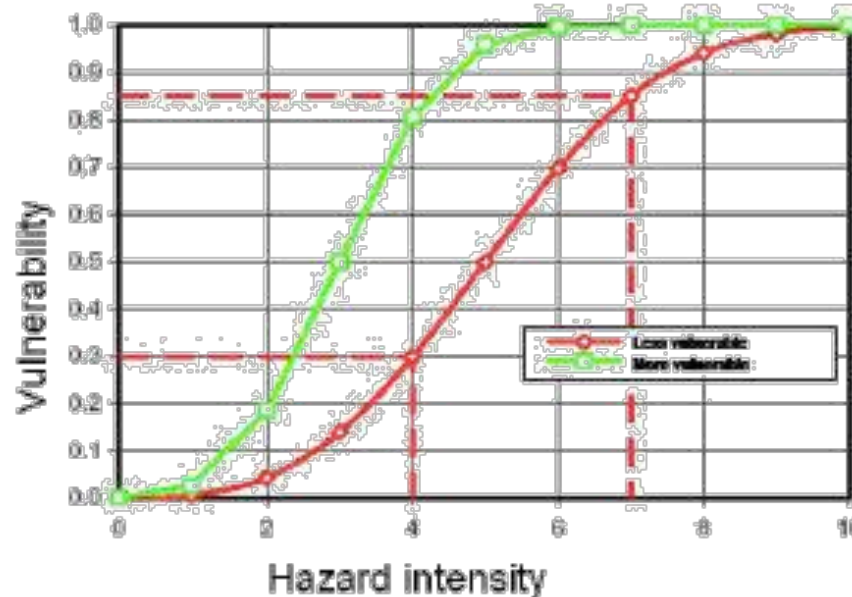
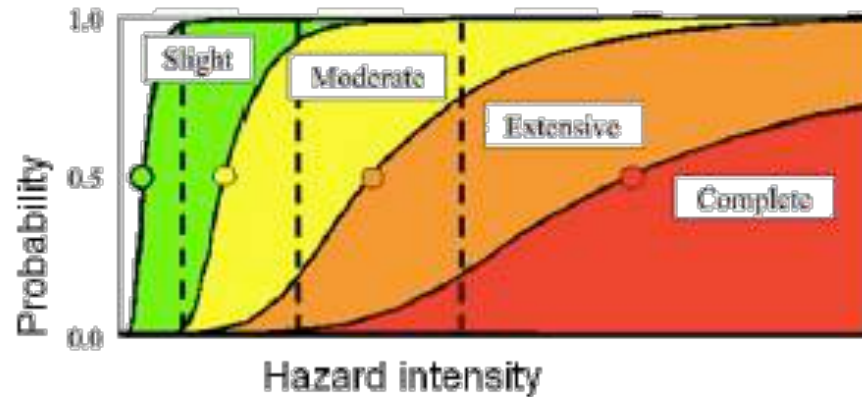
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Vulnerability Assessment

Step 7- Vulnerability Analysis and Fragility Curves



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Consequence Analysis

Step 8- Identifying Consequences

- Consequences
 - Societal
 - Fatalities
 - Injuries
 - Security
 - Fresh Water Supply
 - Food Supply
 - Energy Supply
 - Economic
 - Cost of Repair/Replacement
 - Cost of Labour
 - Availability of Materials
 - Age of the Existing Infrastructure

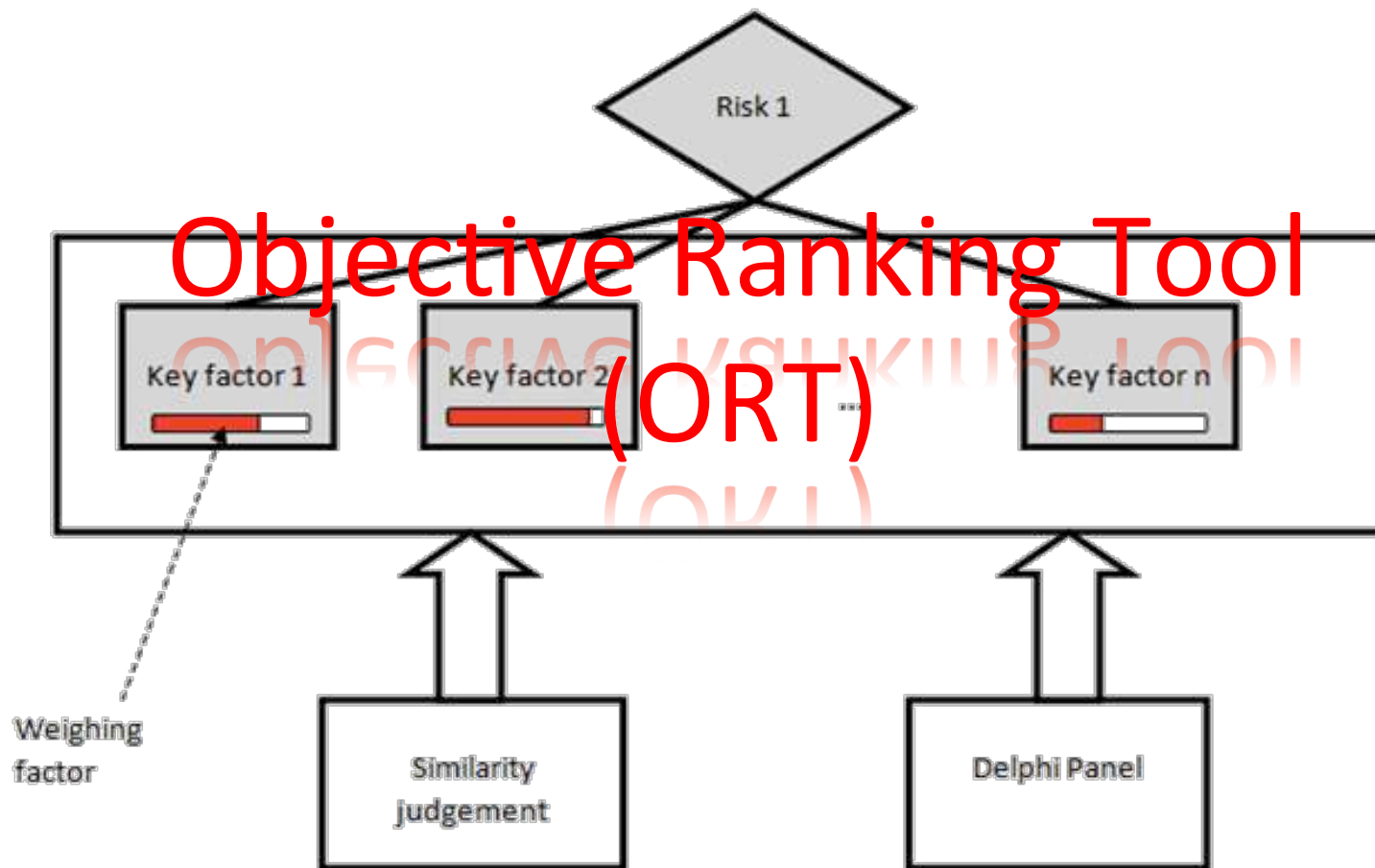
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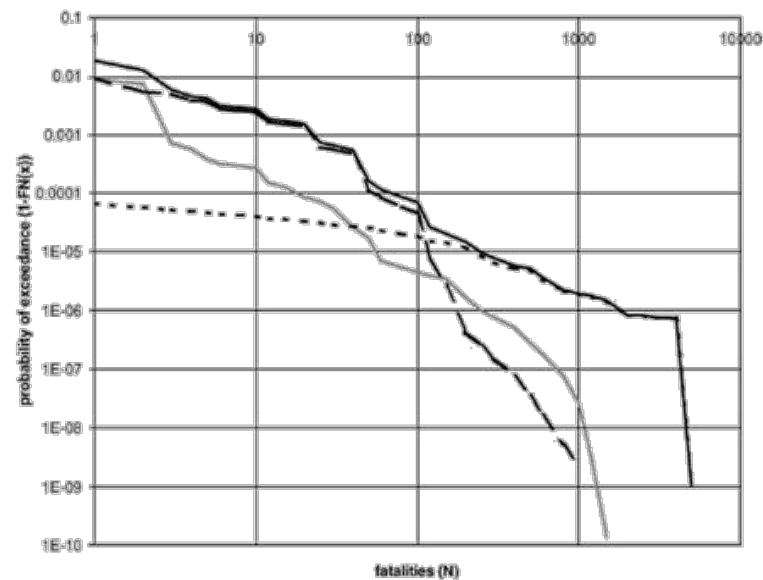
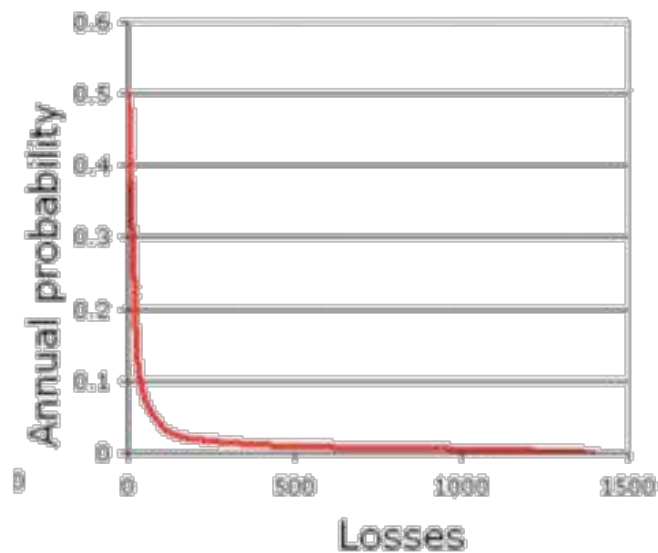
Consequence Analysis

Step 9- Identifying key factors and weights



Consequence Analysis

Step 10- Quantifying consequences

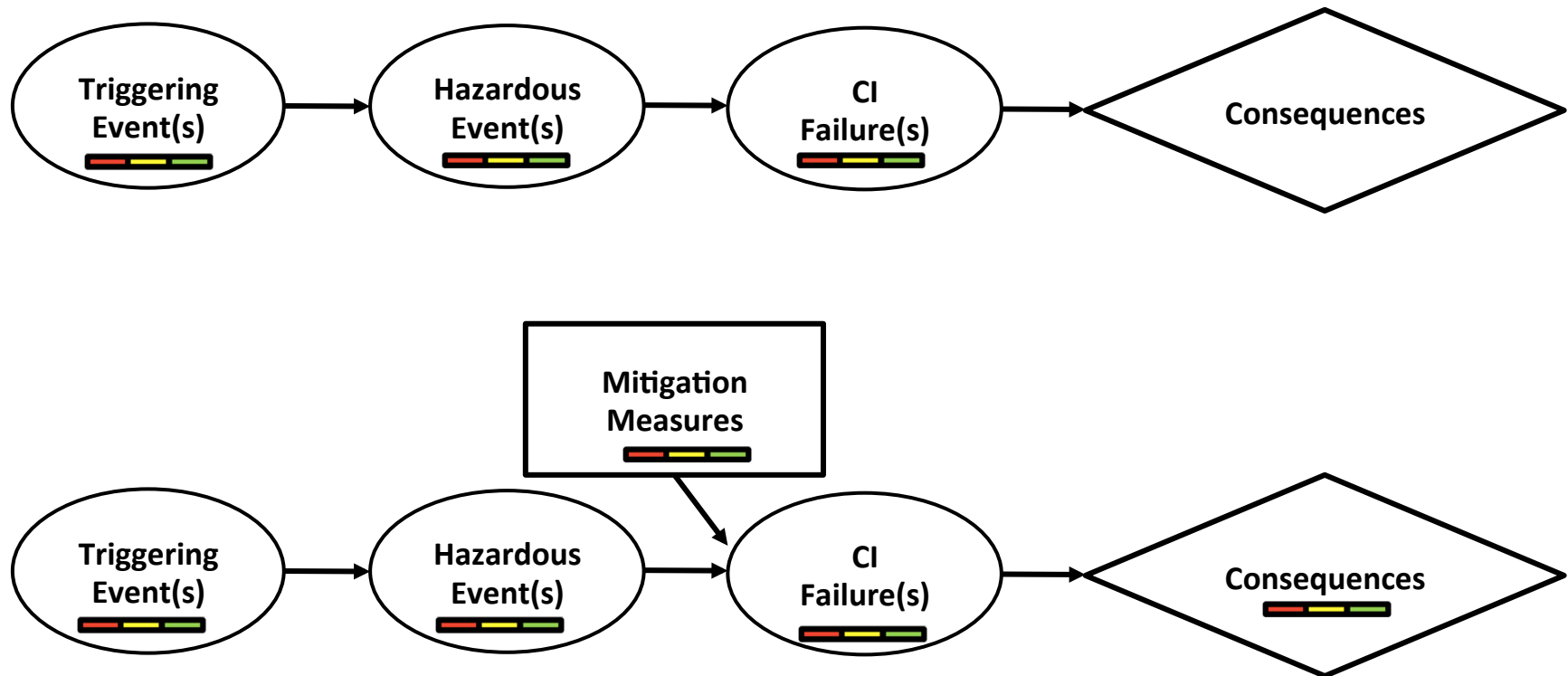


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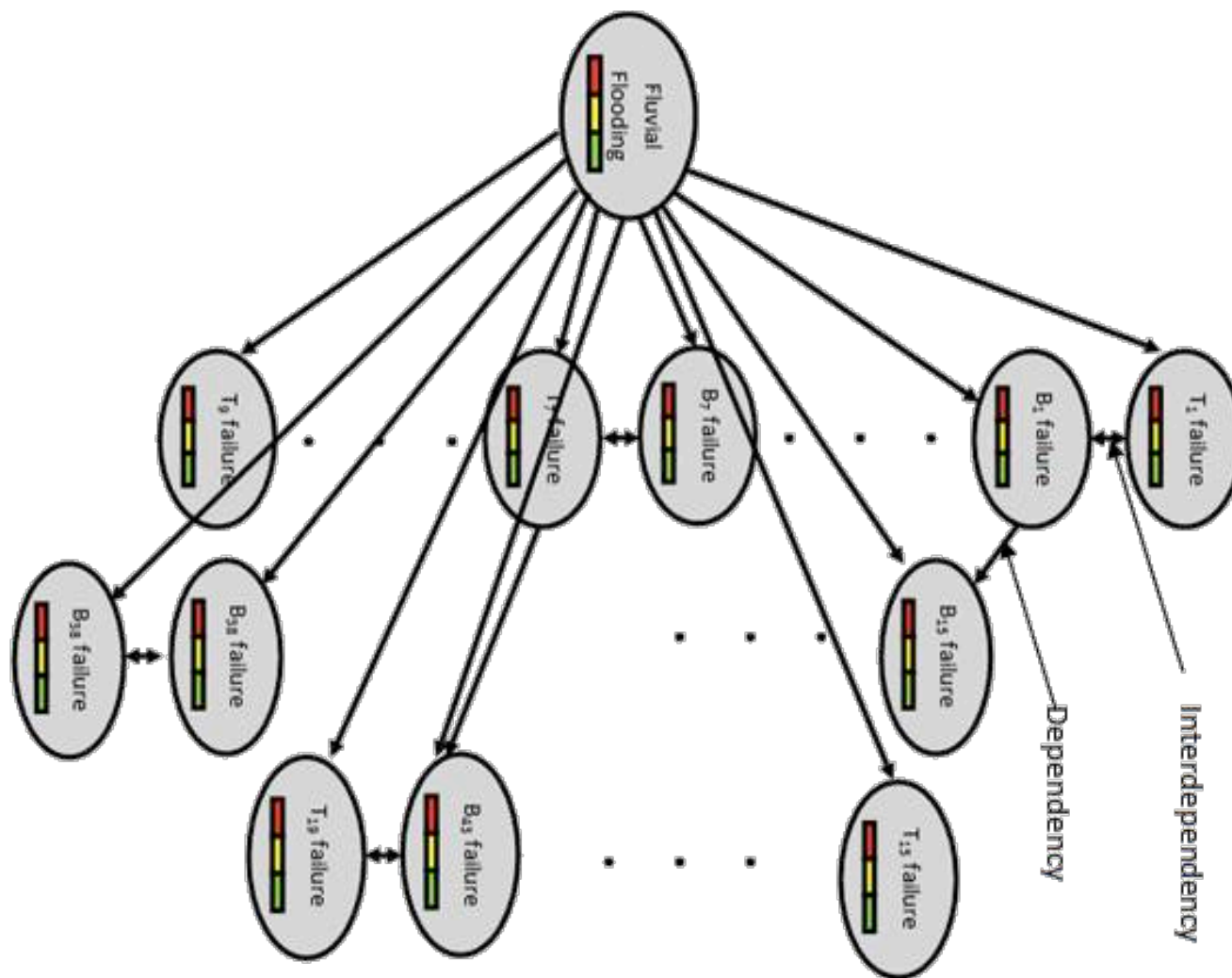
Risk Evaluation

Step 11- Generating Inference Network



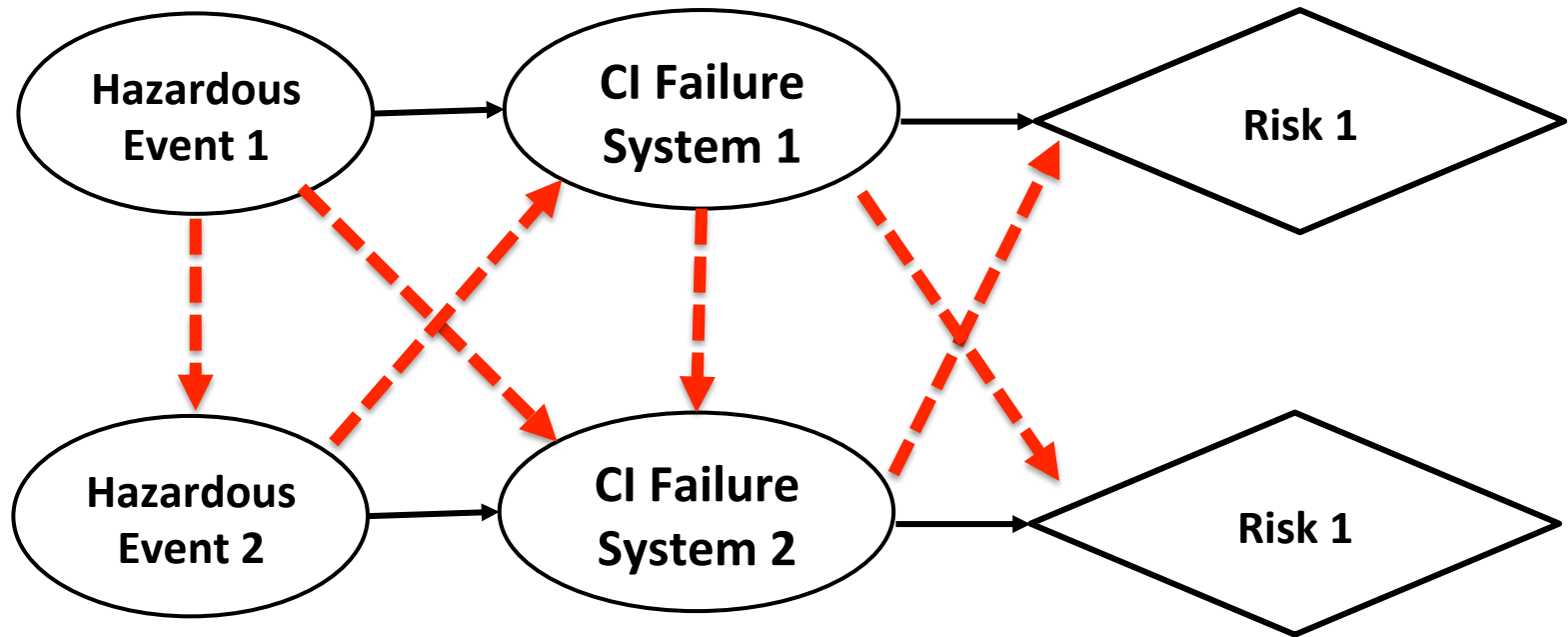
Risk Evaluation

Step 12- Combining Infrastructure Network and Inference Network



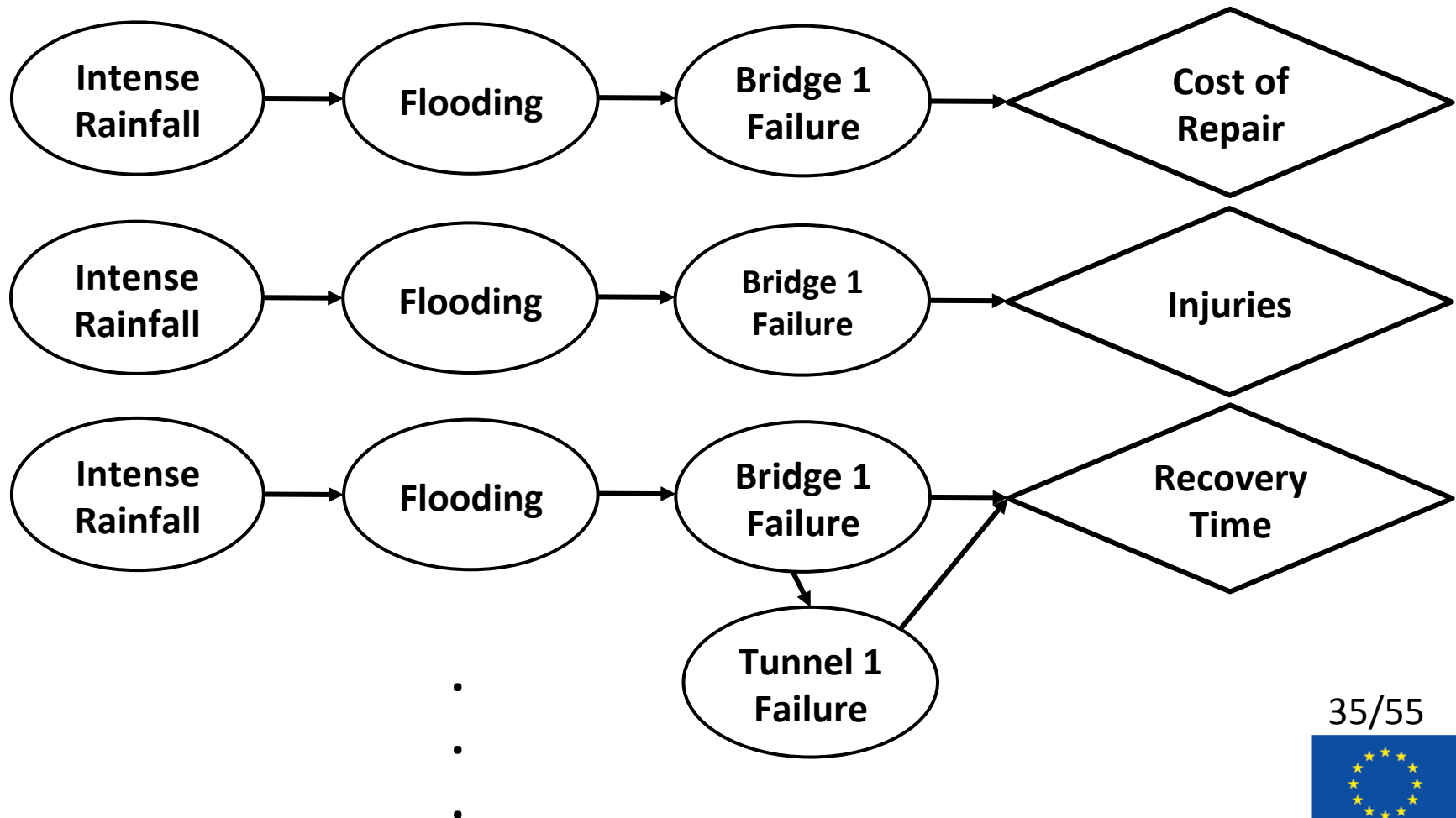
Risk Evaluation

Step 13- Distinguishing between Single Mode risks and Multi Mode Risks



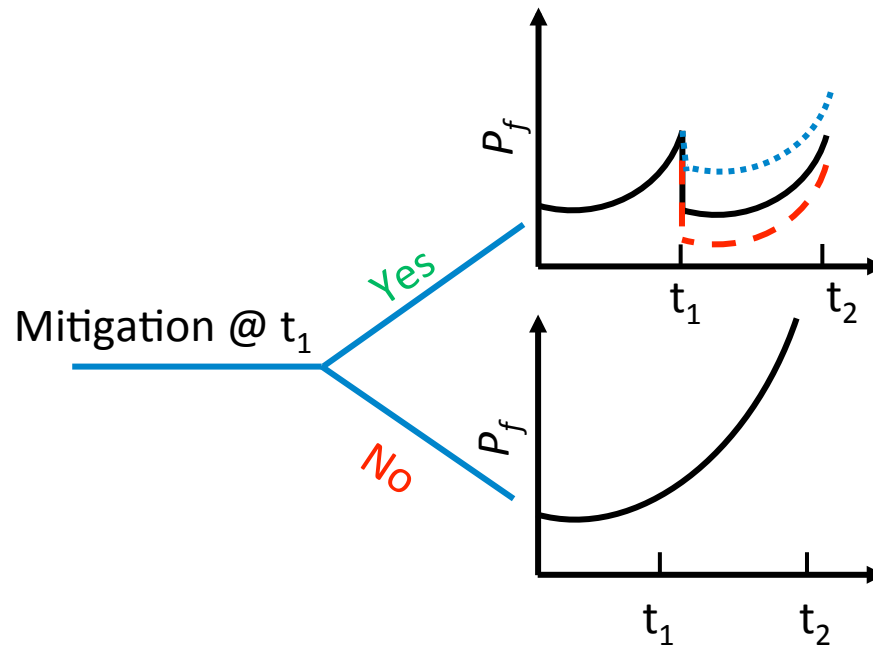
Risk Evaluation

Step 14- Identifying all risk scenarios with assigned probabilities and outcomes



Risk Evaluation

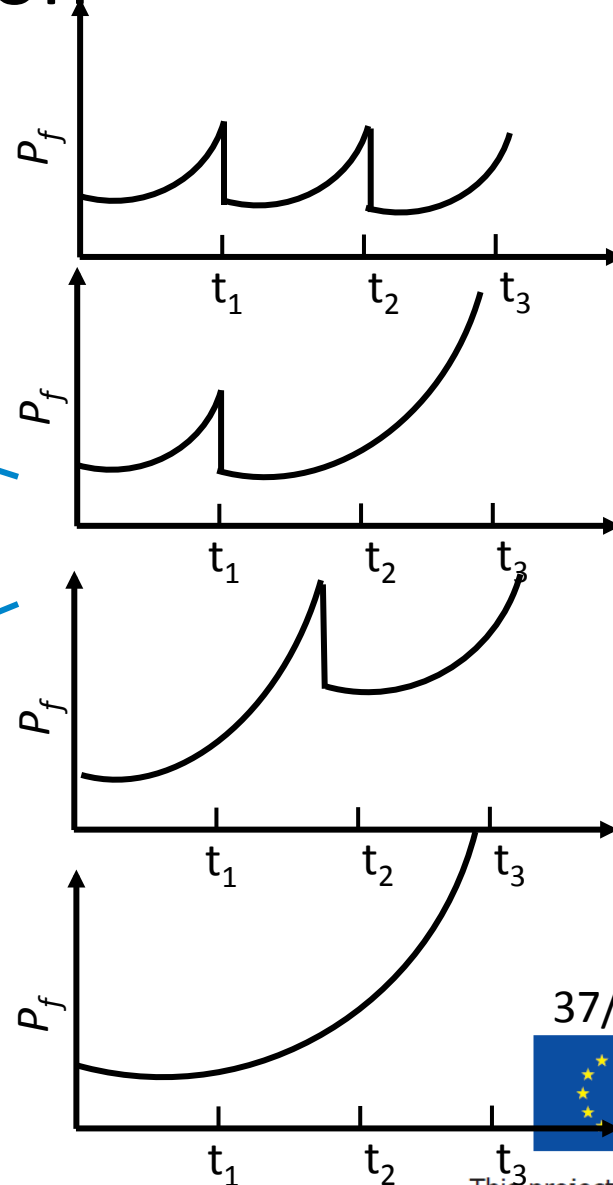
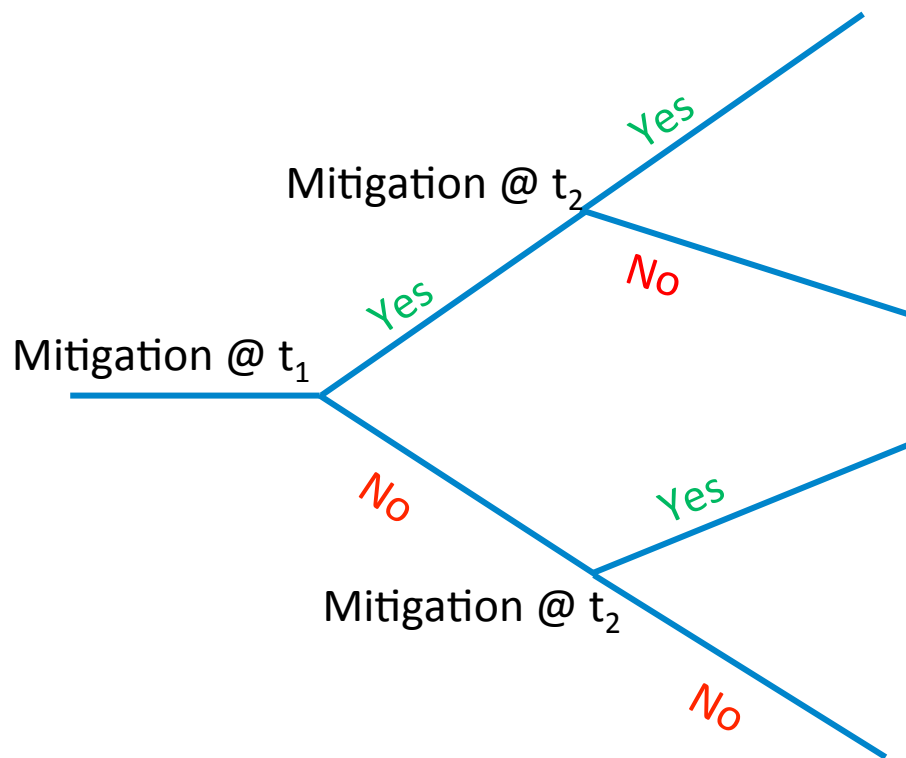
Step 15- Developing Mitigation Strategies



P_f = Probability of Failure
 t_i = Time

Risk Evaluation

Step 15- Developing Mitigation Strategies



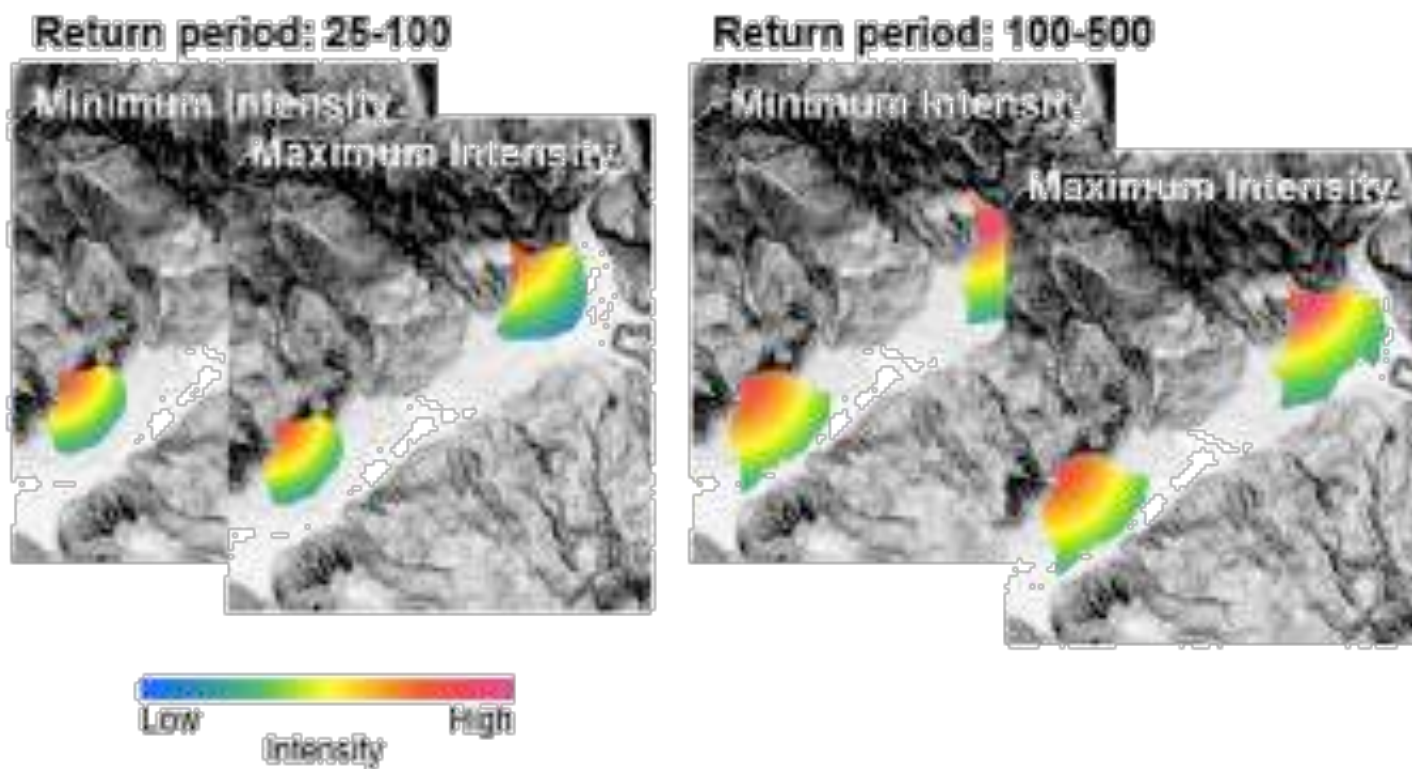
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Risk Evaluation

Step 19- Evaluate Risk for different Return periods and different Risk scenarios



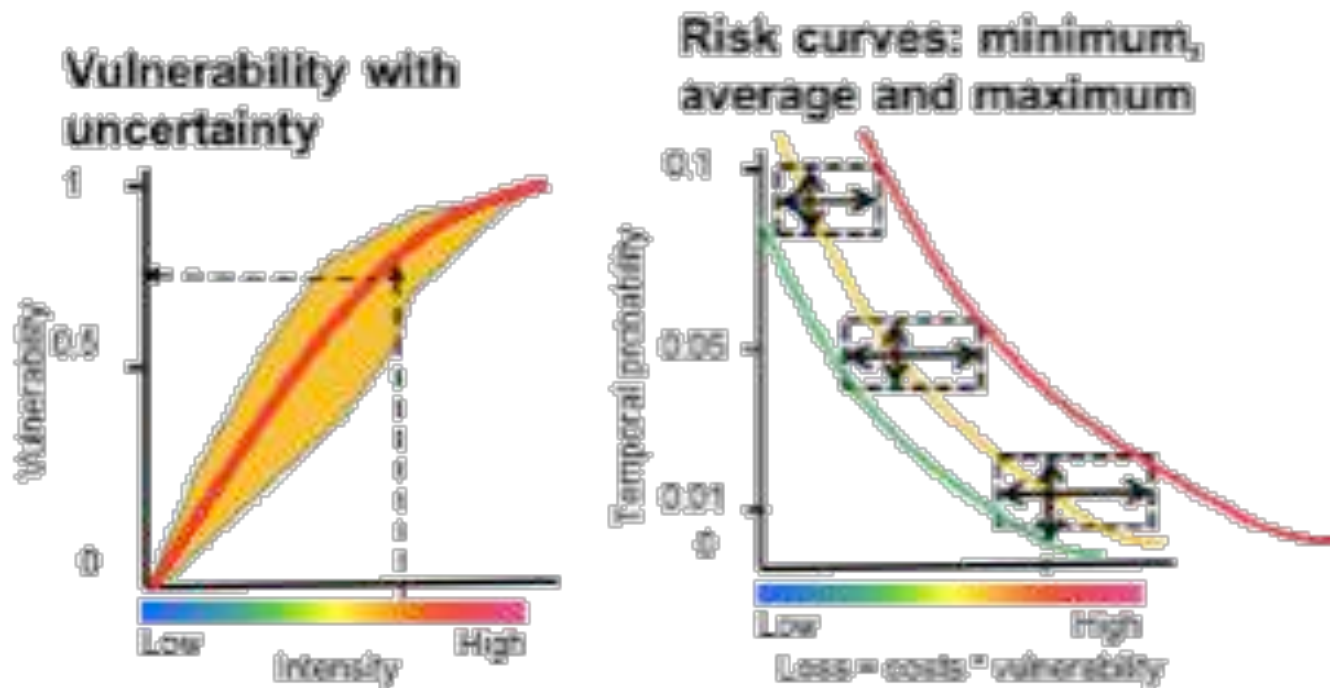
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Risk Evaluation

Step 19- Evaluate Risk for different Return periods and different Risk scenarios



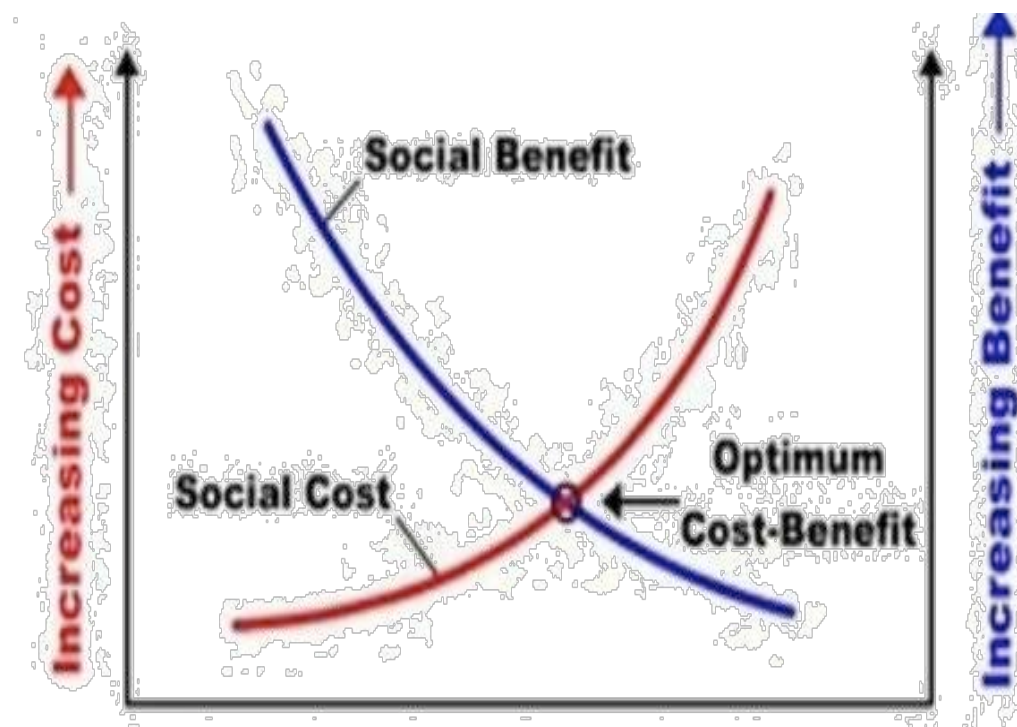
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Risk Evaluation

Step 19- Evaluate Risk for different Return periods and different Risk scenarios



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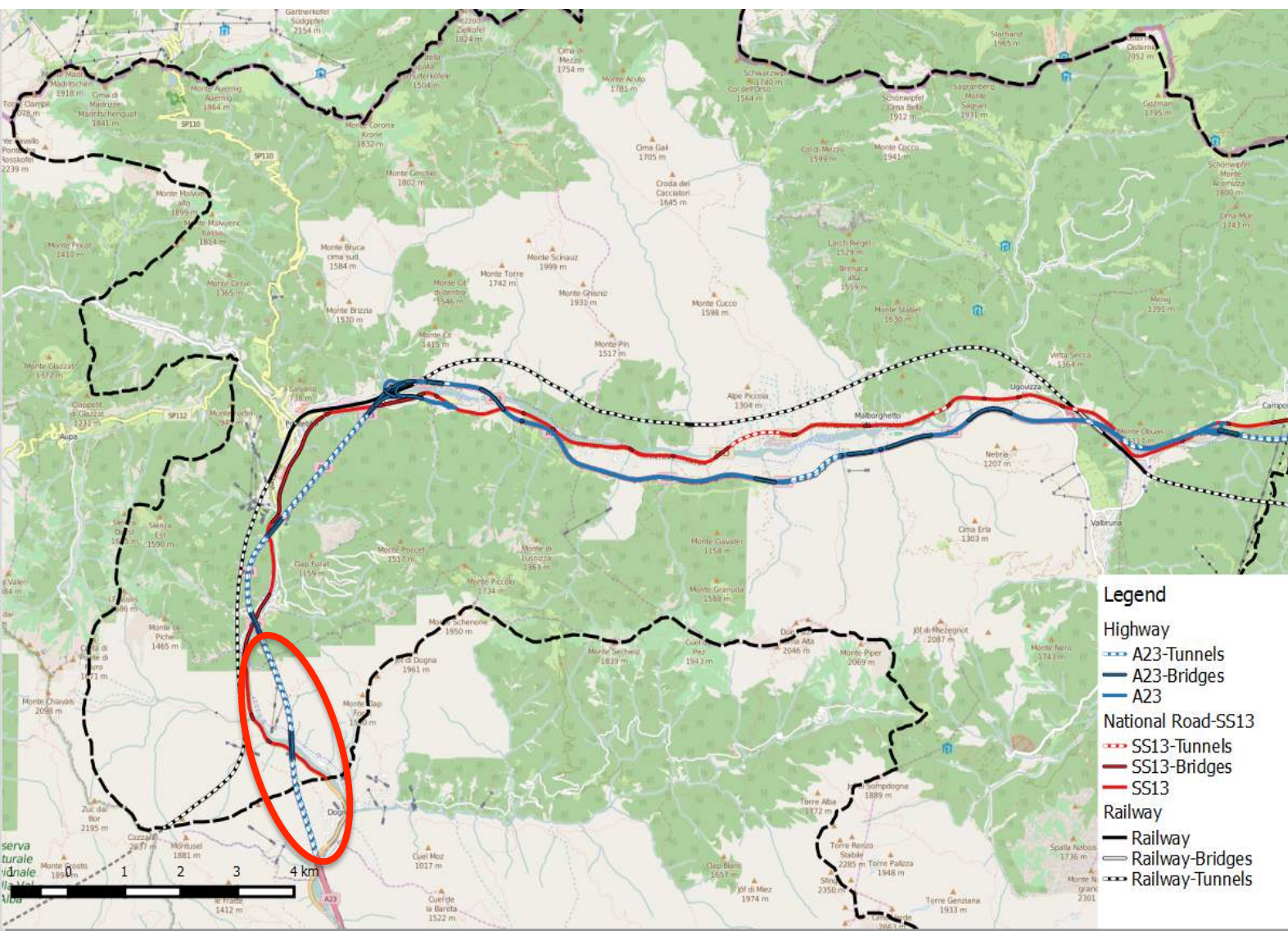


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Risk Evaluation

Example of Bayesian Network Development



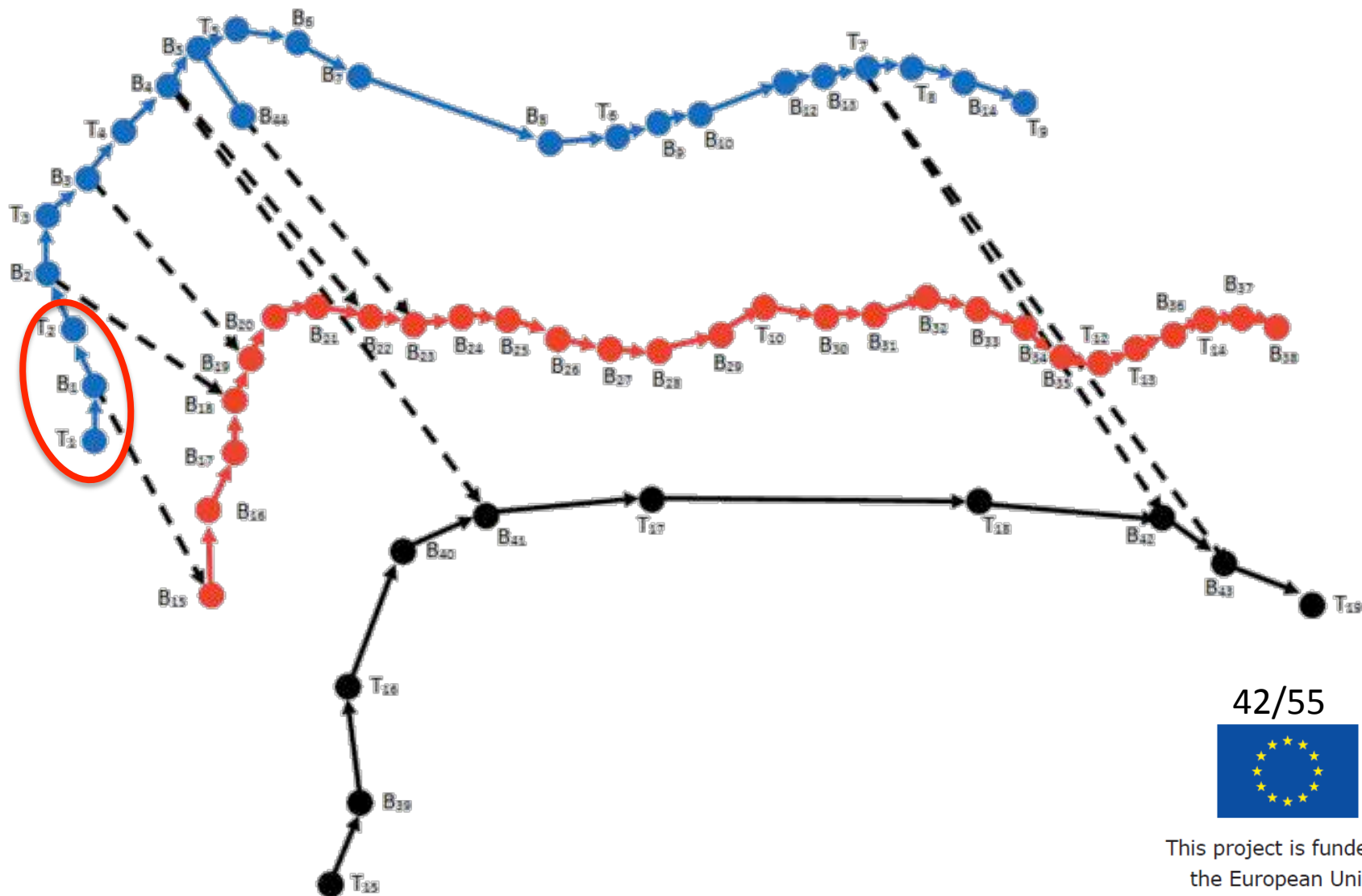
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Risk Evaluation

Example of Bayesian Network Development



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Risk Evaluation

Example of Bayesian Network Development



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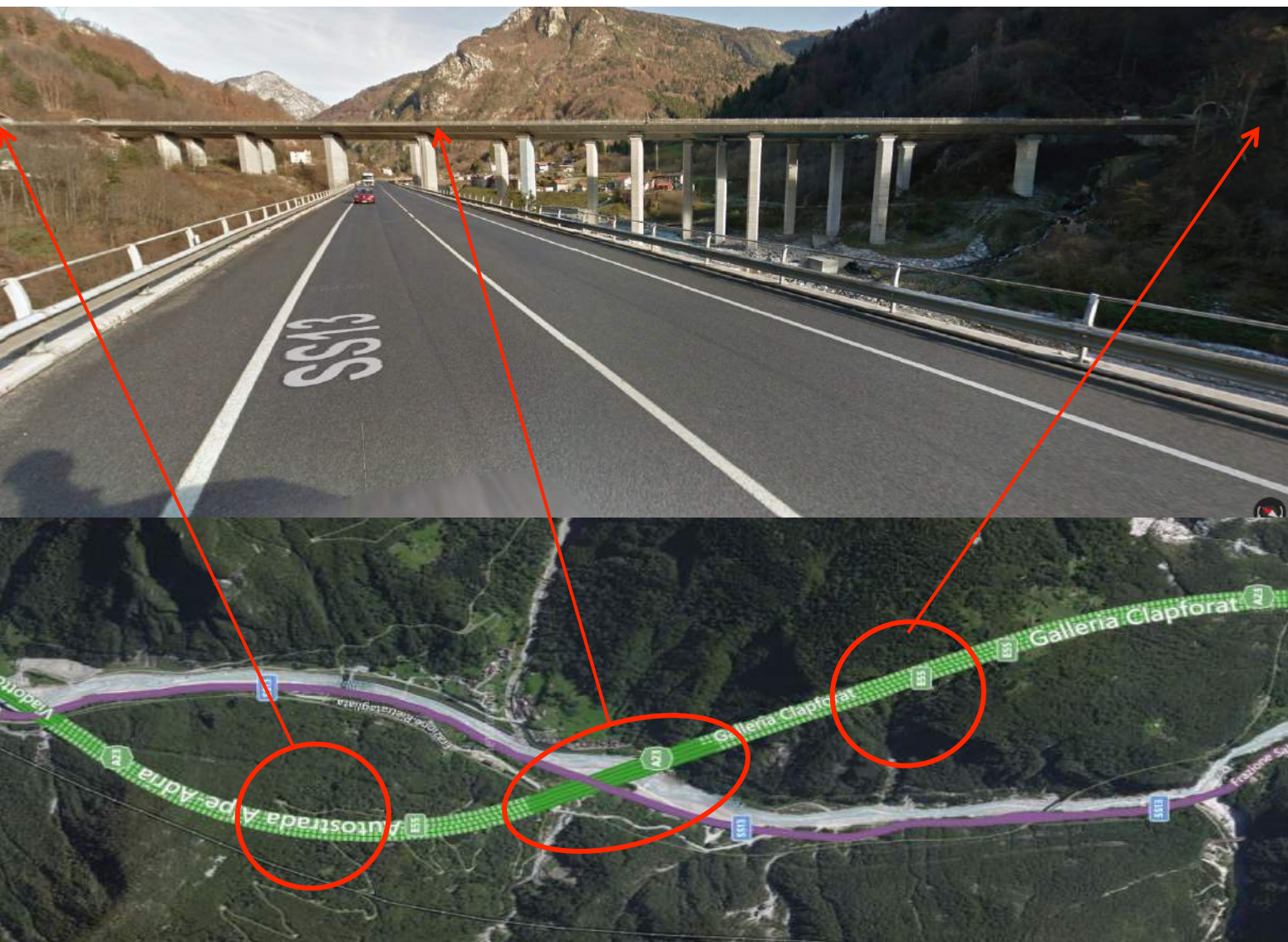


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Risk Evaluation

Example of Bayesian Network Development



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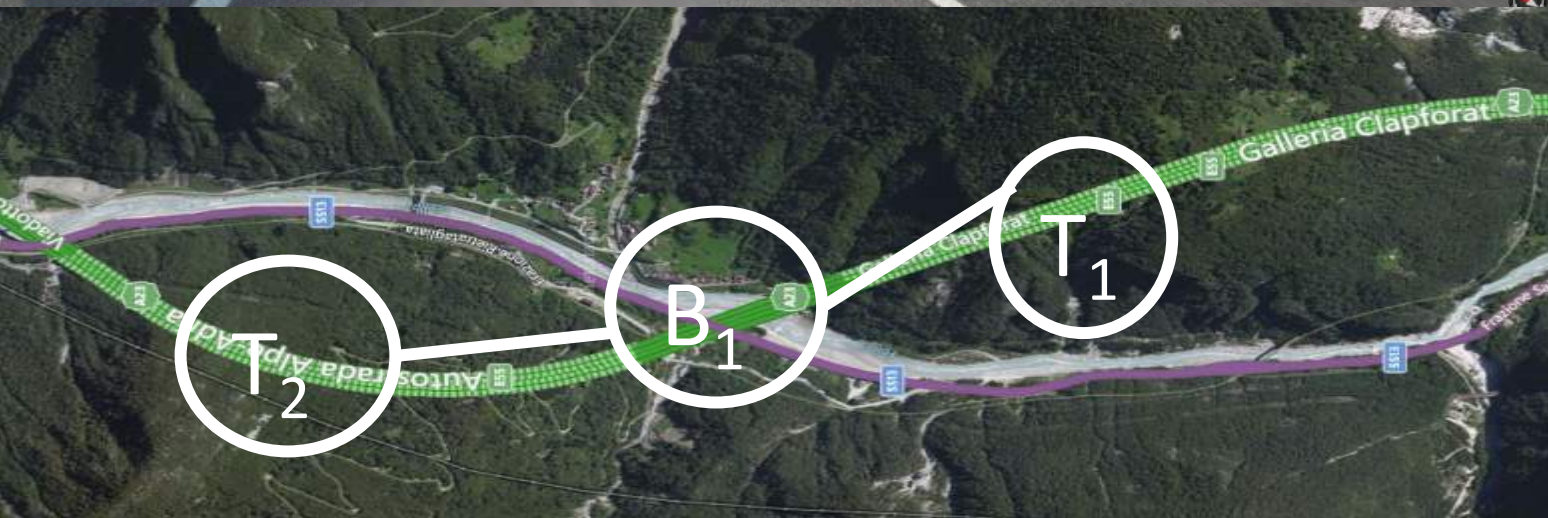


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Risk Evaluation

Example of Bayesian Network Development



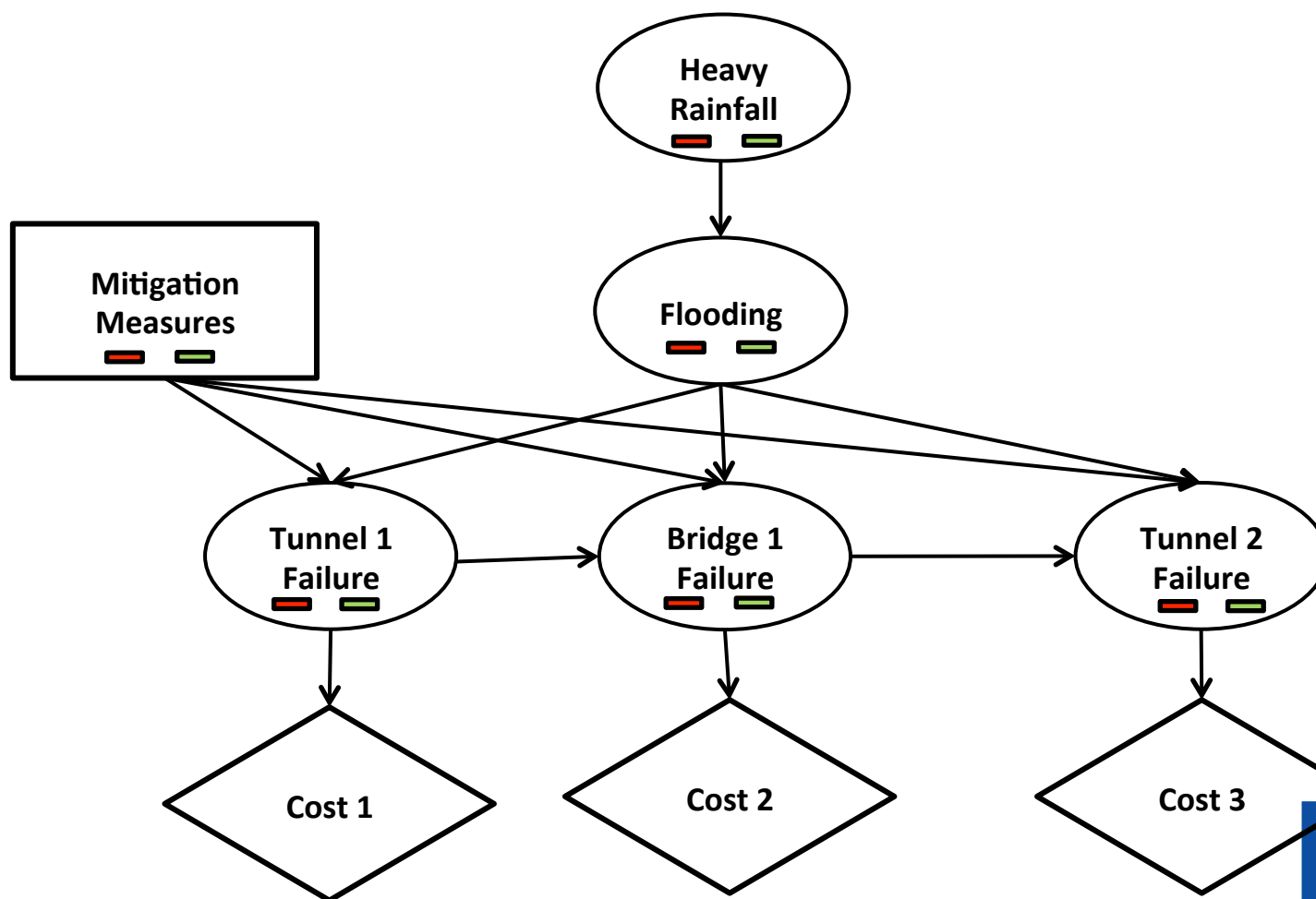
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Risk Evaluation

Example of Bayesian Network Development



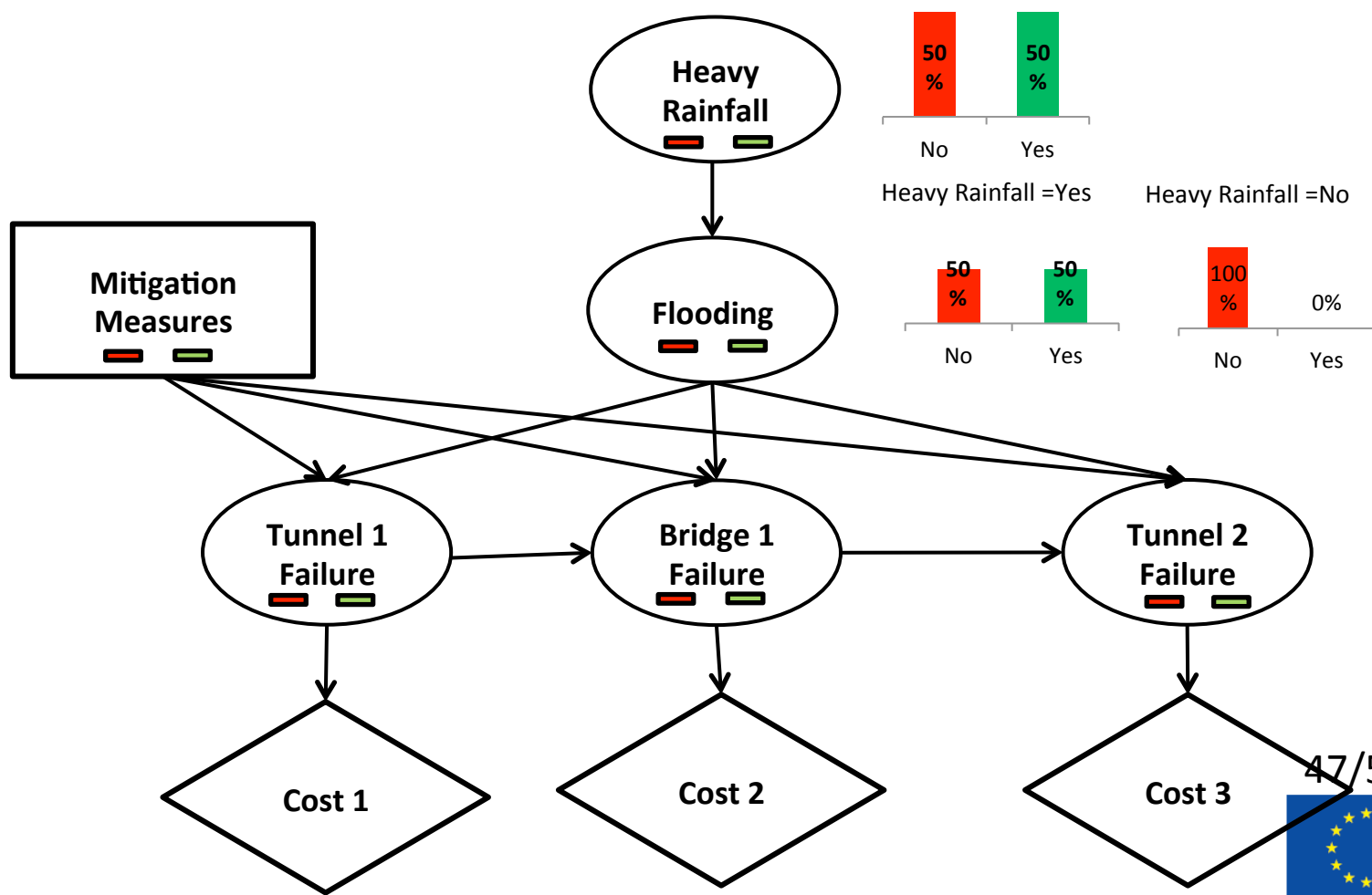
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Risk Evaluation

Example of Bayesian Network Development



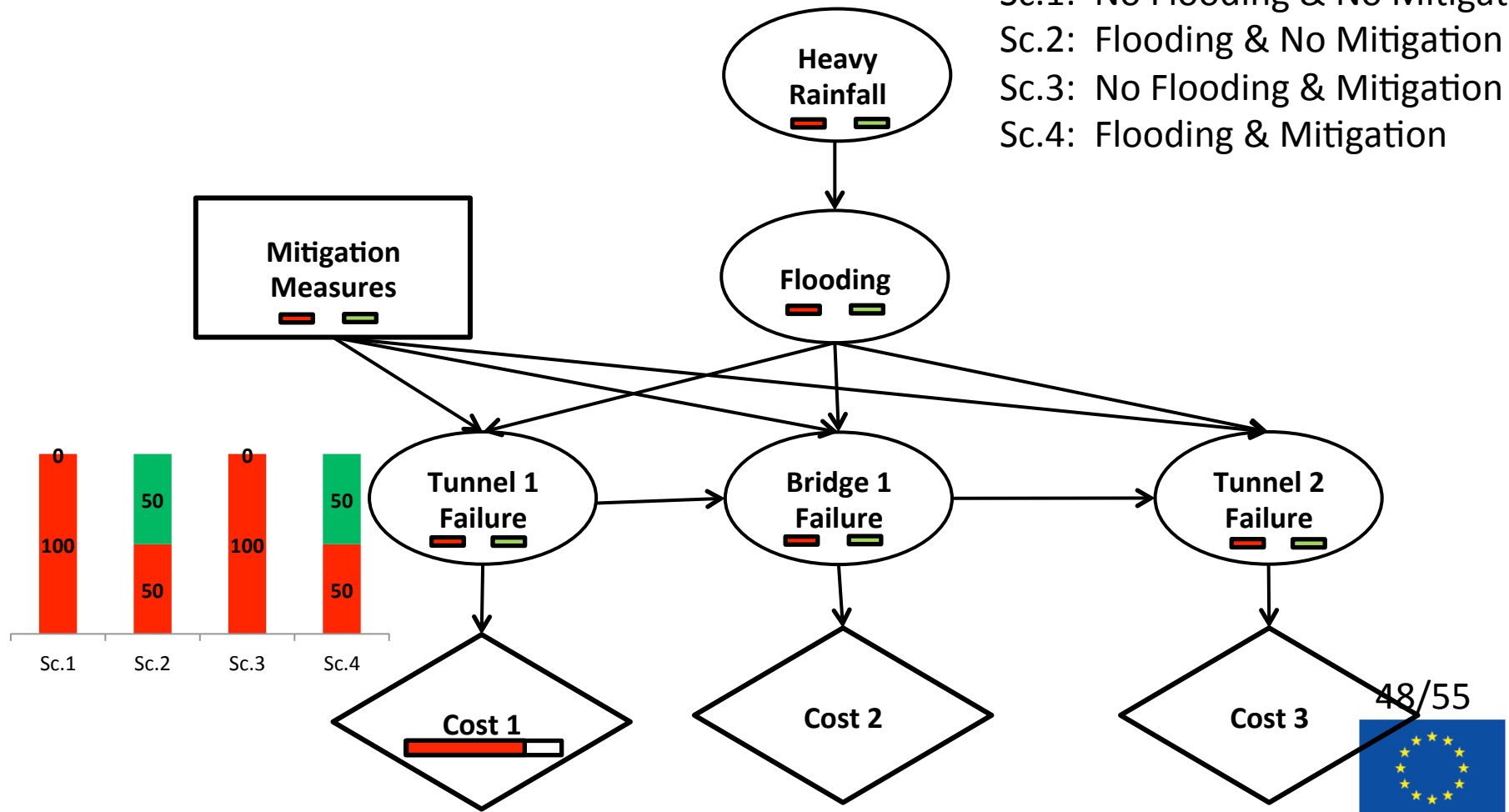
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Risk Evaluation

Example of Bayesian Network Development

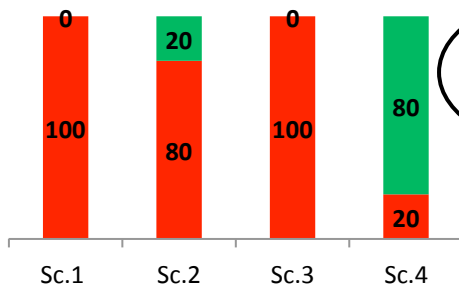
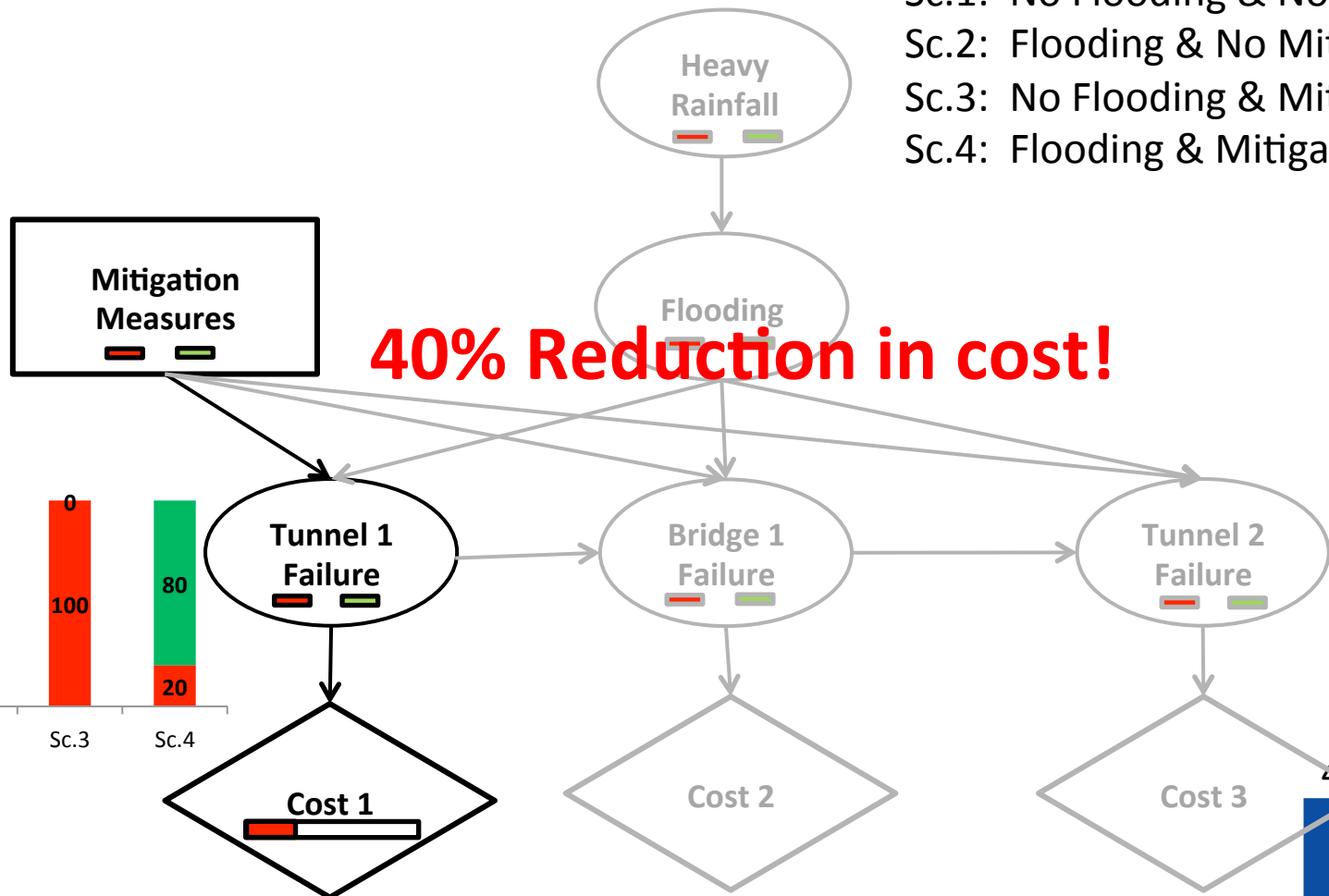
Sc.1: No Flooding & No Mitigation
 Sc.2: Flooding & No Mitigation
 Sc.3: No Flooding & Mitigation
 Sc.4: Flooding & Mitigation



Risk Evaluation

Example of Bayesian Network Development

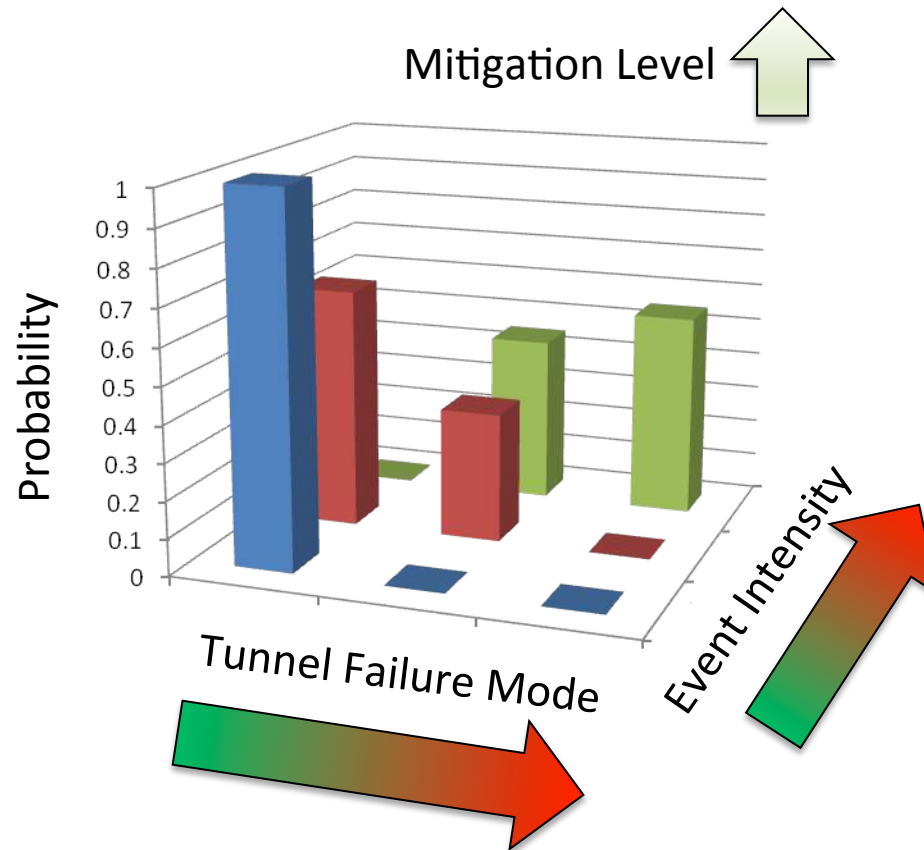
Sc.1: No Flooding & No Mitigation
 Sc.2: Flooding & No Mitigation
 Sc.3: No Flooding & Mitigation
 Sc.4: Flooding & Mitigation



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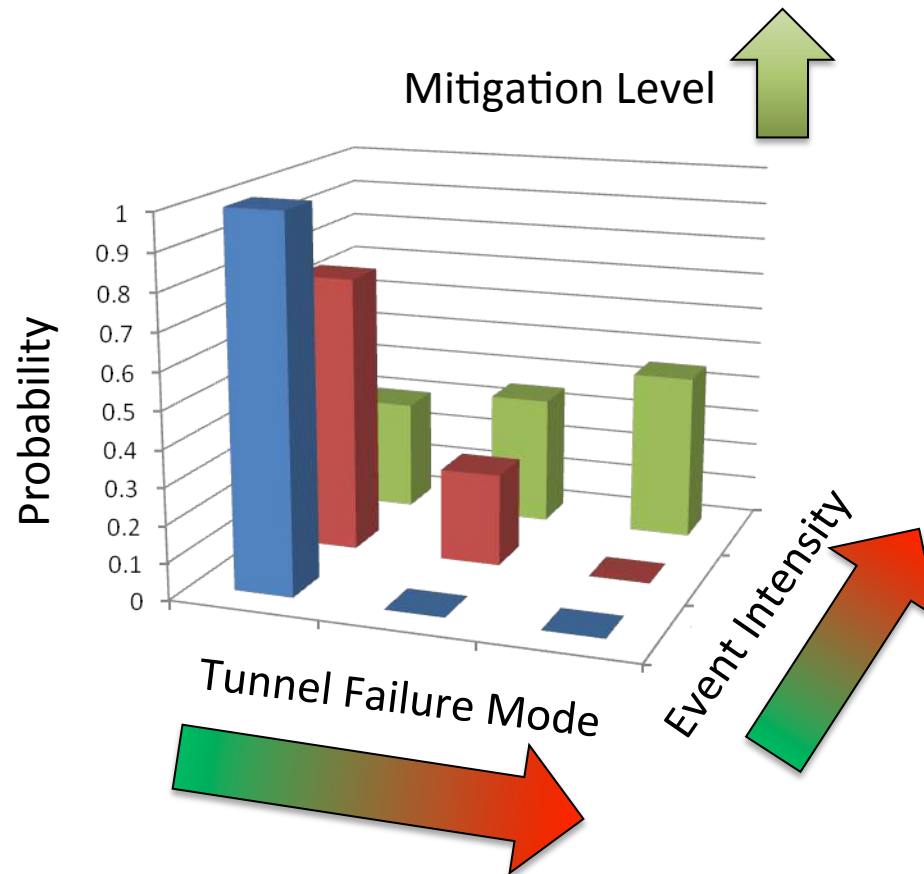
Risk Evaluation



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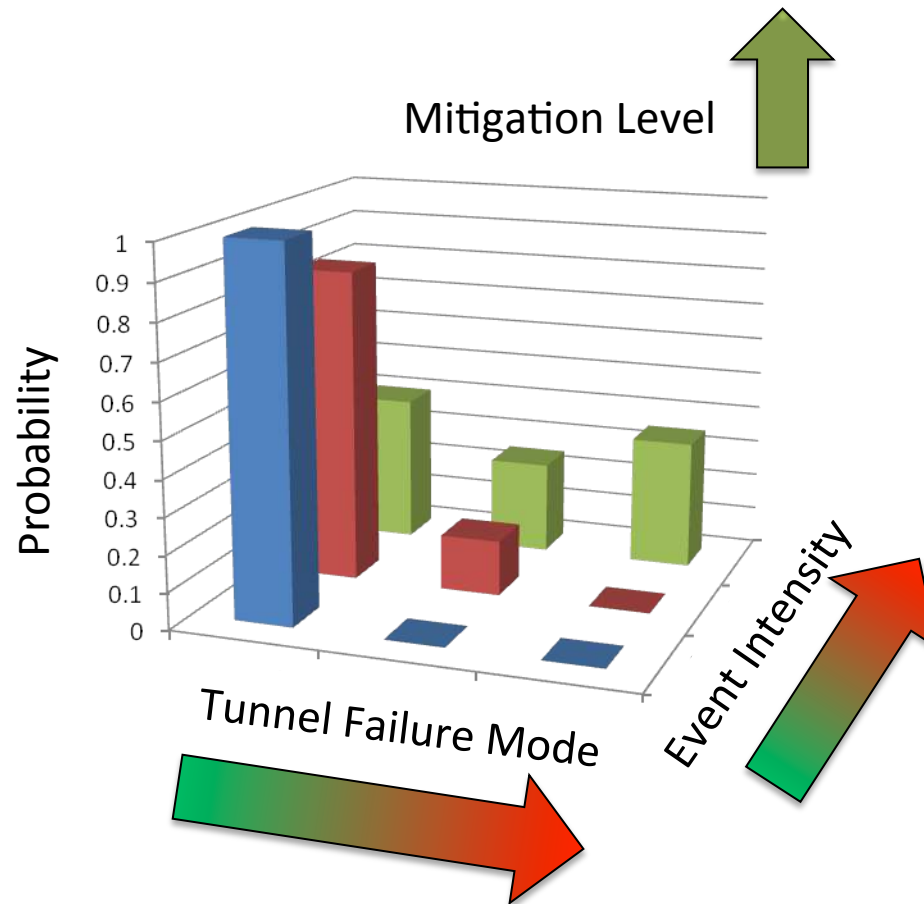
Risk Evaluation



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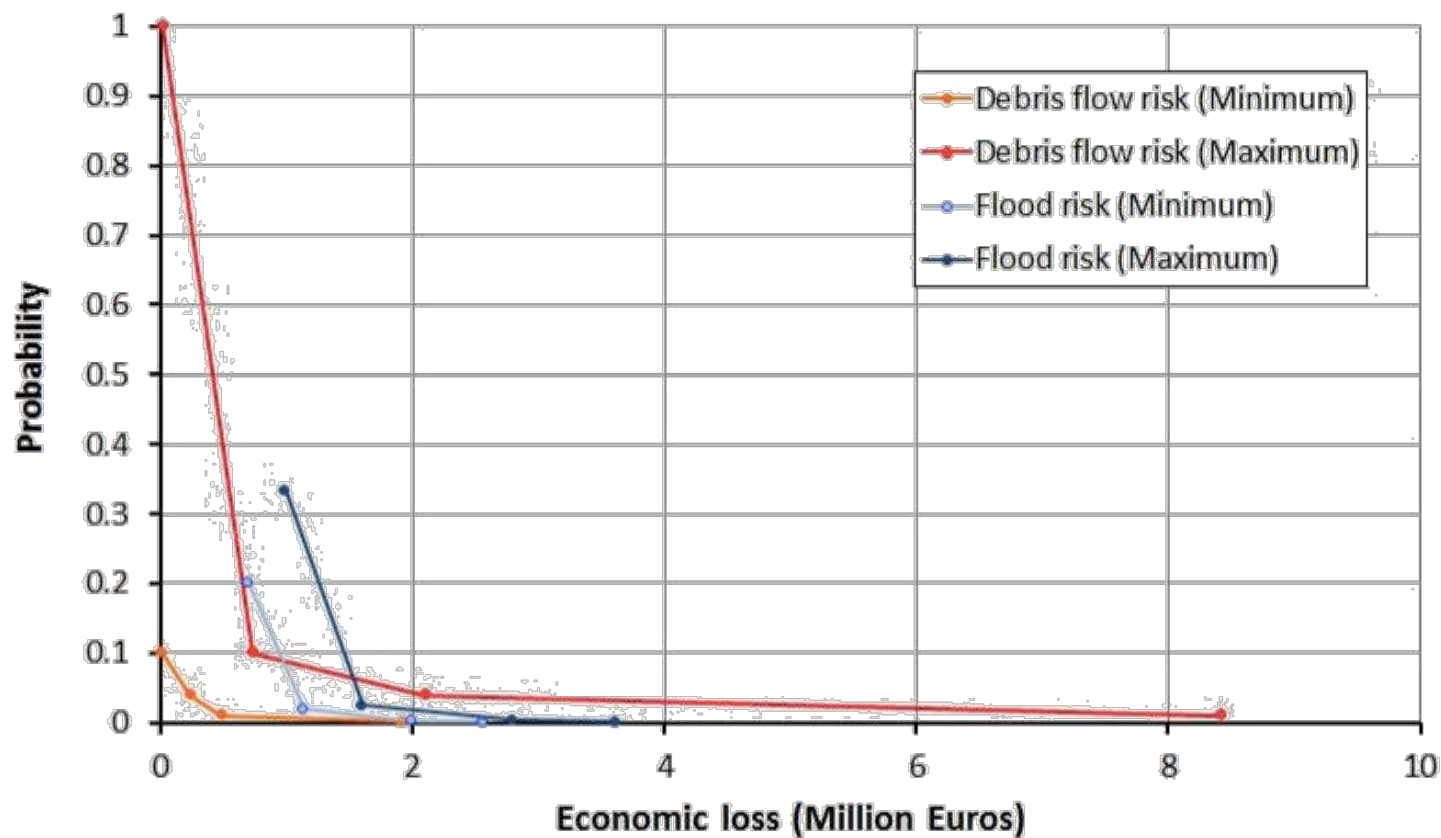
Risk Evaluation



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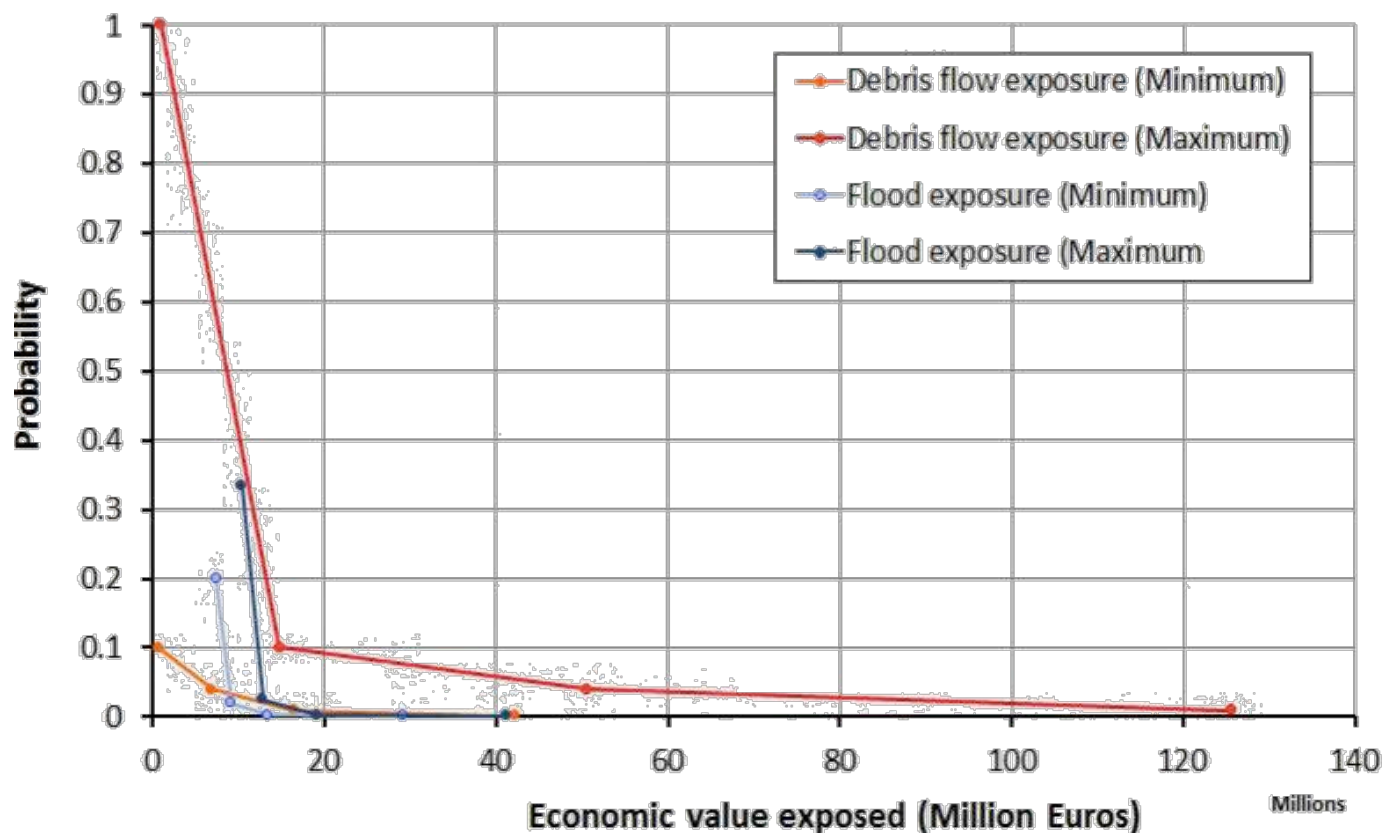
Risk Evaluation



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Risk Evaluation



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