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 **IN**frastructure networks in response to extreme weather events and develops an optimization tool for series of mitigation strategies

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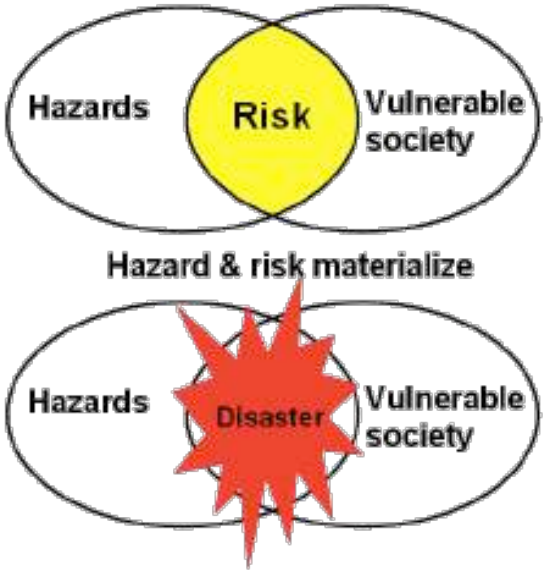
Introduction



- 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

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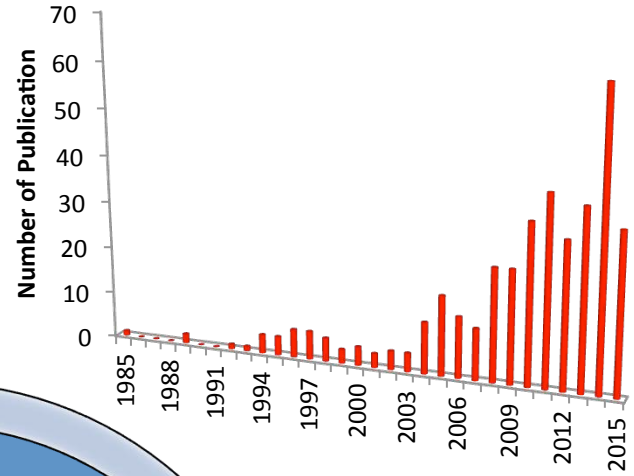
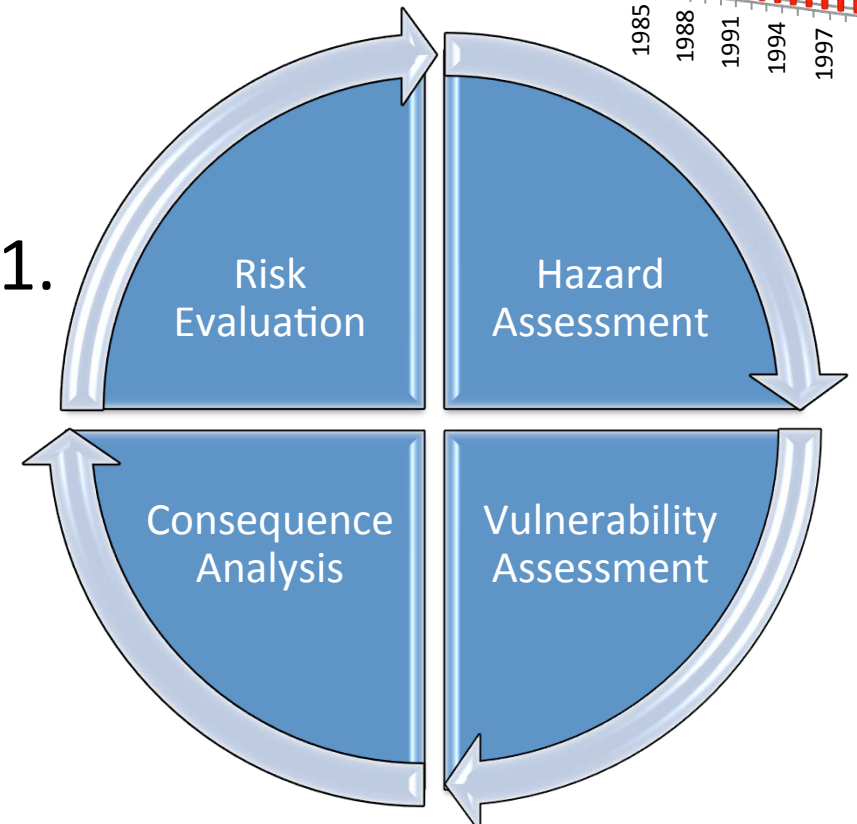
Introduction

- 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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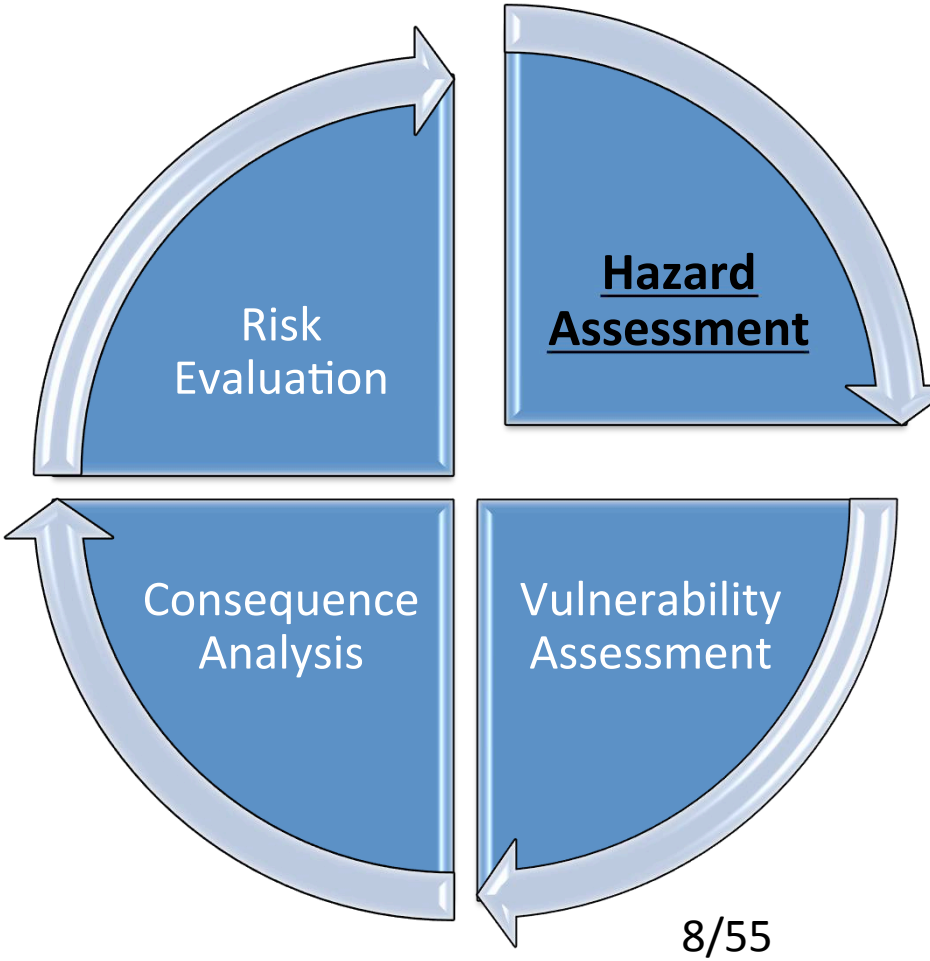
Risk Assessment Framework

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



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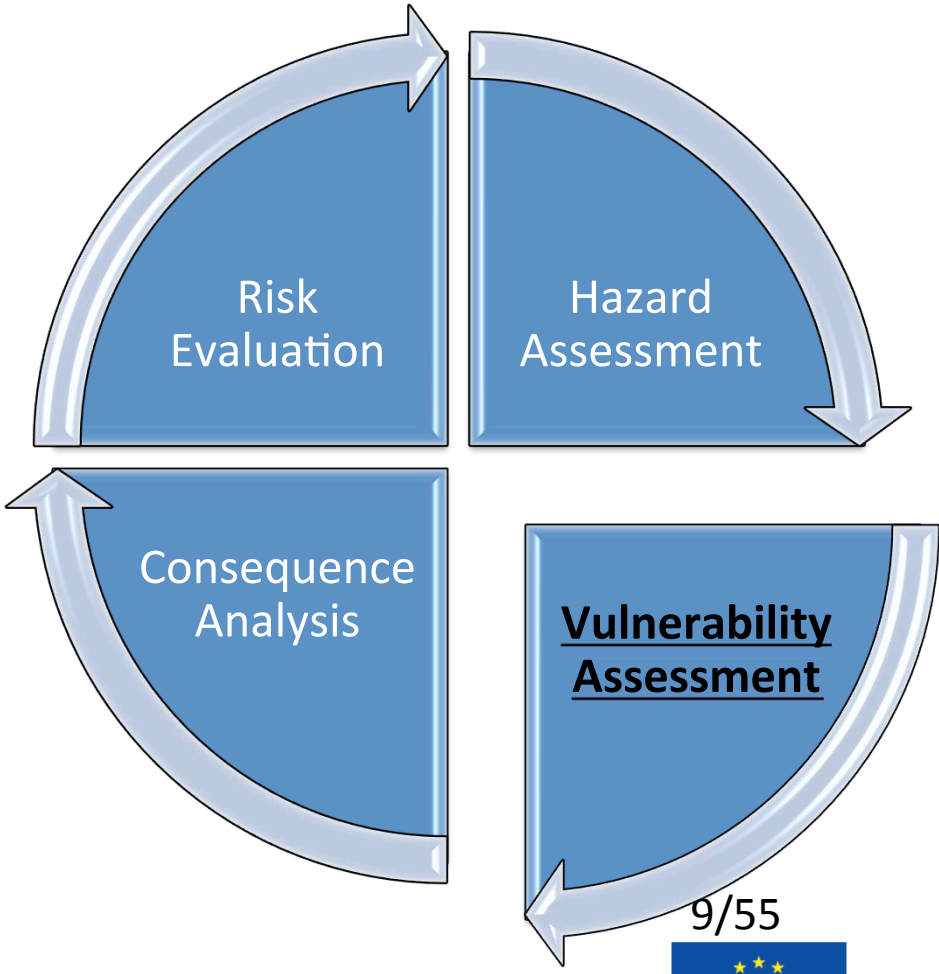
Risk Assessment Framework

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



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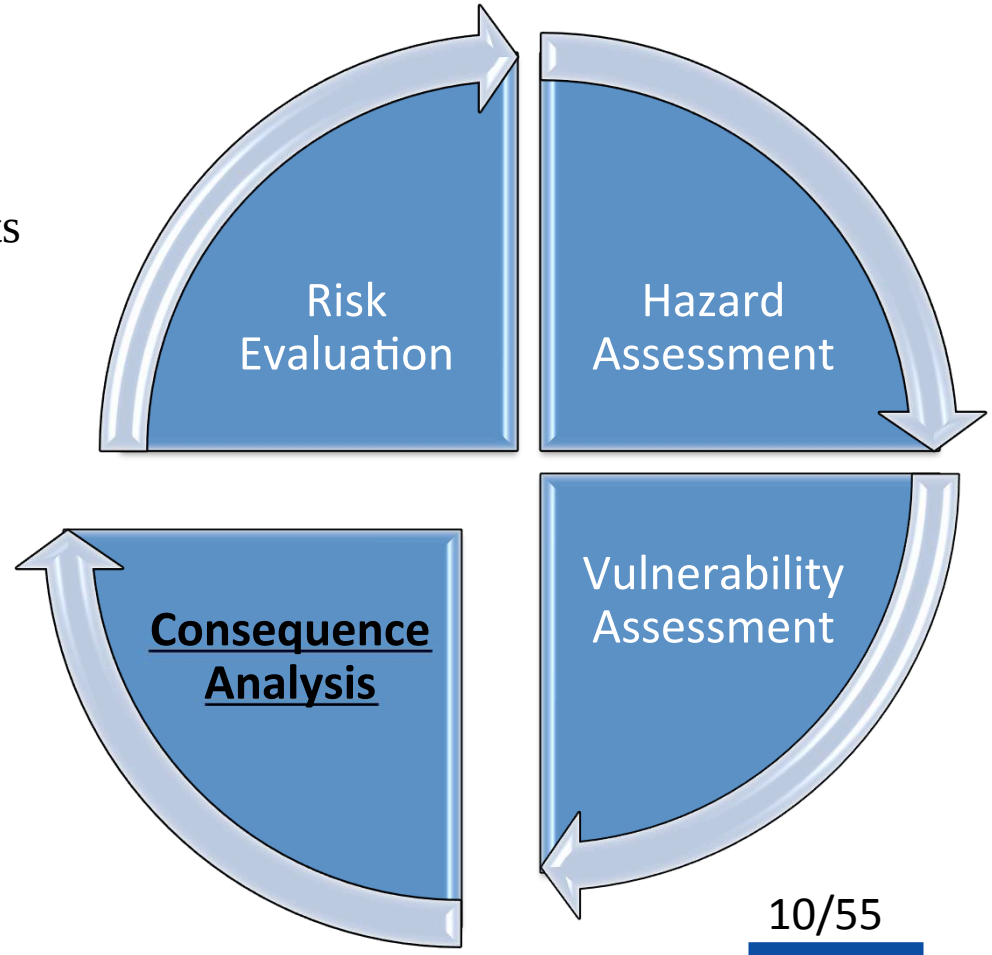
Risk Assessment Framework

- 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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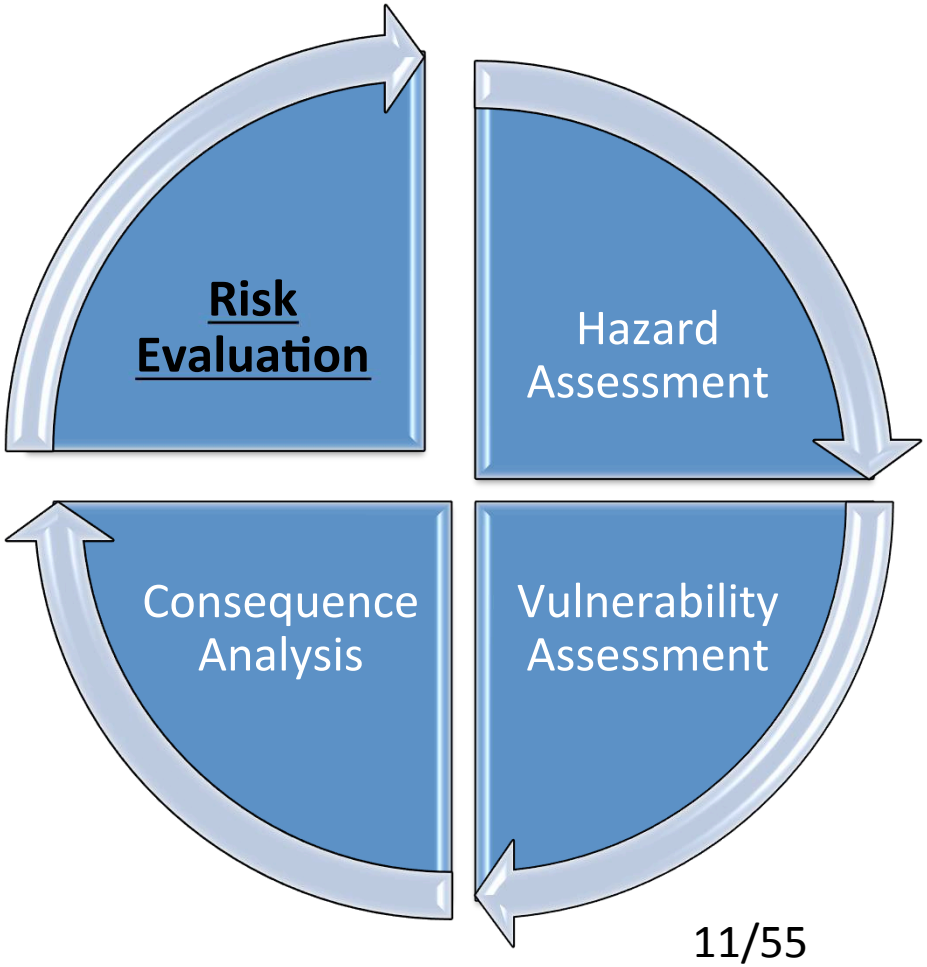
Risk Assessment Framework

- 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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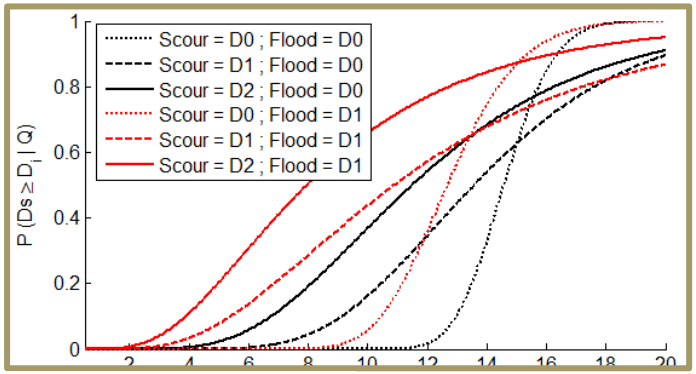
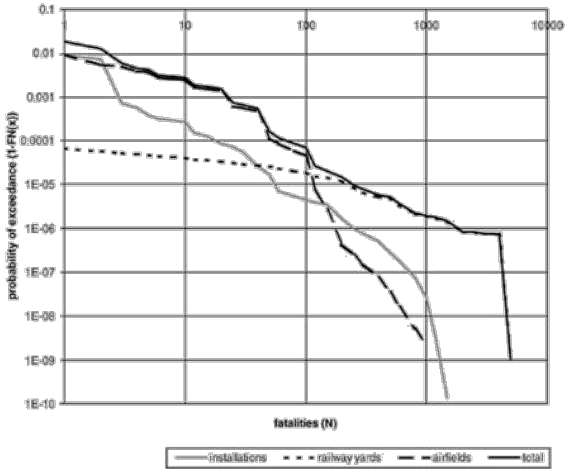
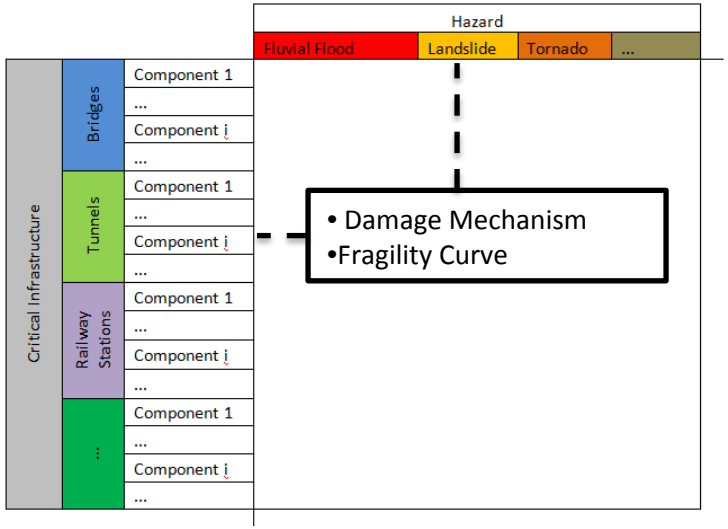
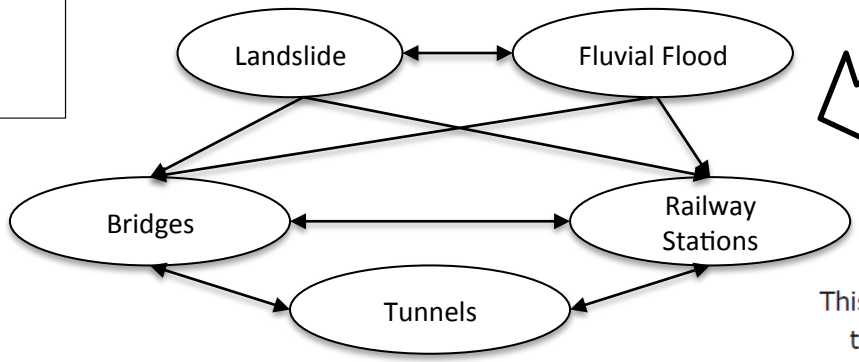
Risk Assessment Framework









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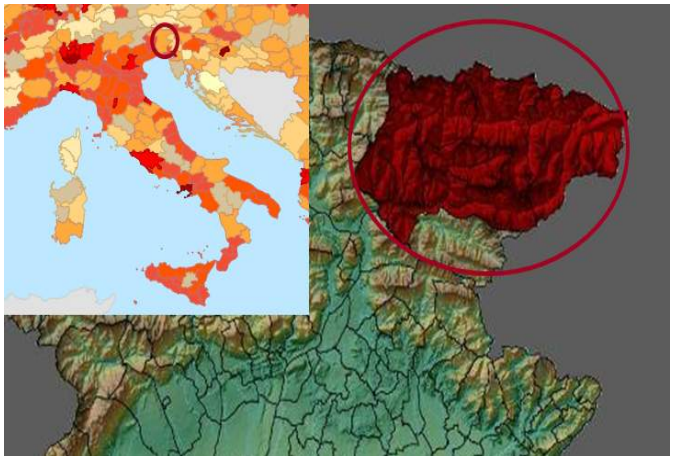
Example of Risk Assessment

Alpine Region

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



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Establishing the Context

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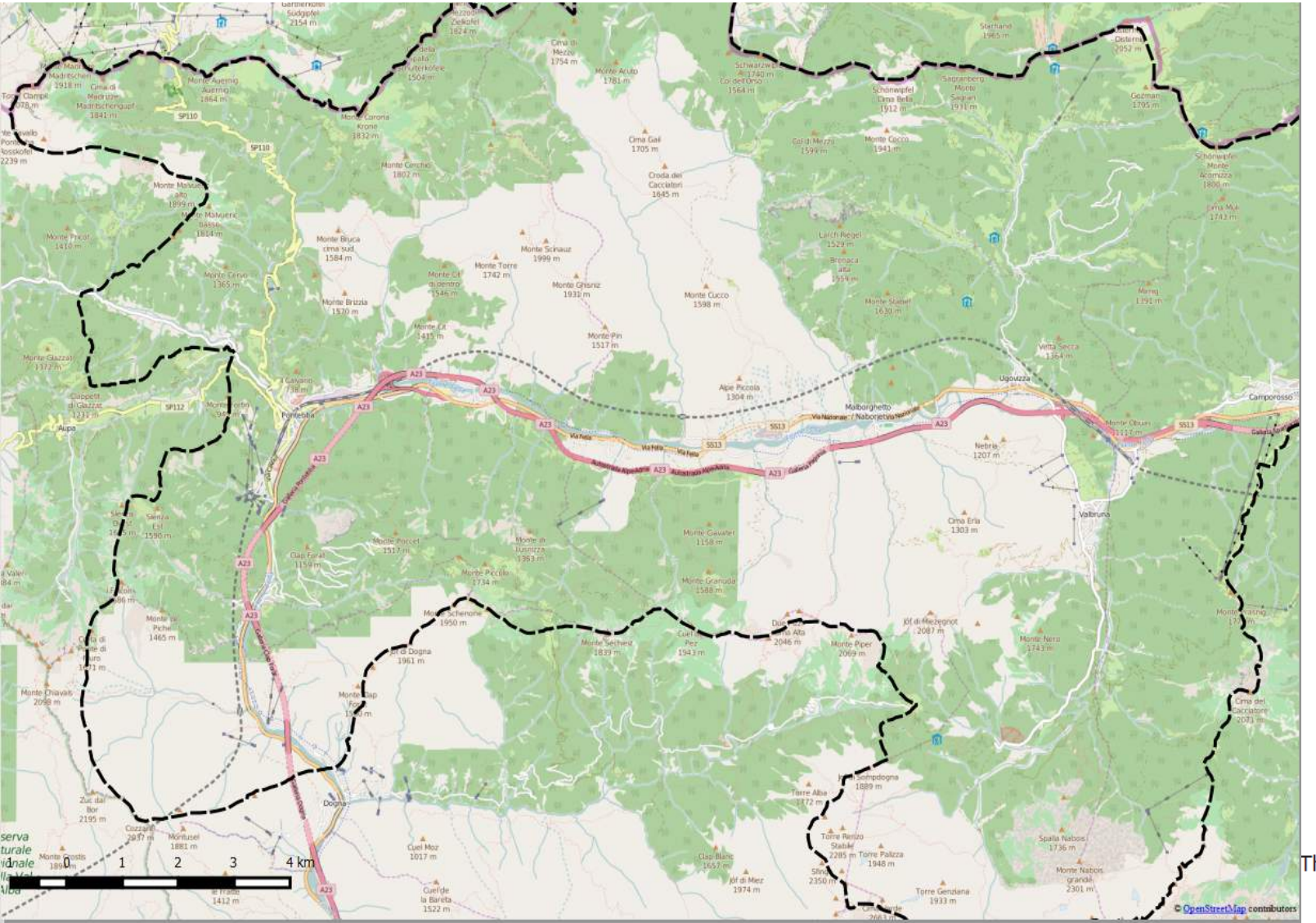
Establishing the Context

Step 1- Isolating the Case Study Area



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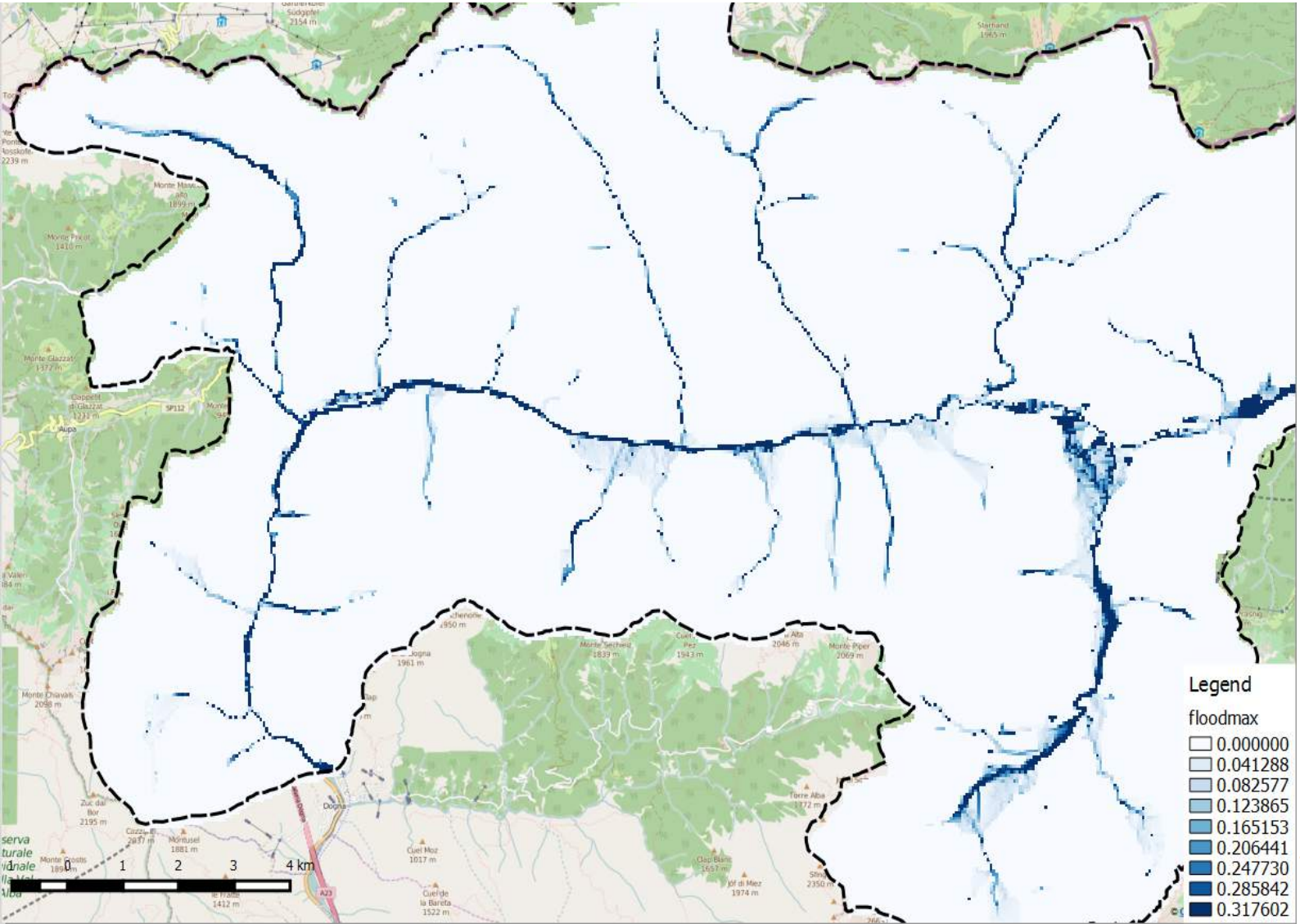
Hazard Assessment

Step 2- Identifying hazards, thresholds and corresponding probabilities



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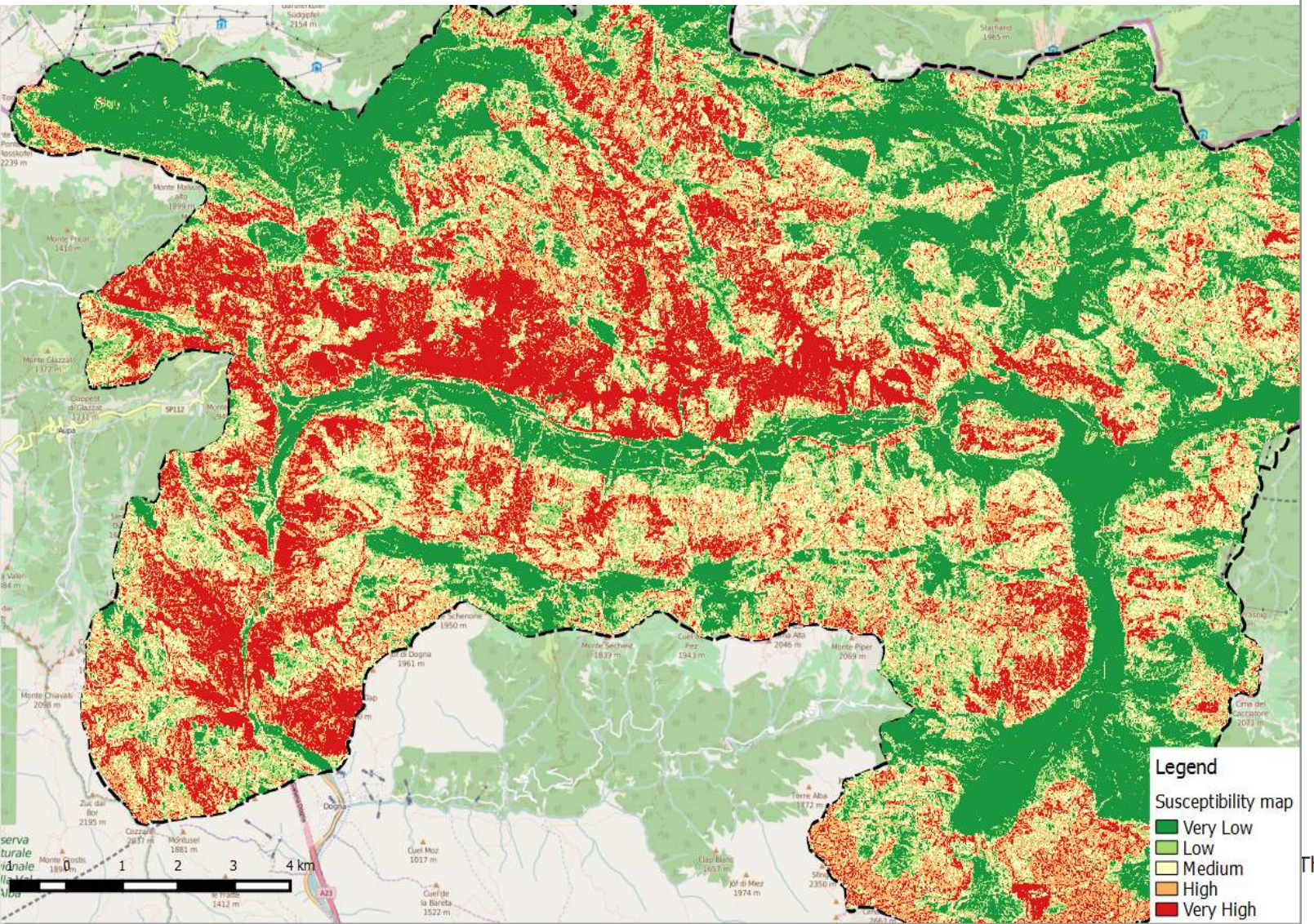

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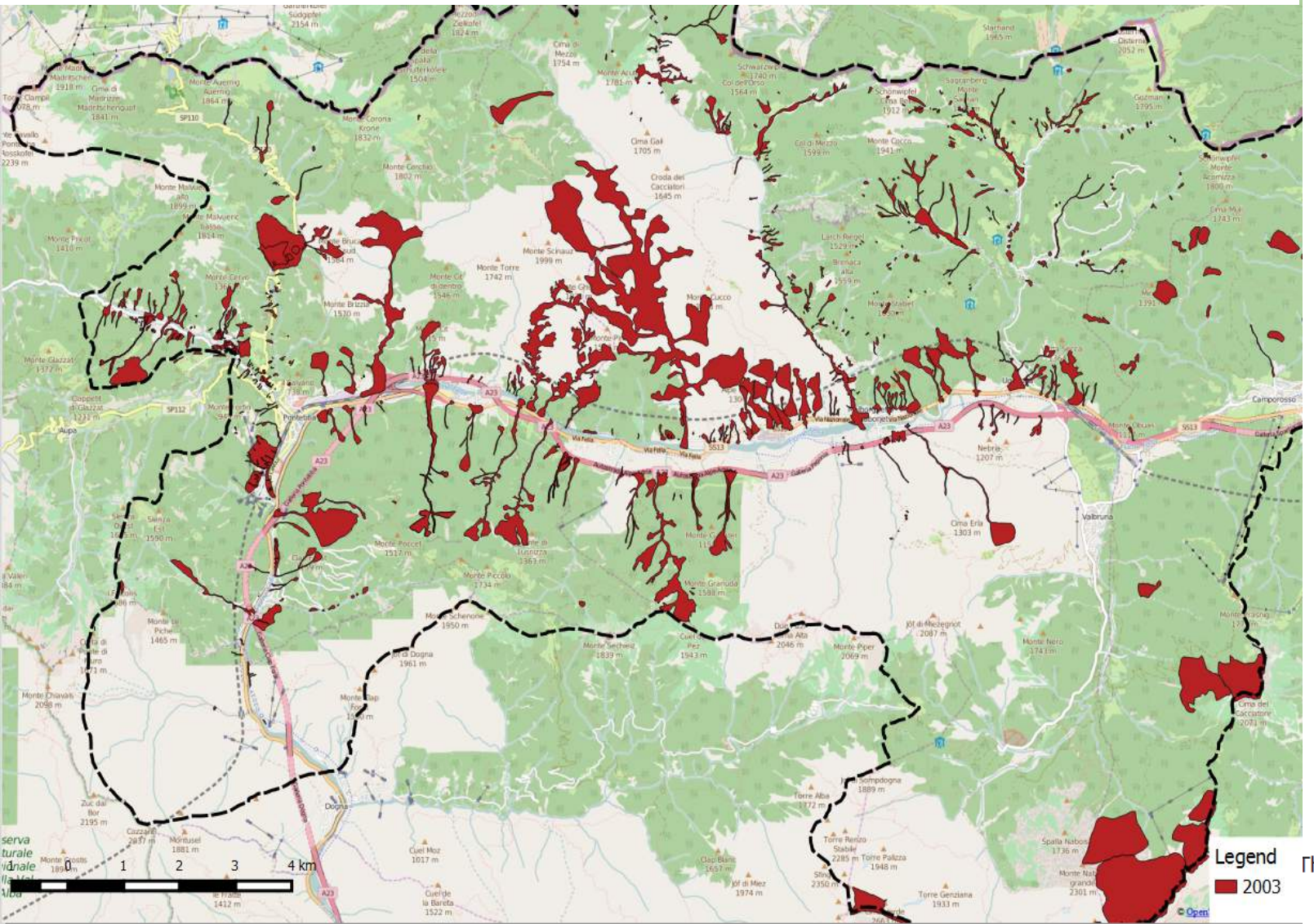
Hazard Assessment

Step 2- Identifying hazards, thresholds



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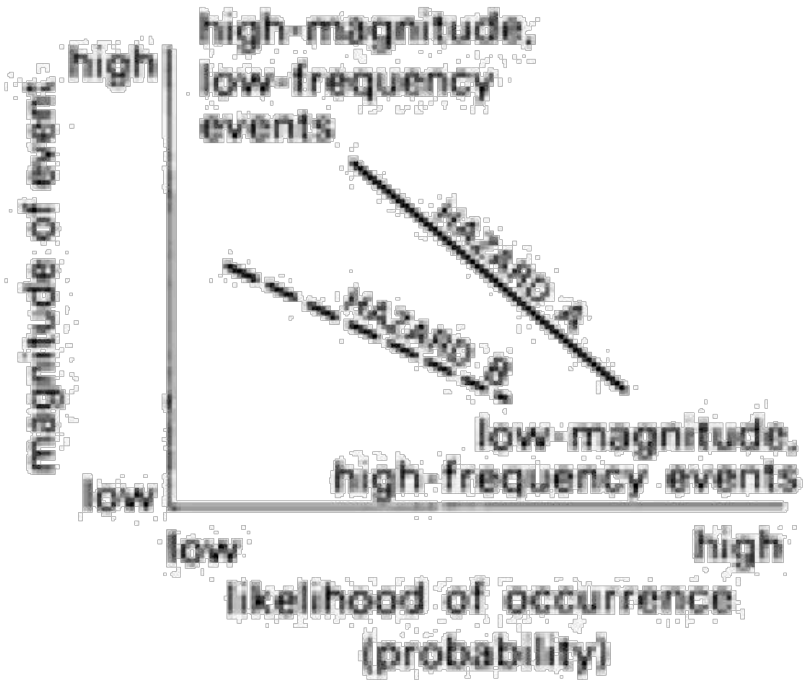
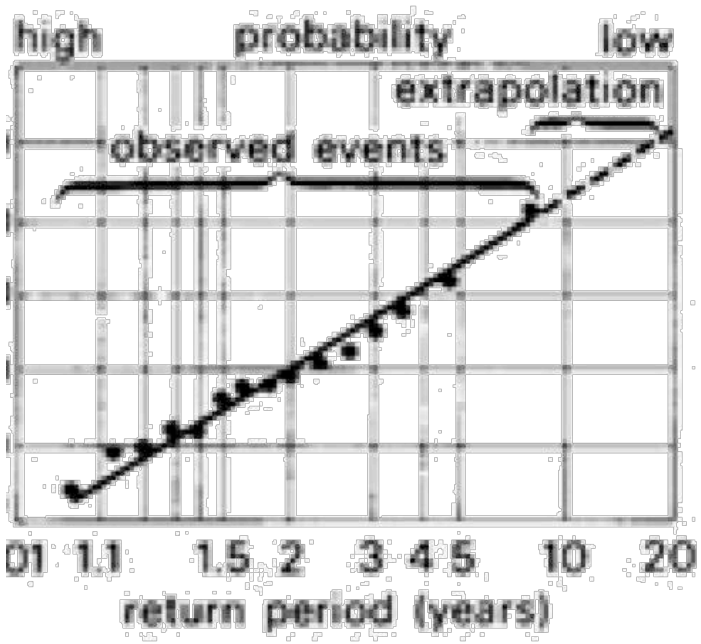
Hazard Assessment

Step 3- Evaluation Probability of Extreme Weather Event





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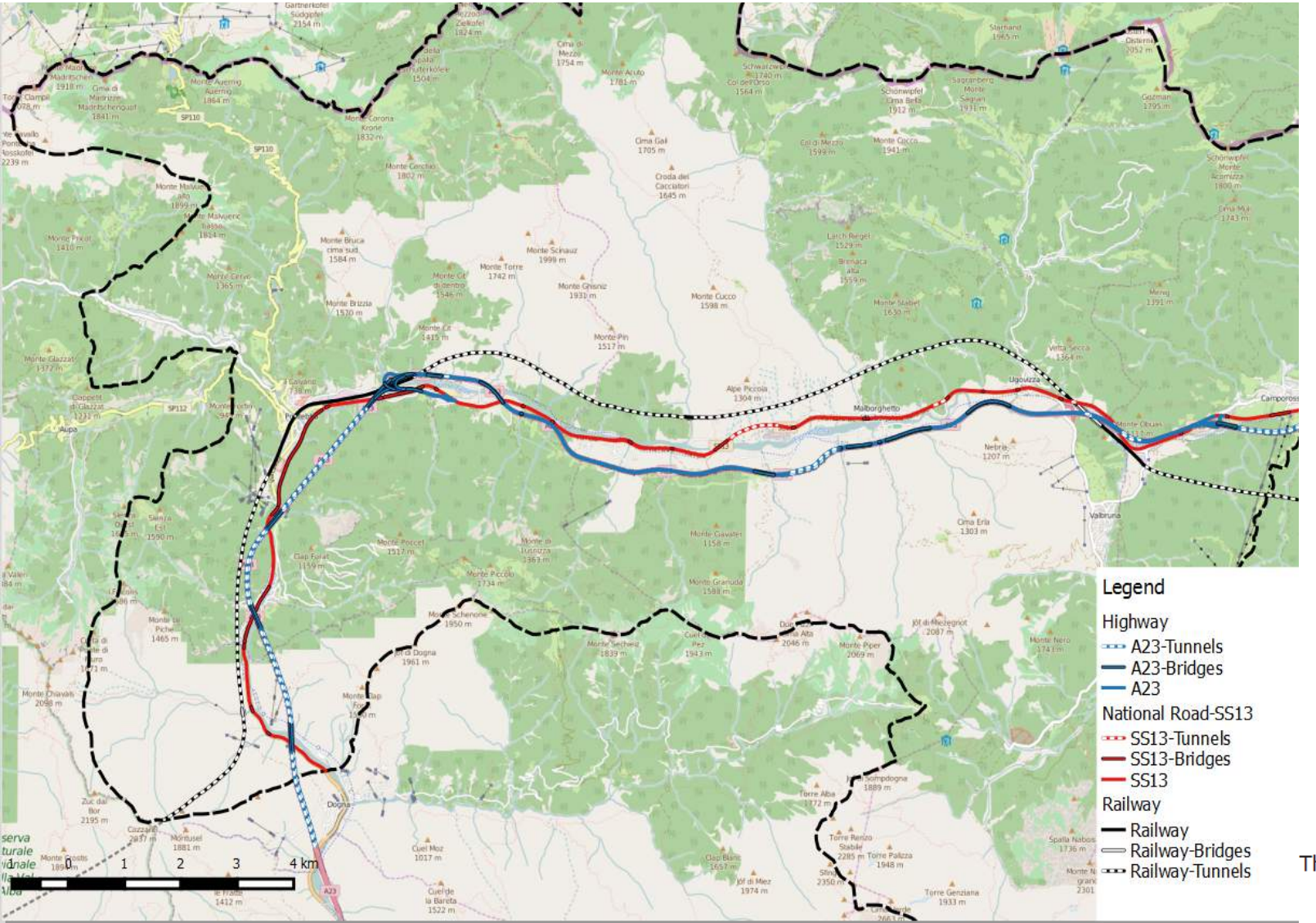
Vulnerability Assessment

Step 4- Identifying vulnerable elements



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Vulnerability Assessment

Step 4- Identifying vulnerable elements

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Vulnerability Assessment

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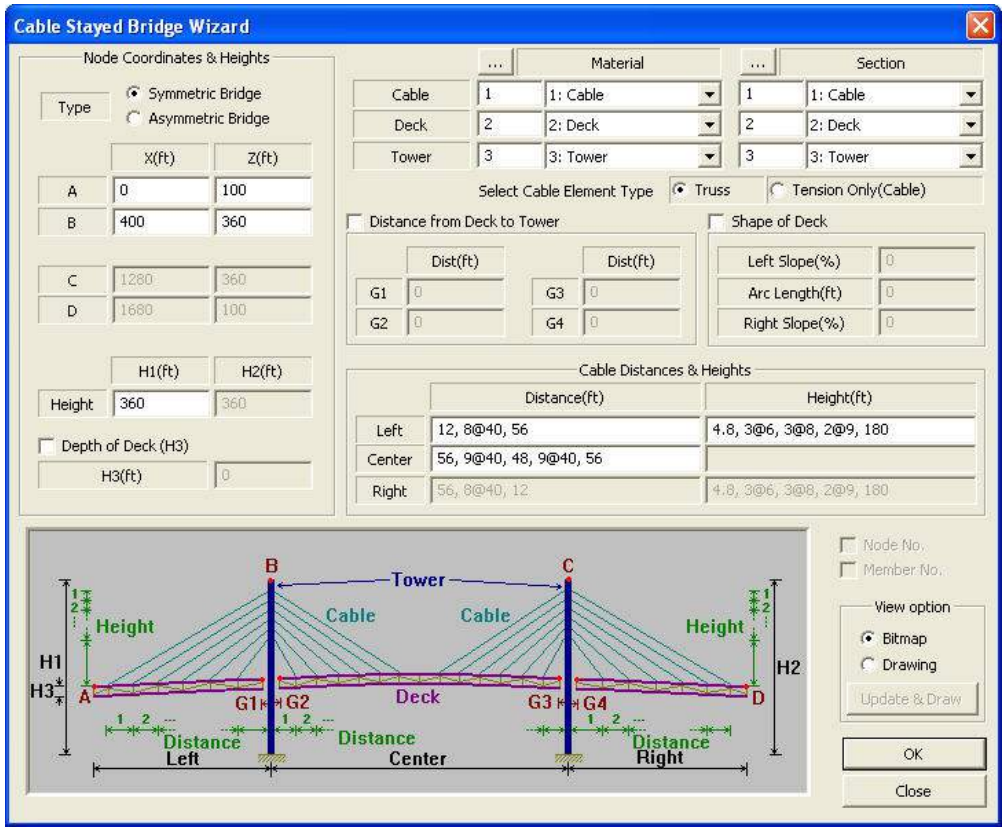

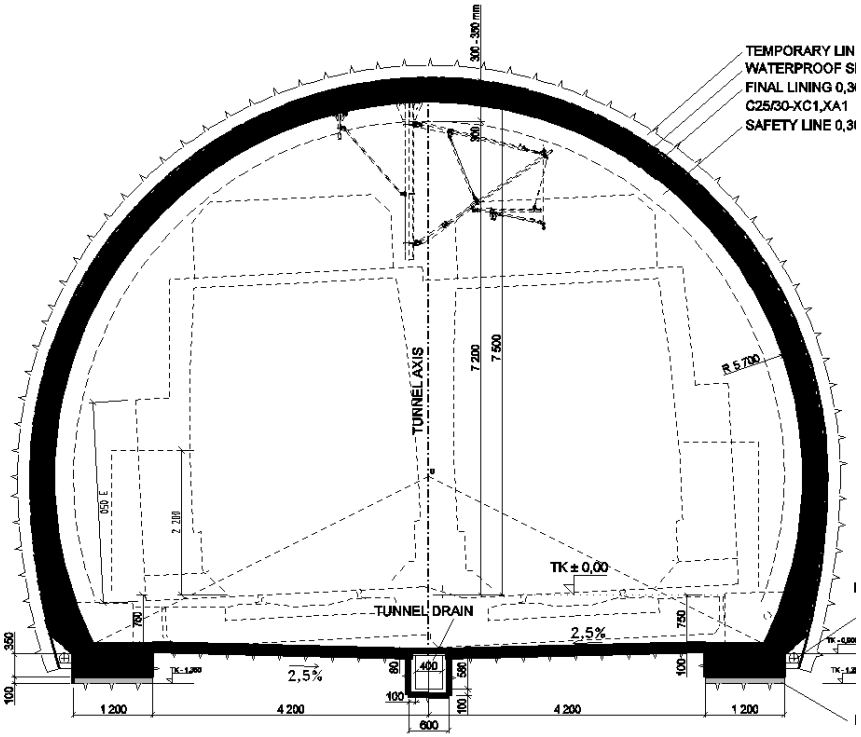

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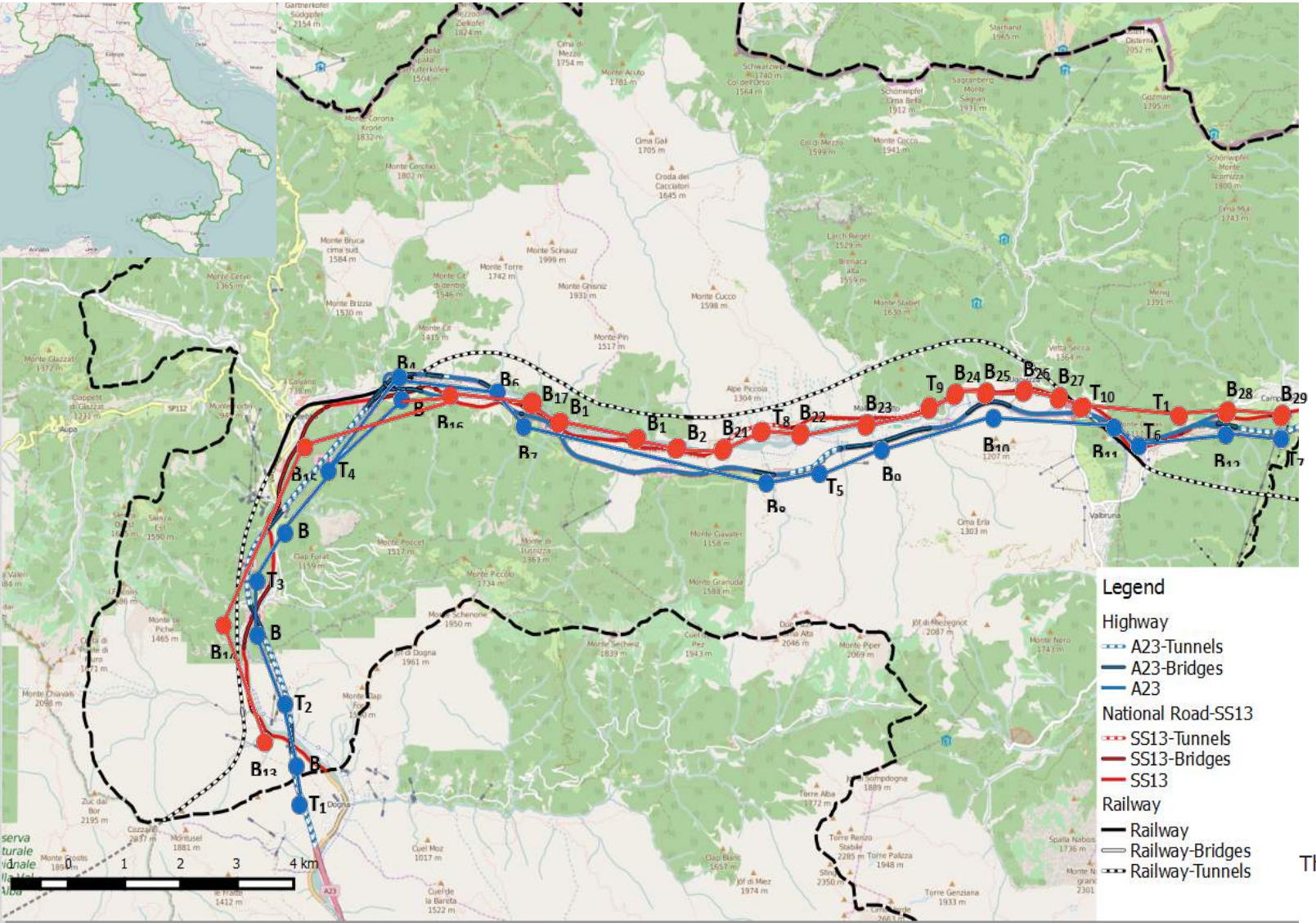
Vulnerability Assessment

Step 5- Identifying critical locations



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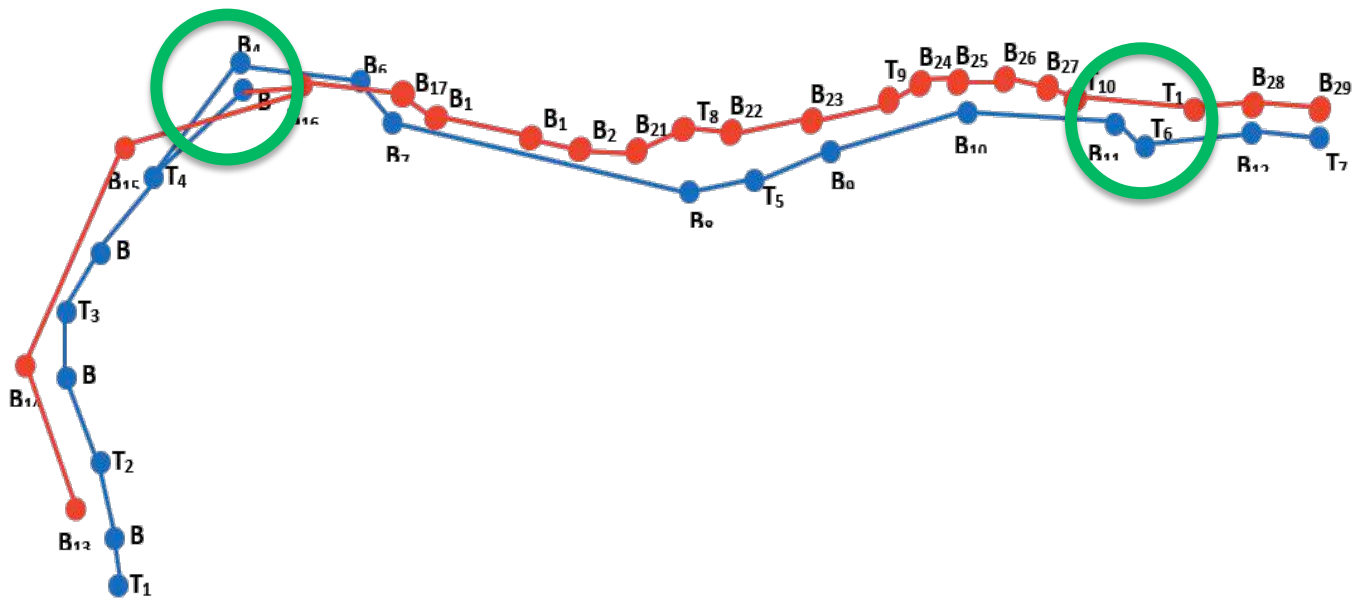
Vulnerability Assessment

Step 5- Identifying critical locations



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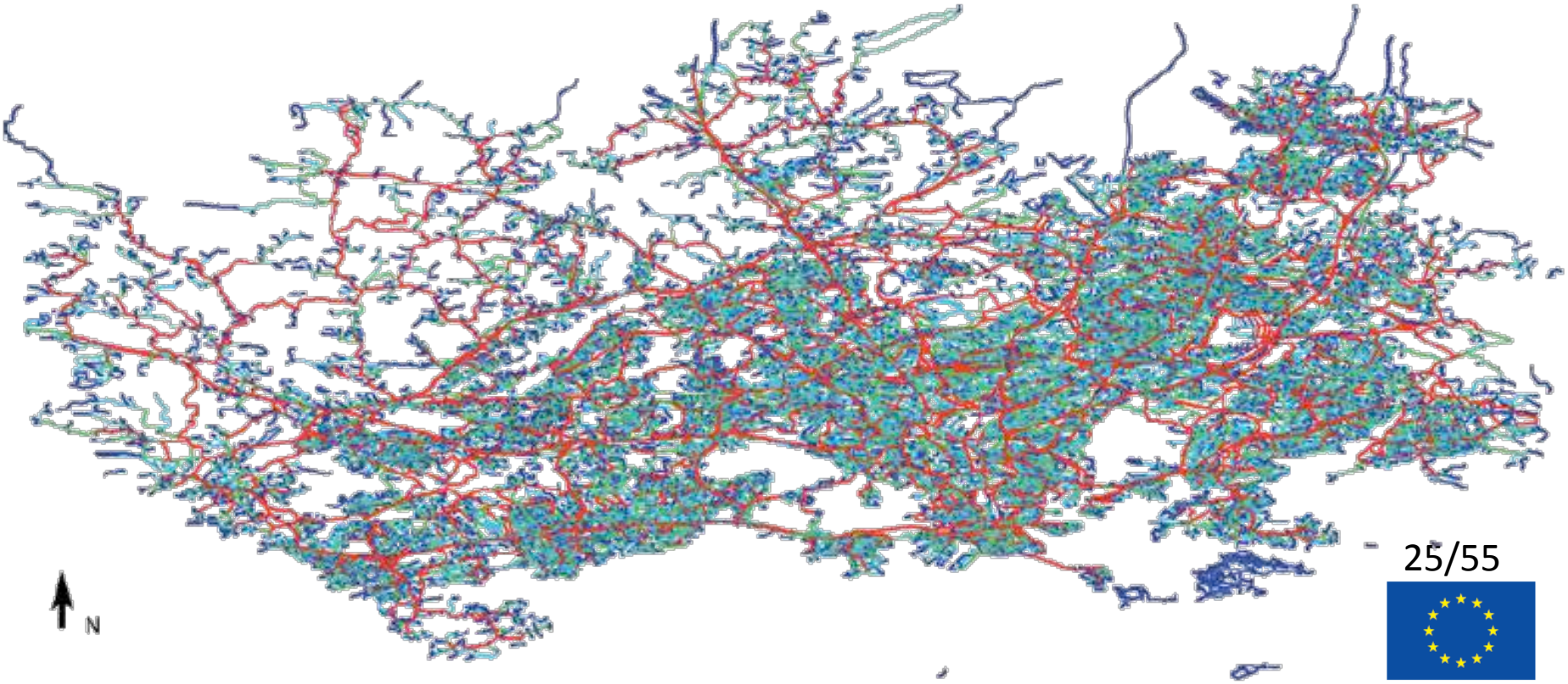
Vulnerability Assessment

Step 5- Identifying critical locations



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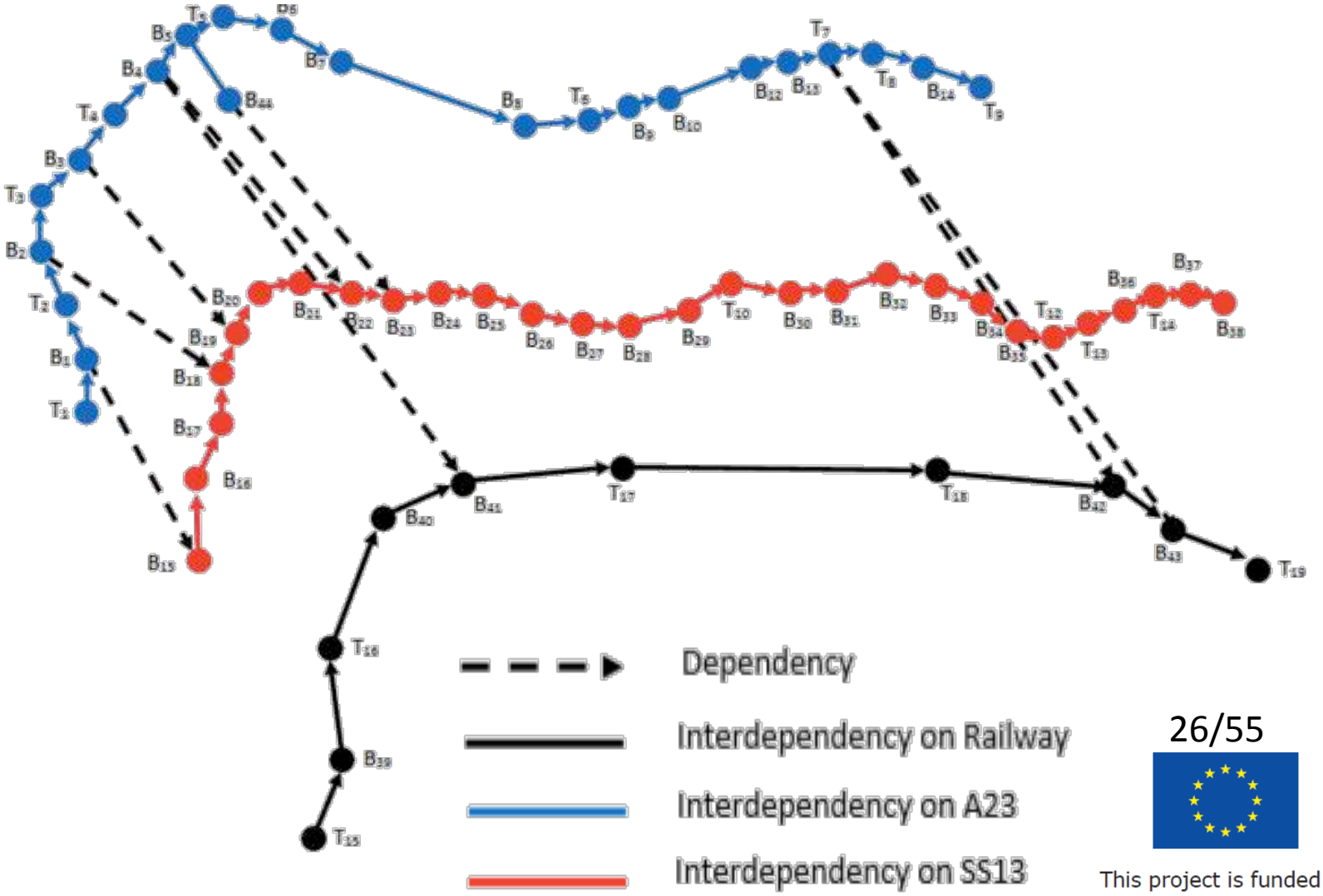
Vulnerability Assessment

Step 6- Identifying (inter)dependencies



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Vulnerability Assessment

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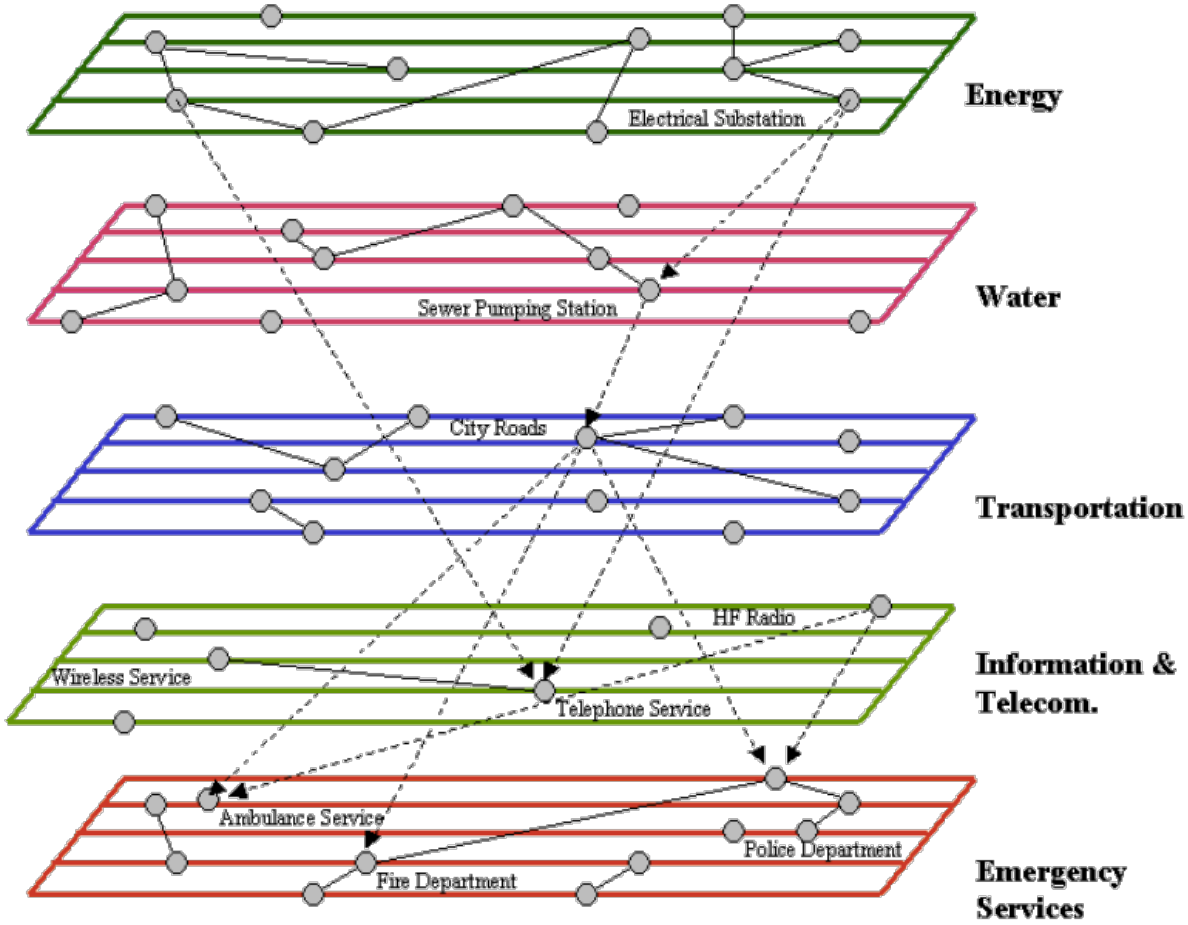

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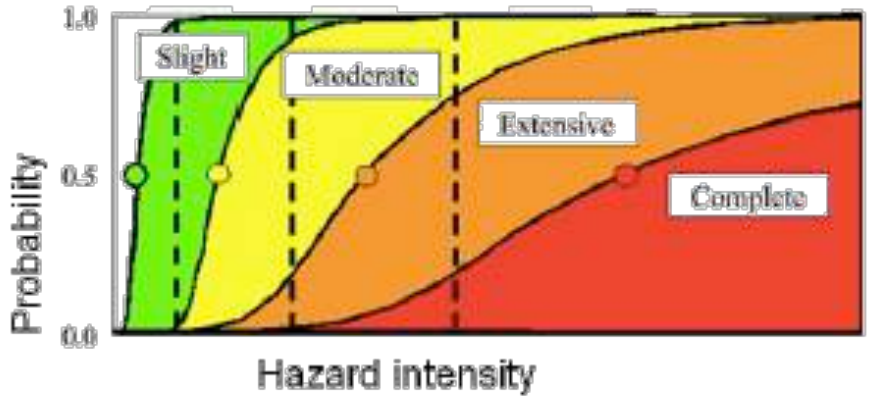
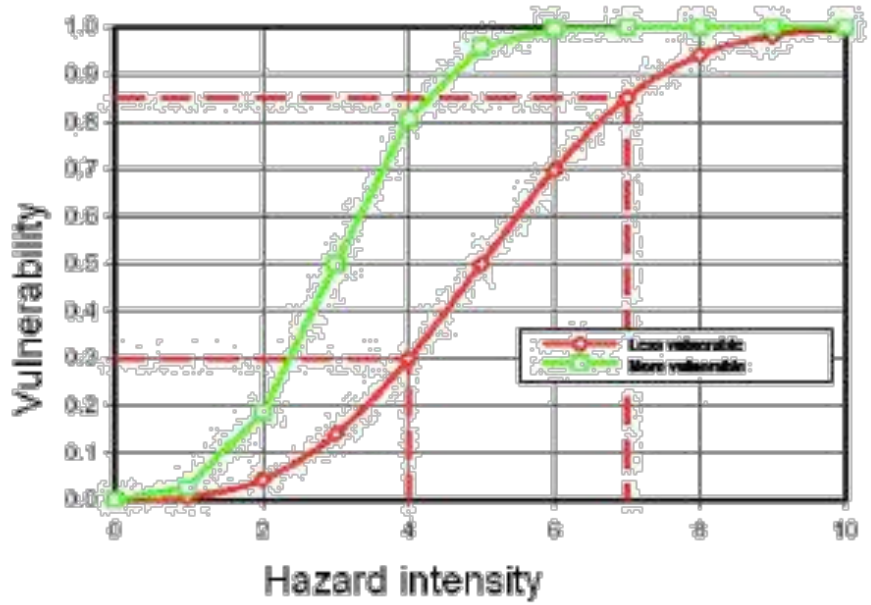
Vulnerability Assessment

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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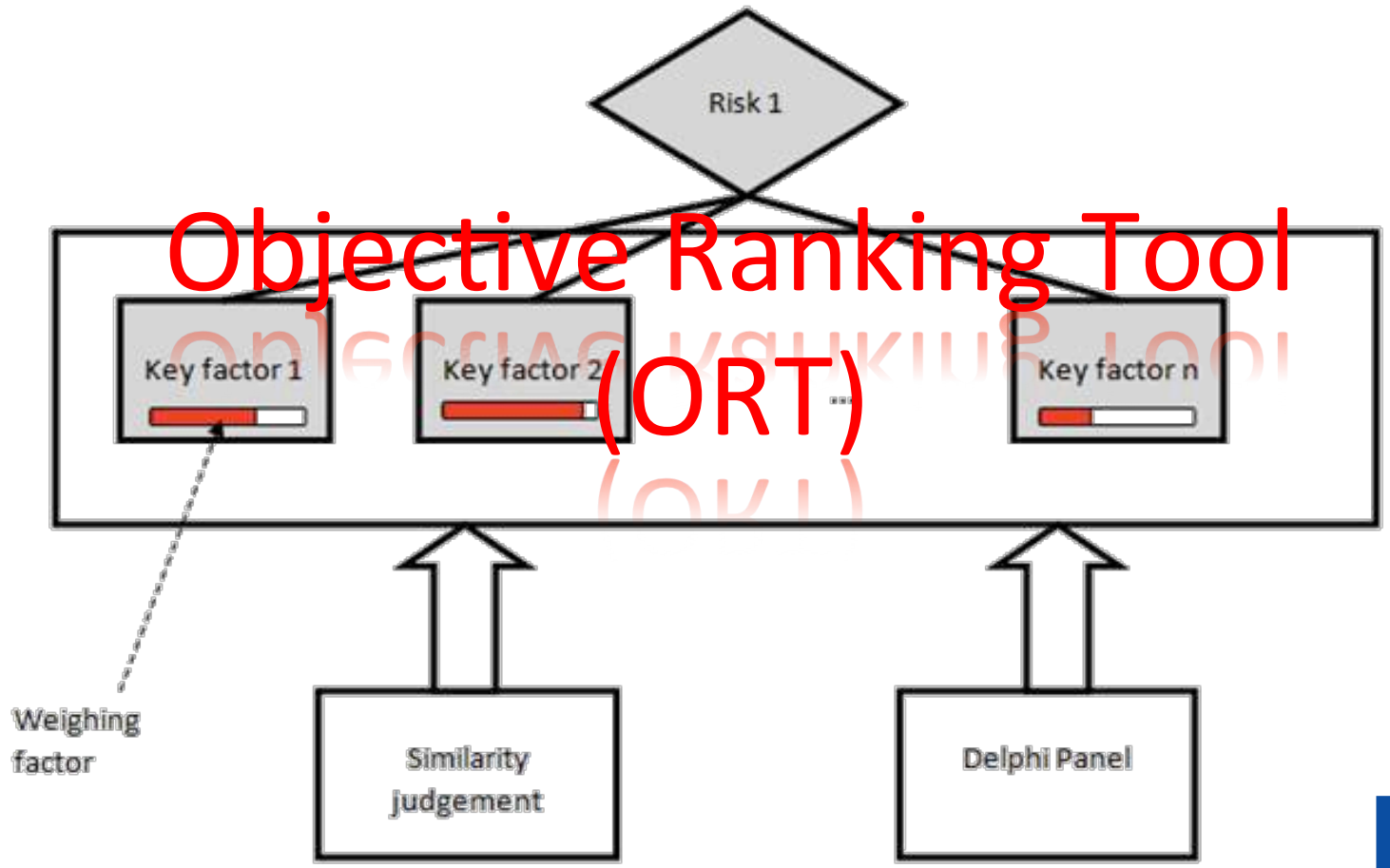
Consequence Analysis

Step 9- Identifying key factors and weights



Objective Ranking Tool (ORT)

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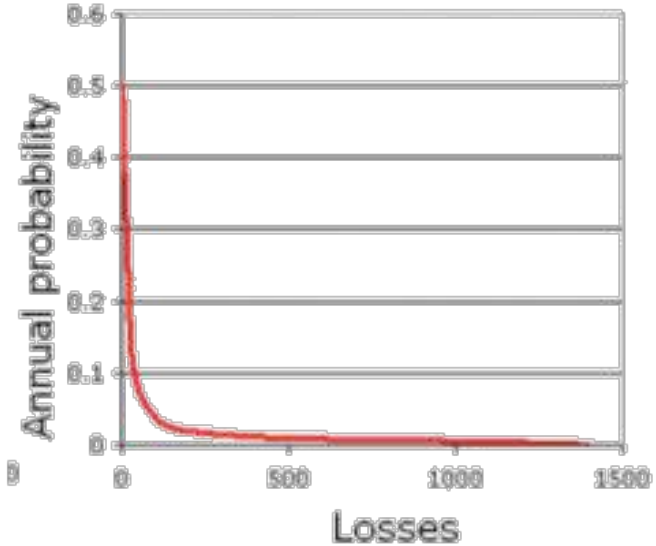
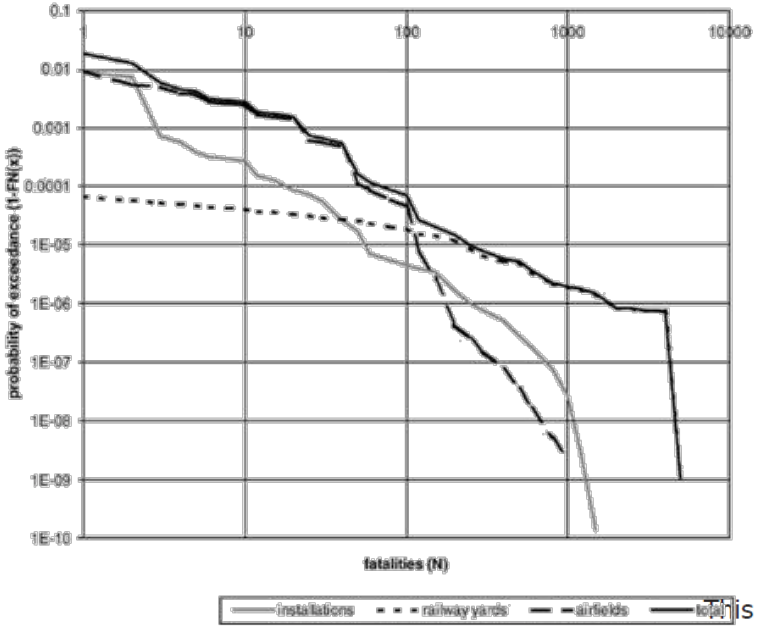
Consequence Analysis

Step 10- Quantifying consequences





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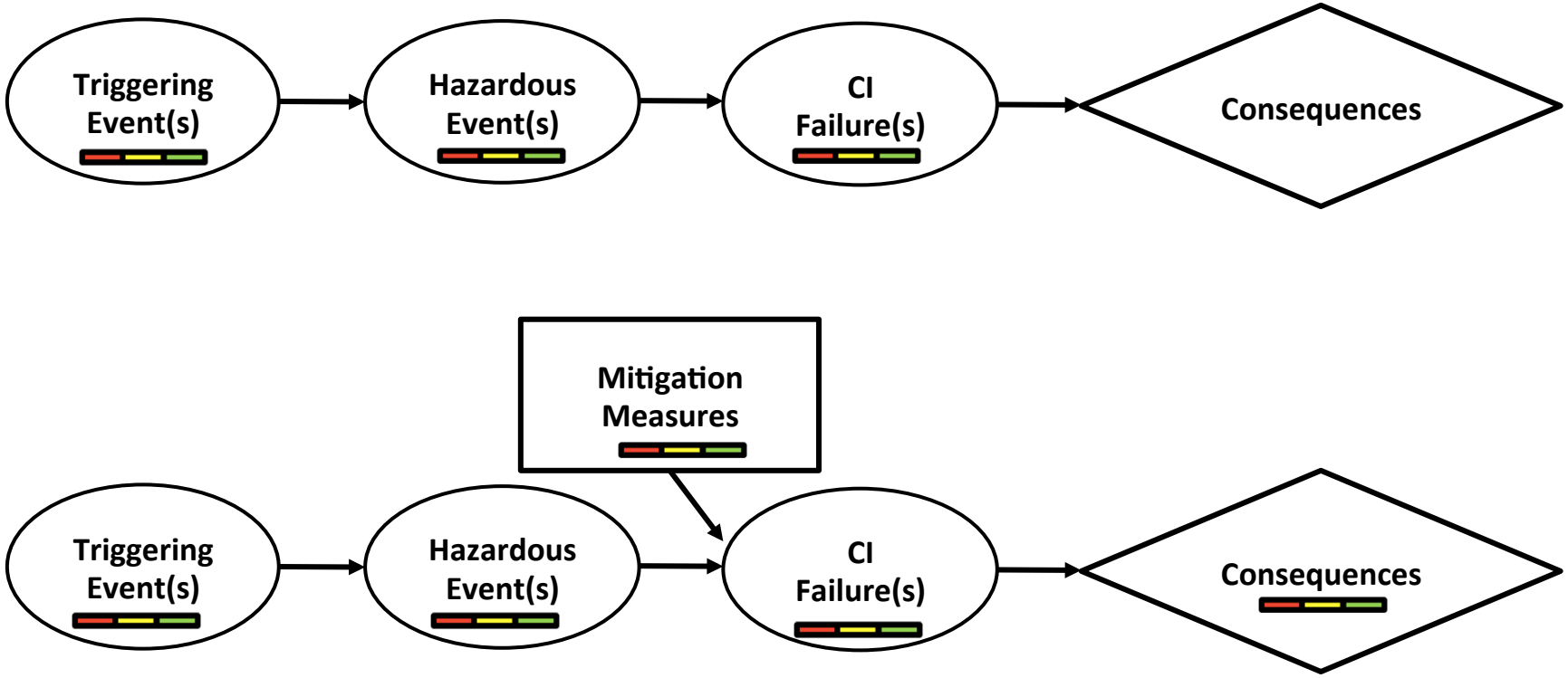
Risk Evaluation

Step 11- Generating Inference Network



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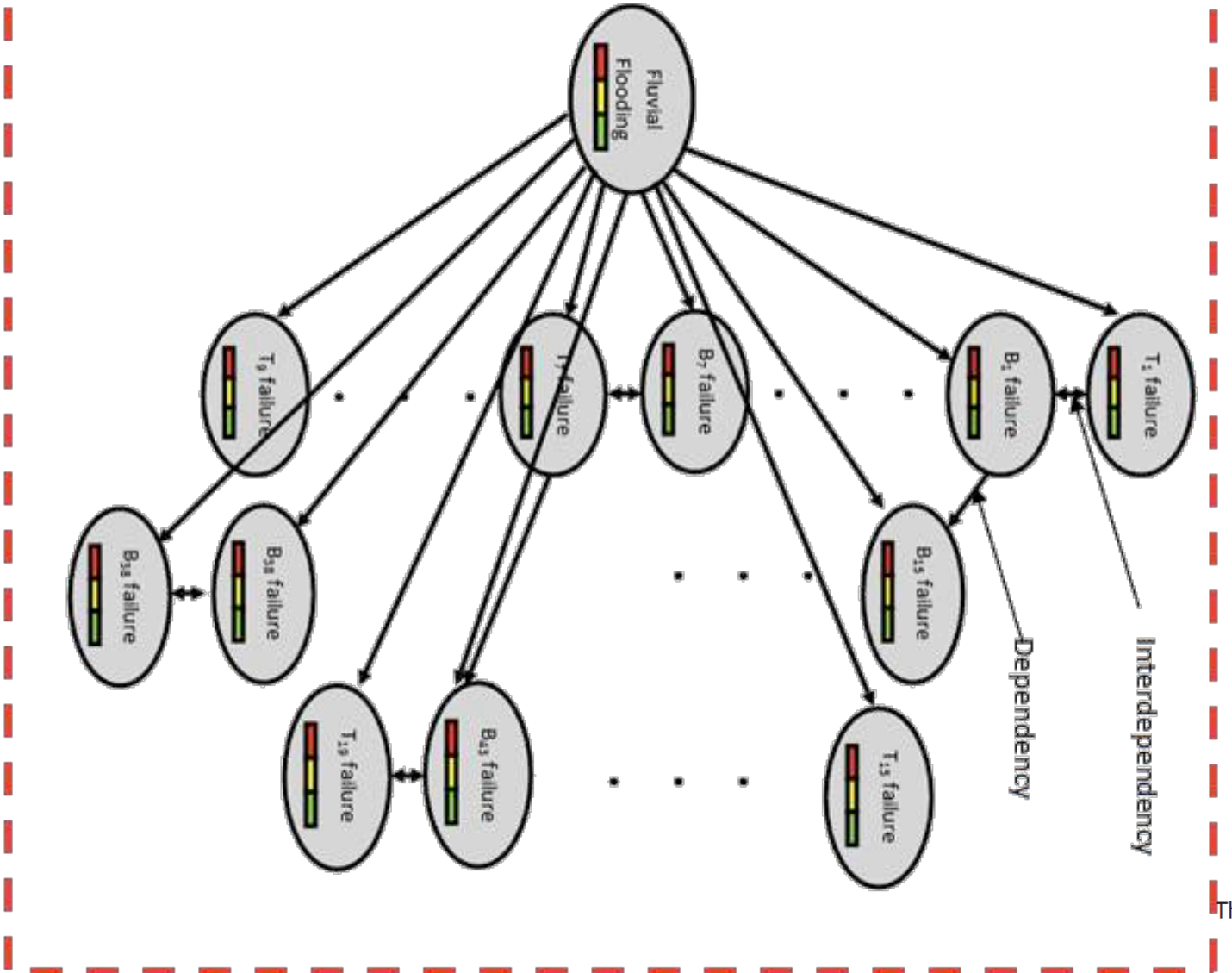
Risk Evaluation

Step 12- Combining Infrastructure Network and Inference Network



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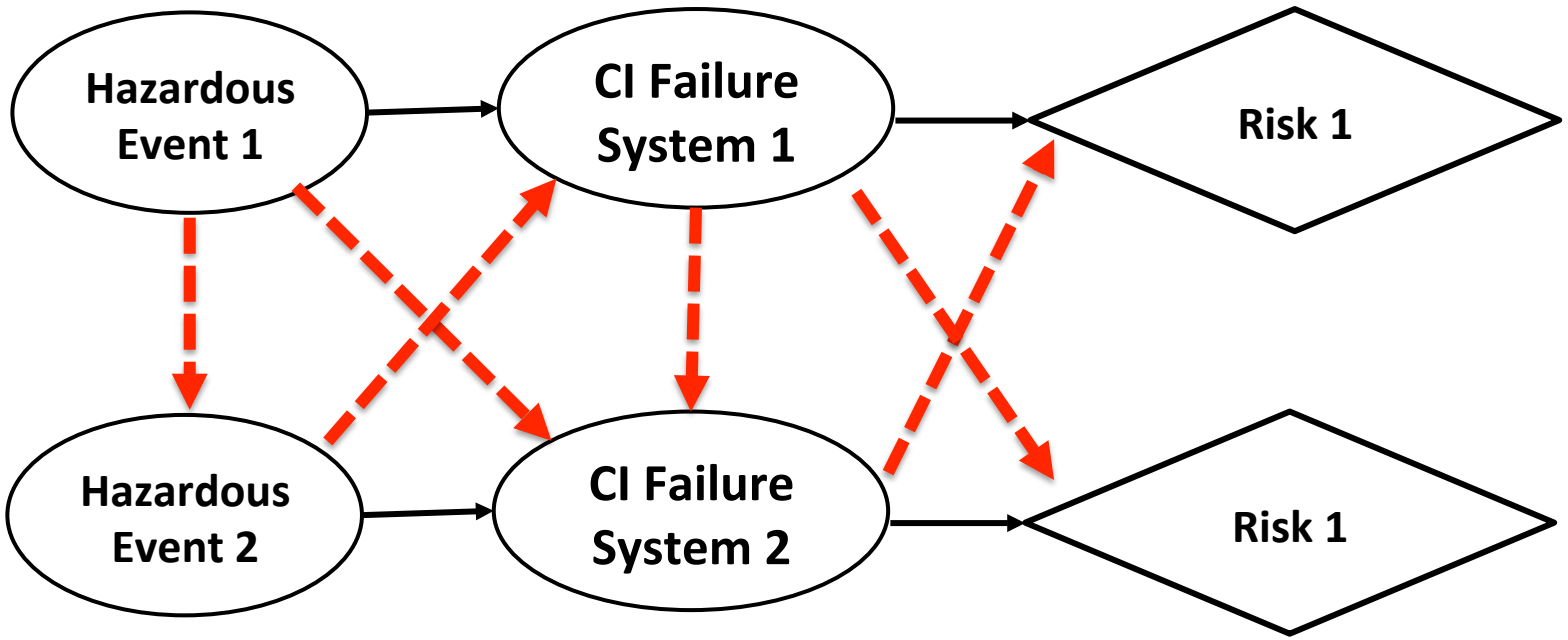
Risk Evaluation

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



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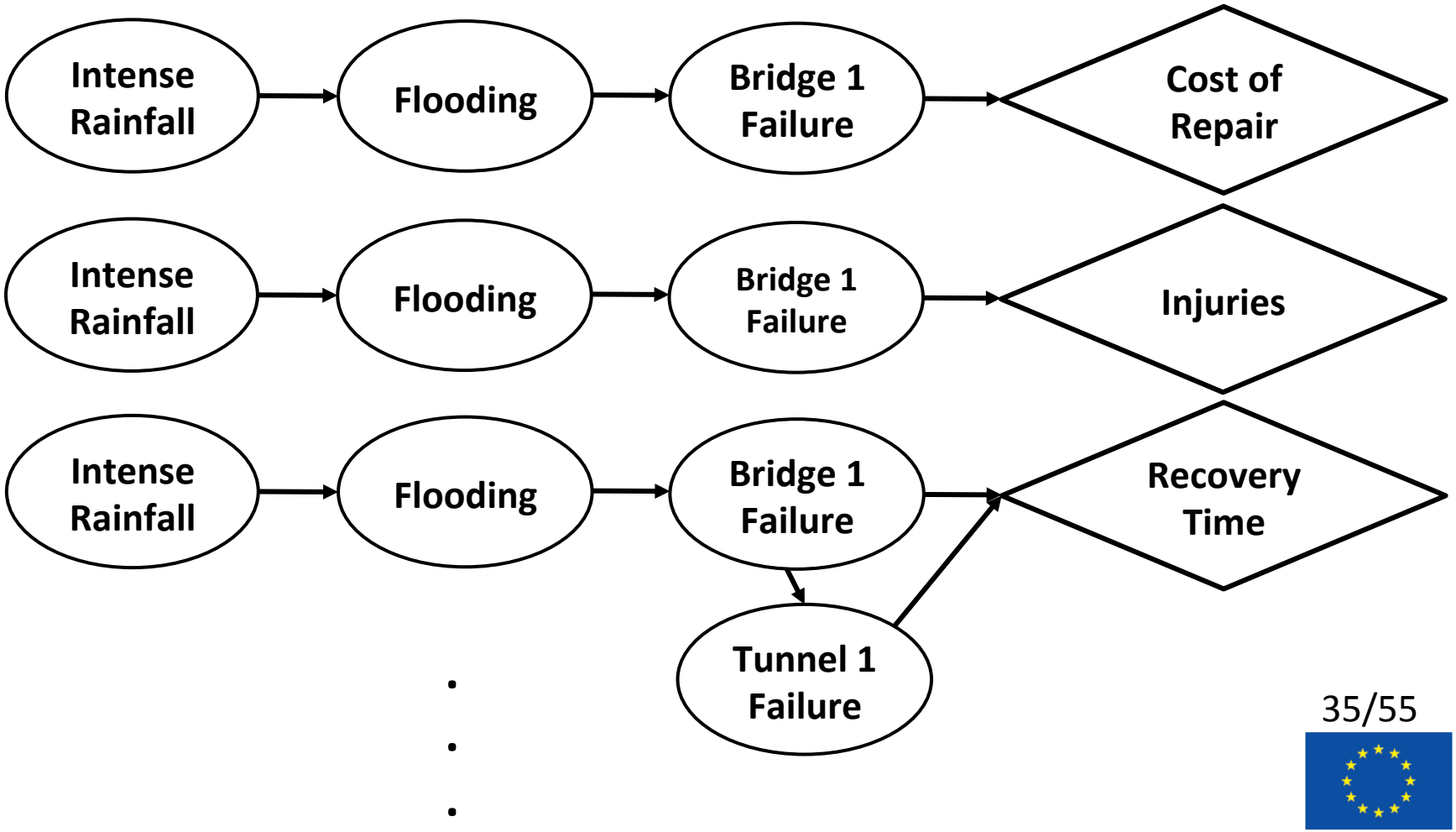
Risk Evaluation

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



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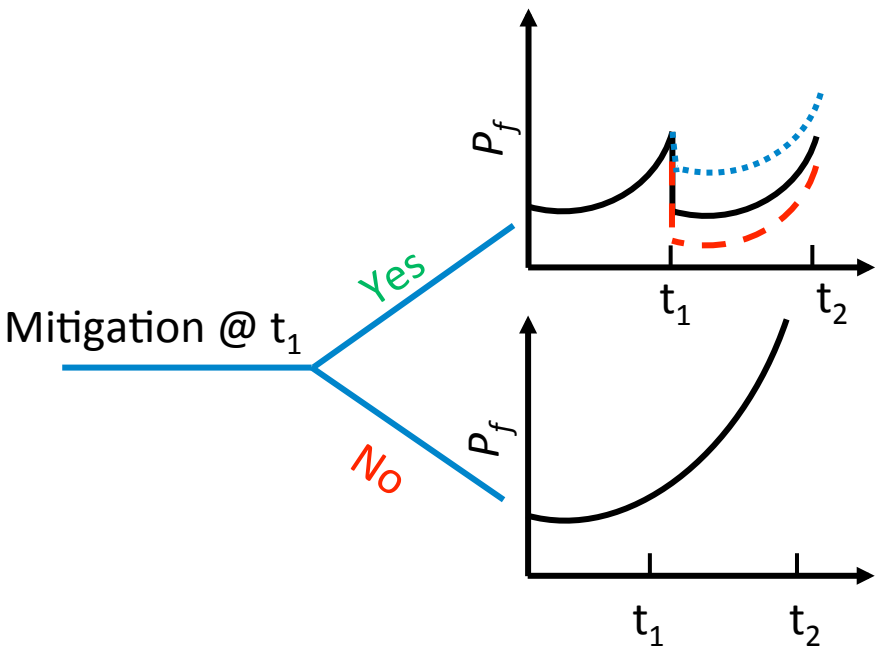
Risk Evaluation

Step 15- Developing Mitigation Strategies



P_f = Probability of Failure
t_i = Time

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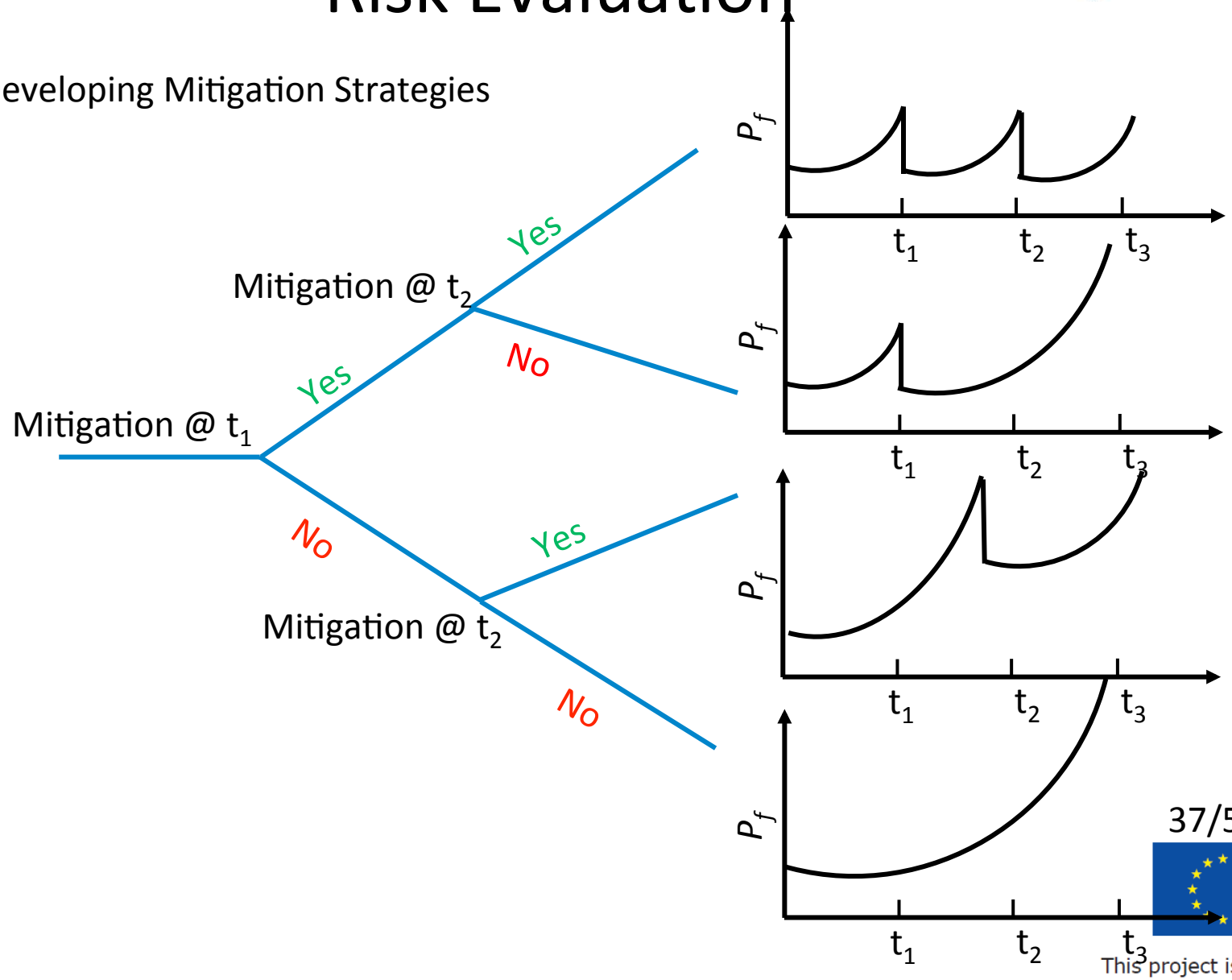
Risk Evaluation

Step 15- Developing Mitigation Strategies



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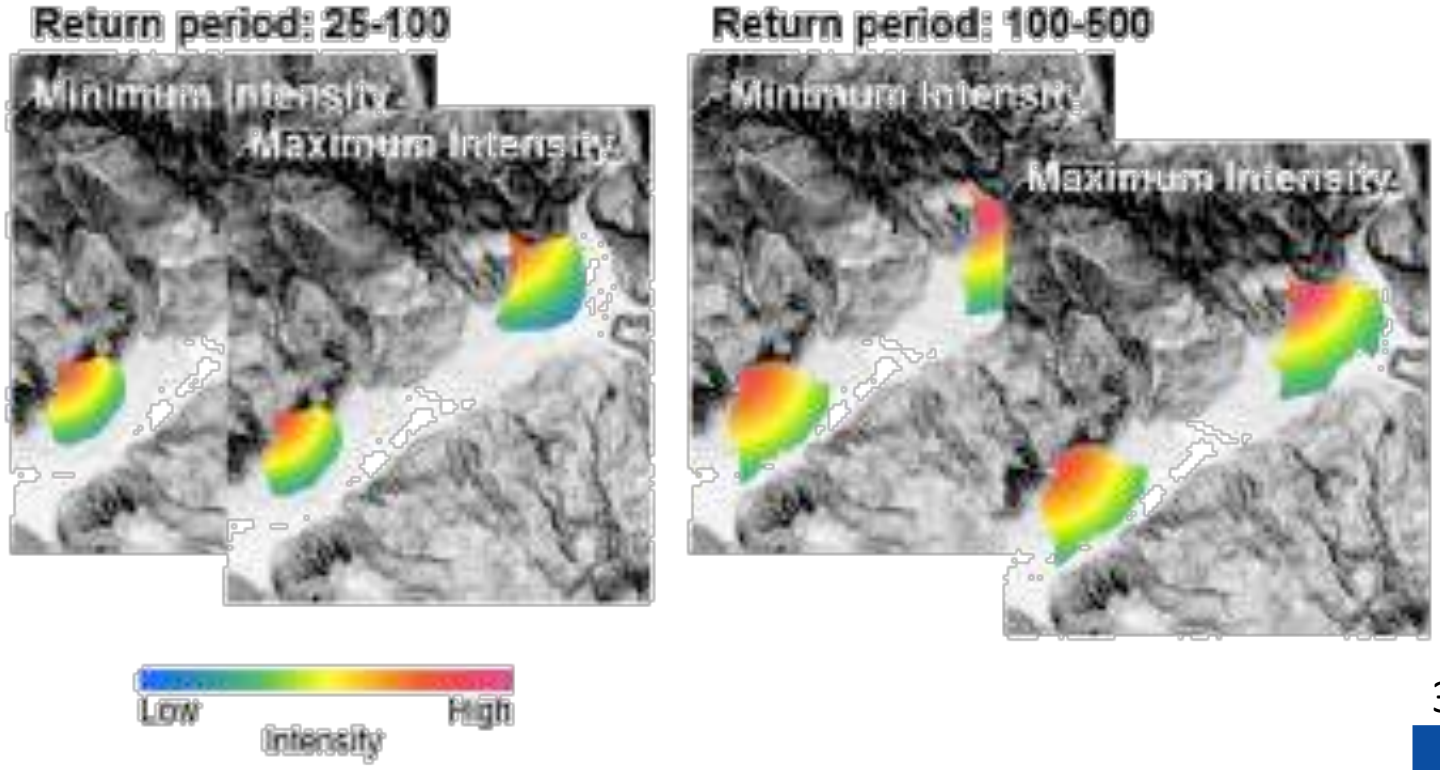
Risk Evaluation

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



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Risk Evaluation

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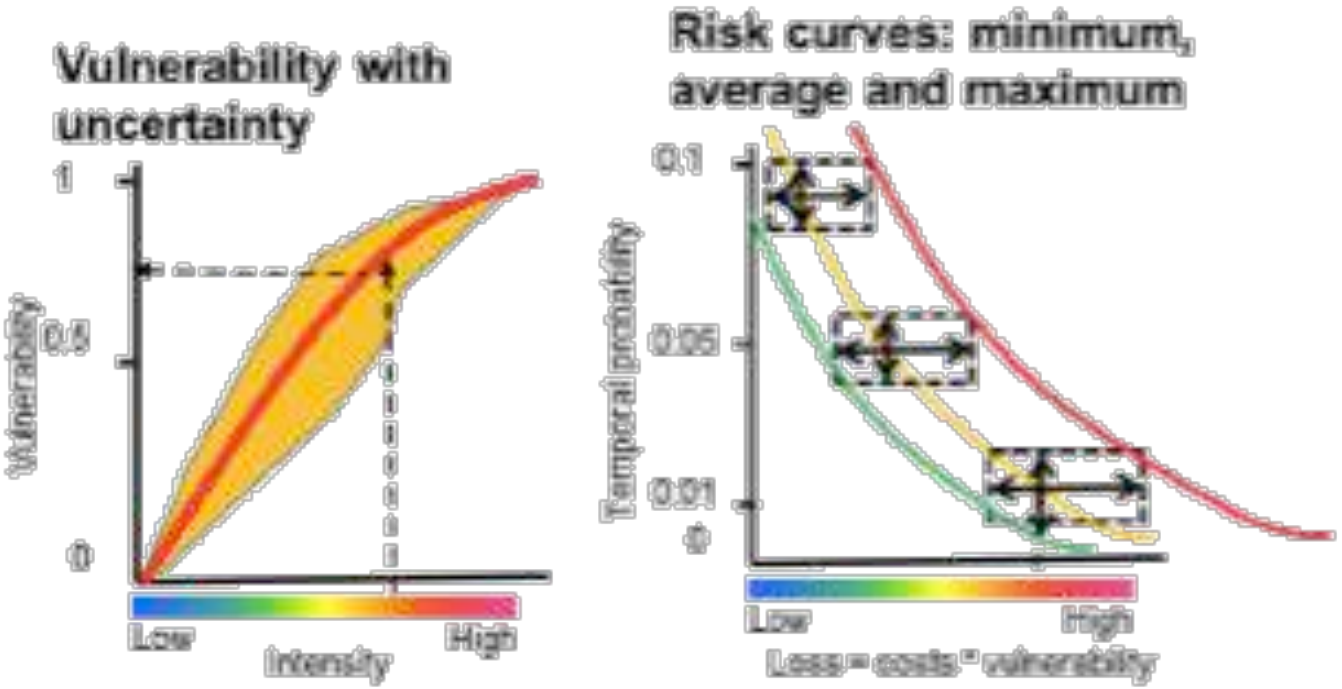

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Risk Evaluation

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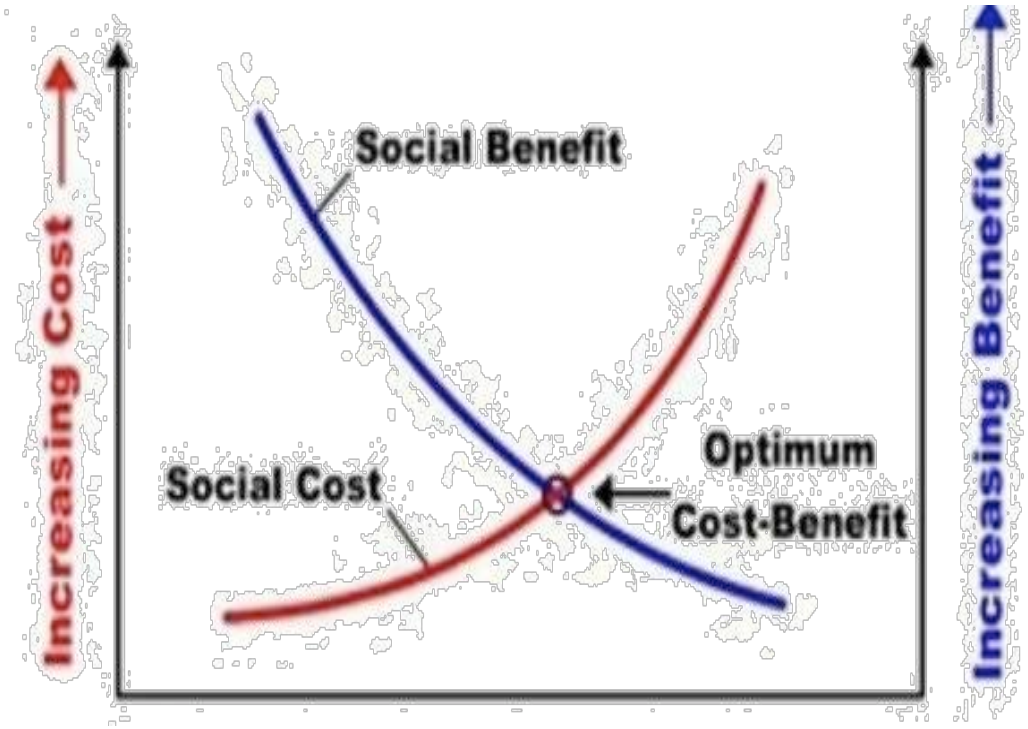

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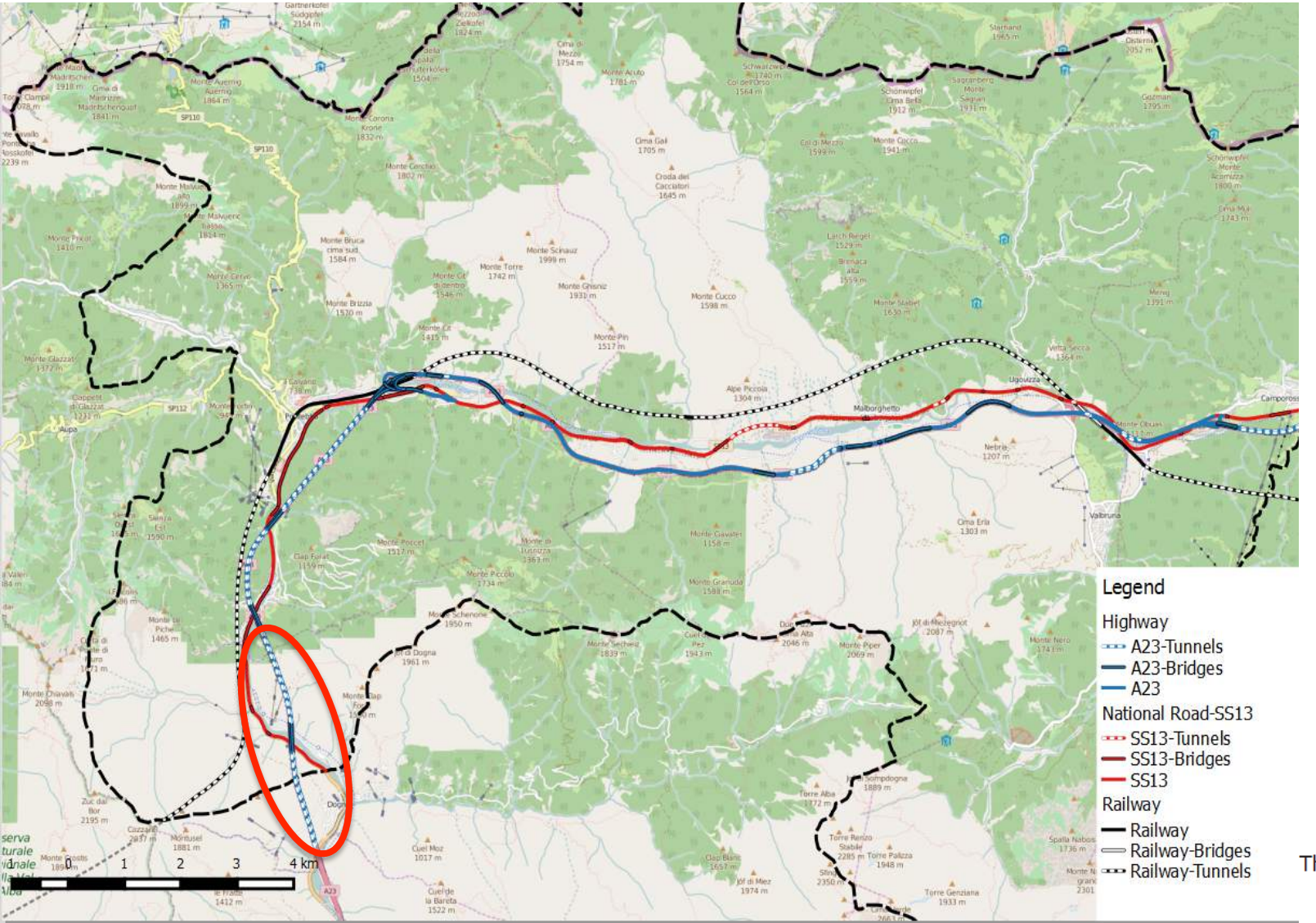
Risk Evaluation

Example of Bayesian Network Development



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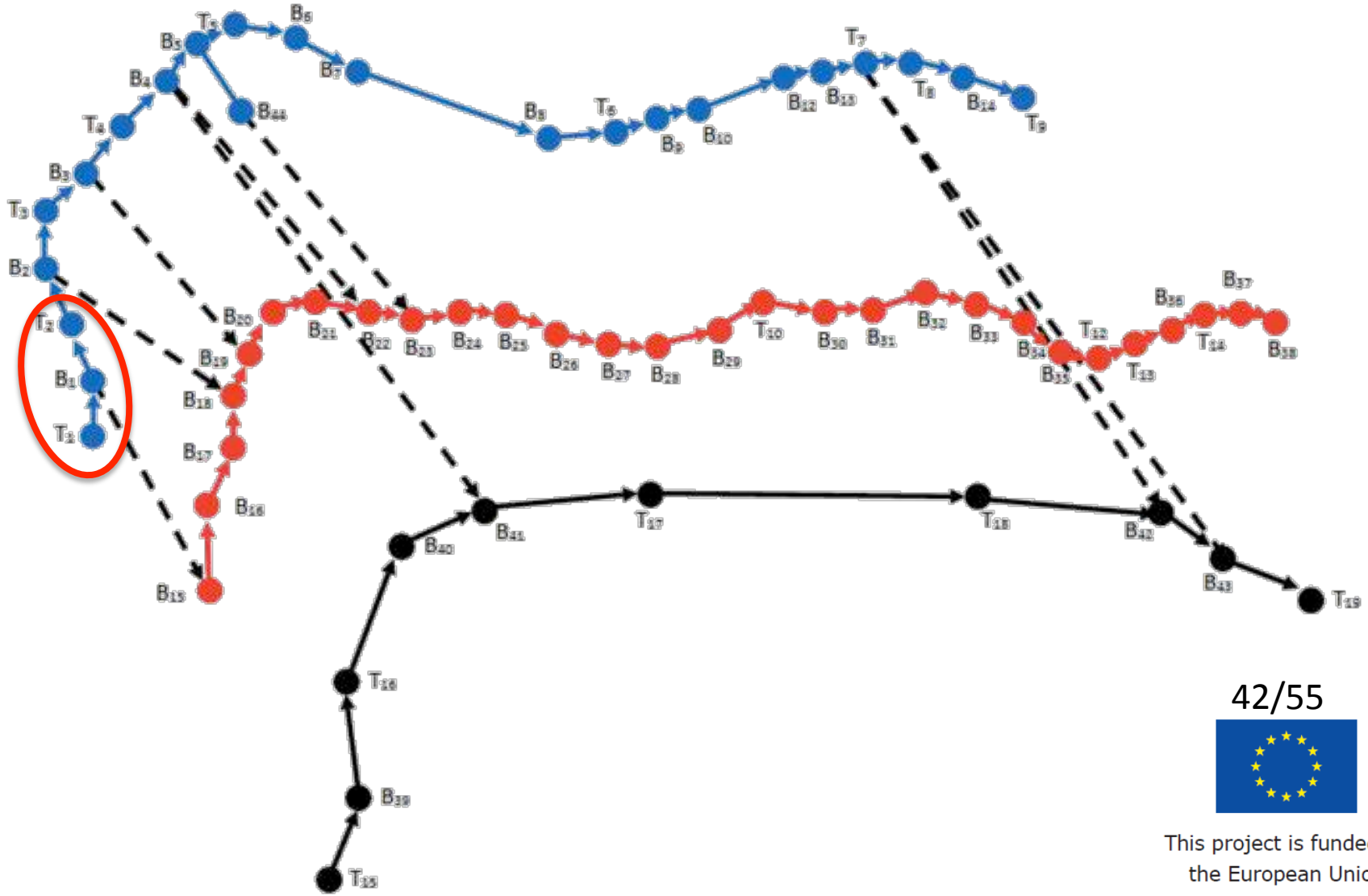
Risk Evaluation

Example of Bayesian Network Development



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Risk Evaluation

Example of Bayesian Network Development

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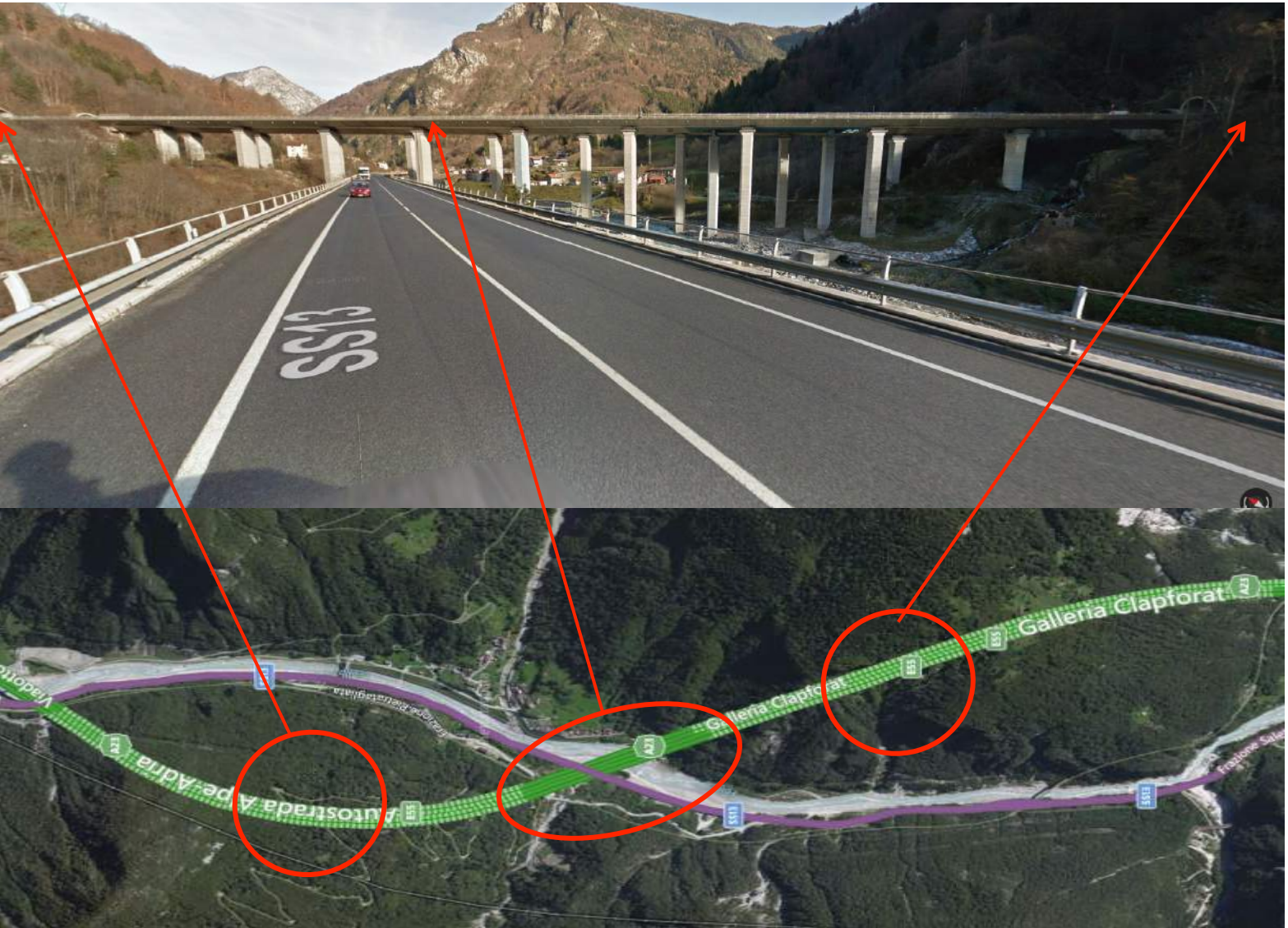
Risk Evaluation

Example of Bayesian Network Development



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Risk Evaluation

Example of Bayesian Network Development

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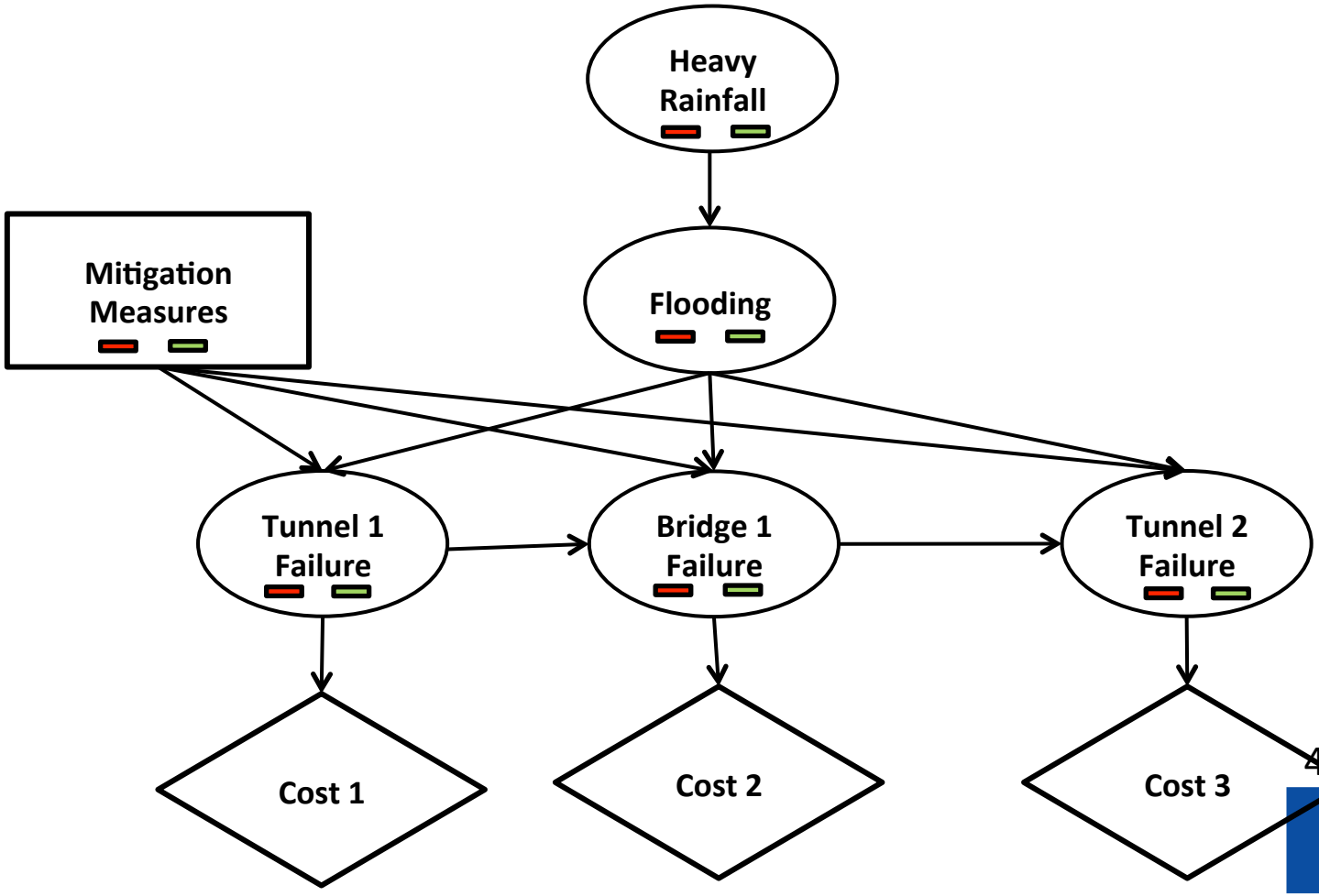
Risk Evaluation

Example of Bayesian Network Development



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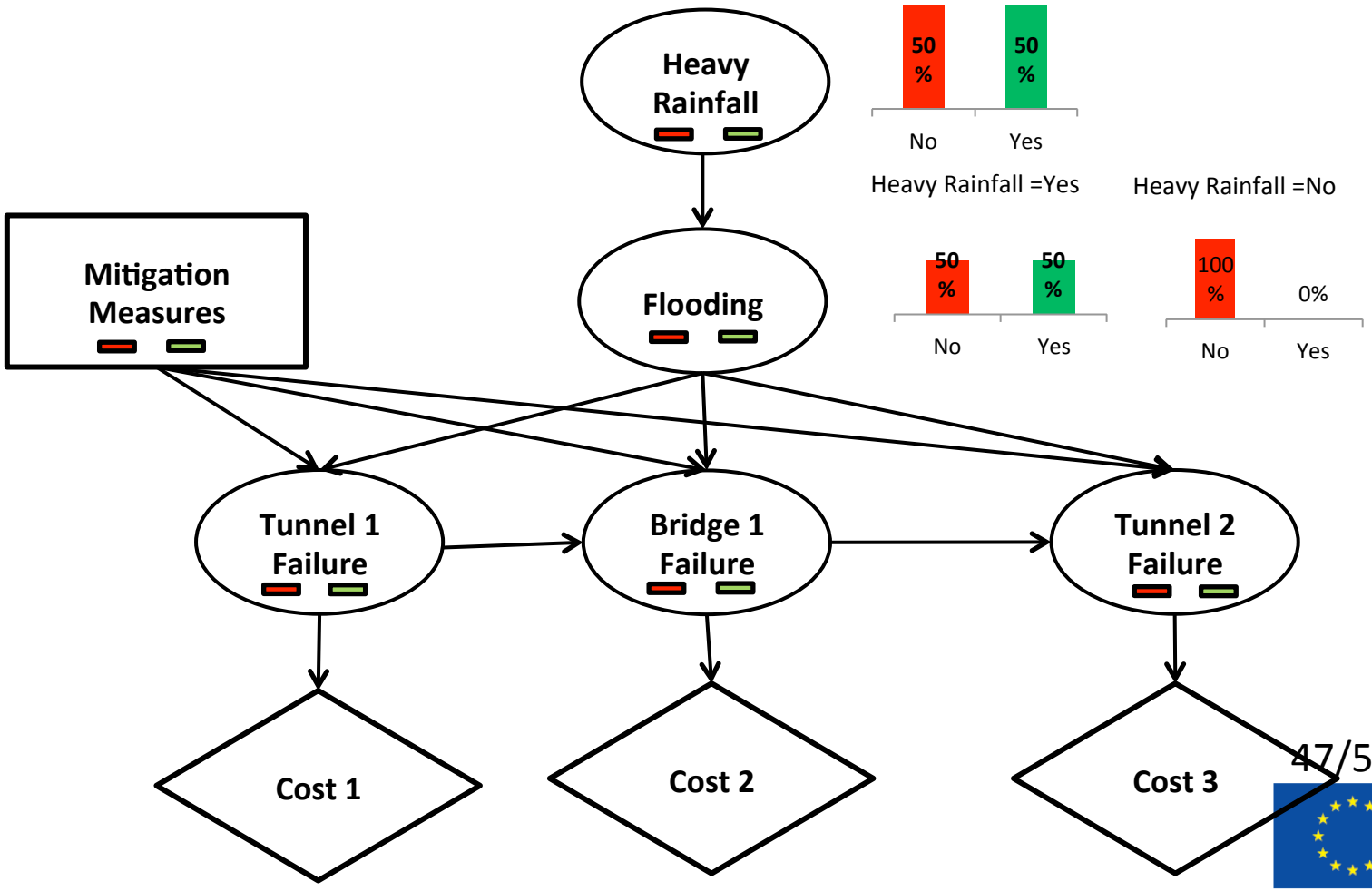
Risk Evaluation

Example of Bayesian Network Development



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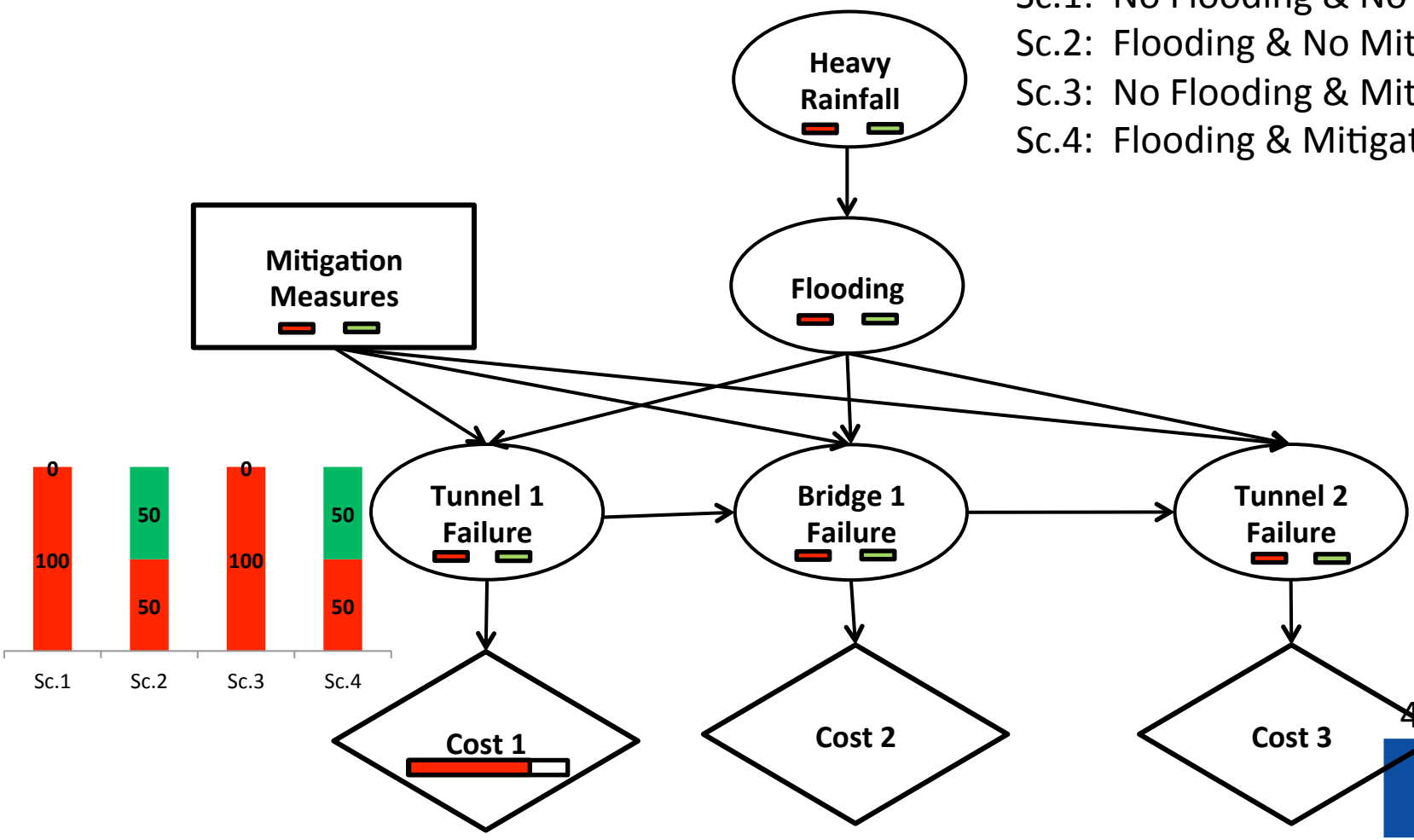
Risk Evaluation

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



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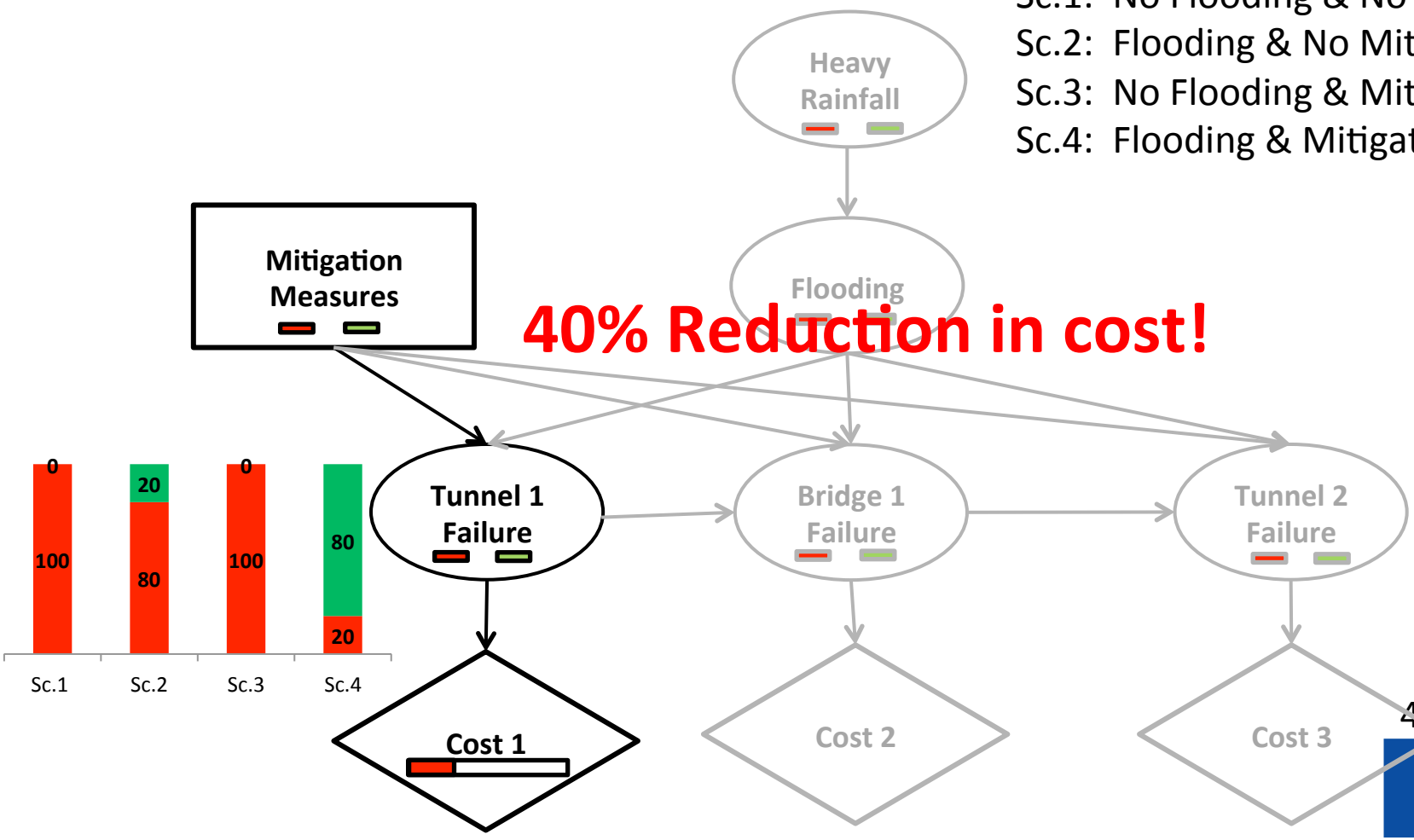
Risk Evaluation

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



40% Reduction in cost!

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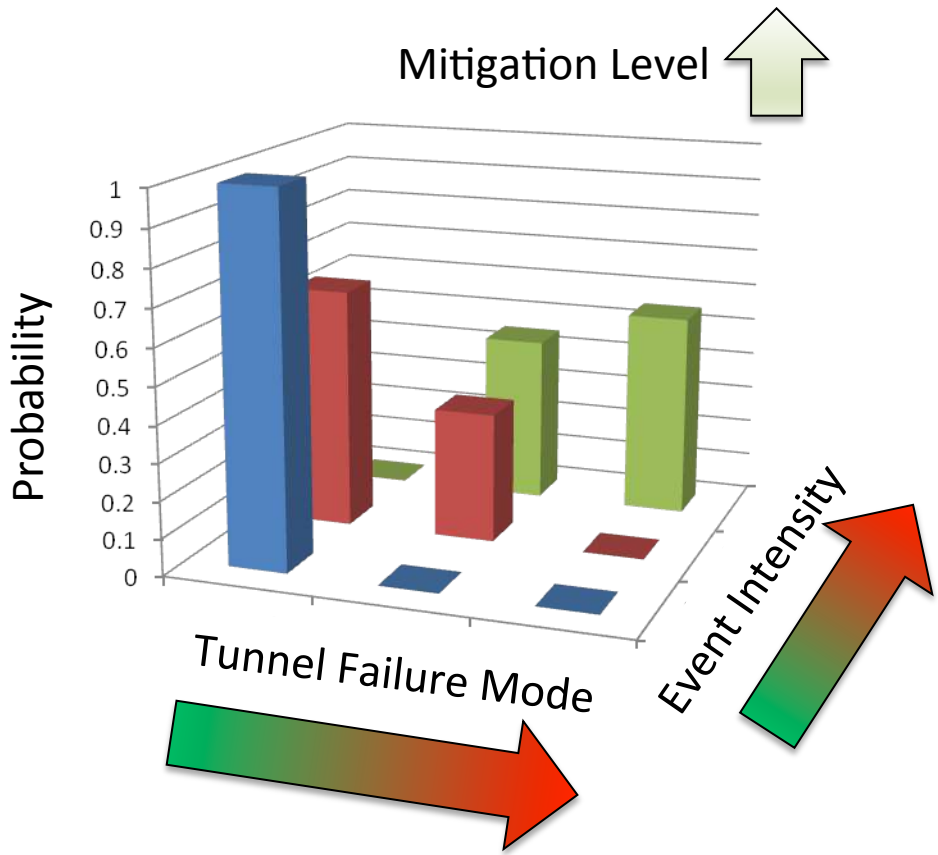
Risk Evaluation



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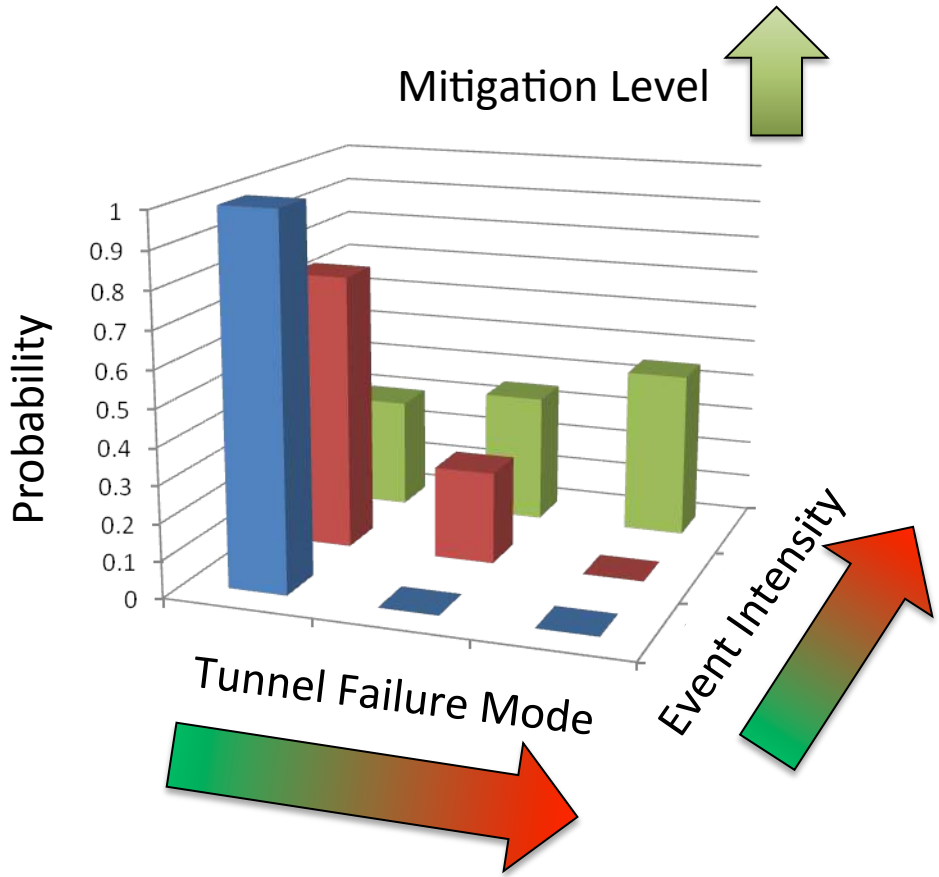
Risk Evaluation



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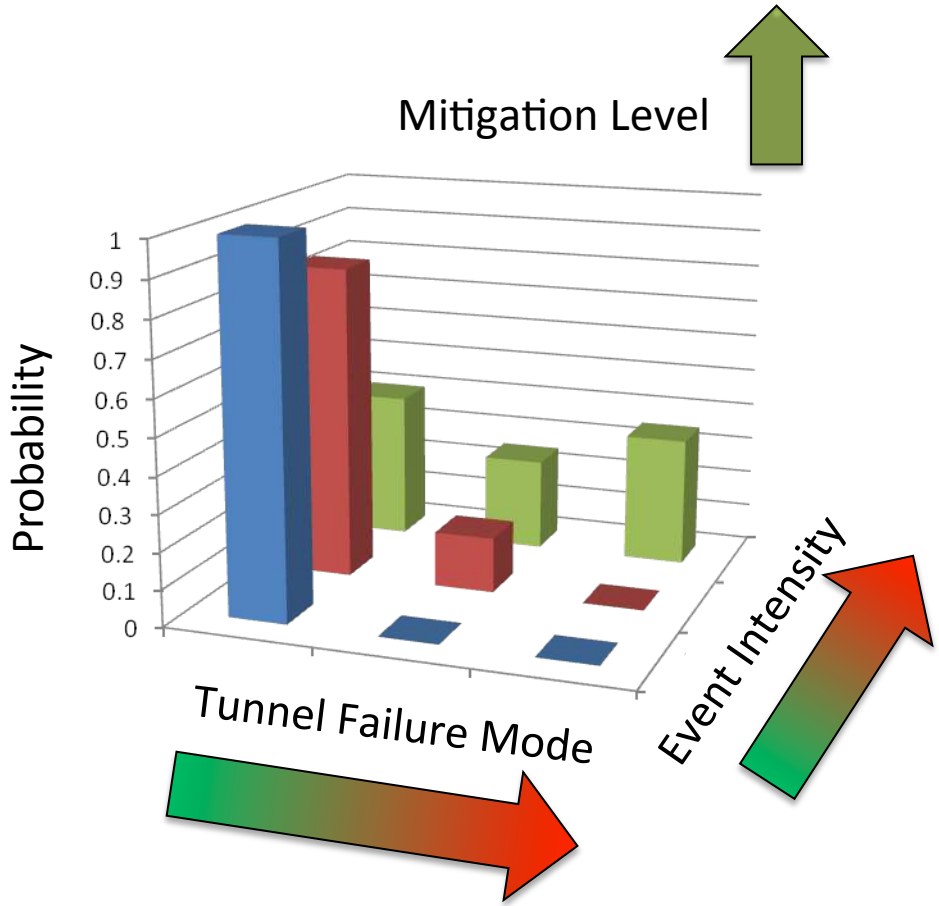
Risk Evaluation



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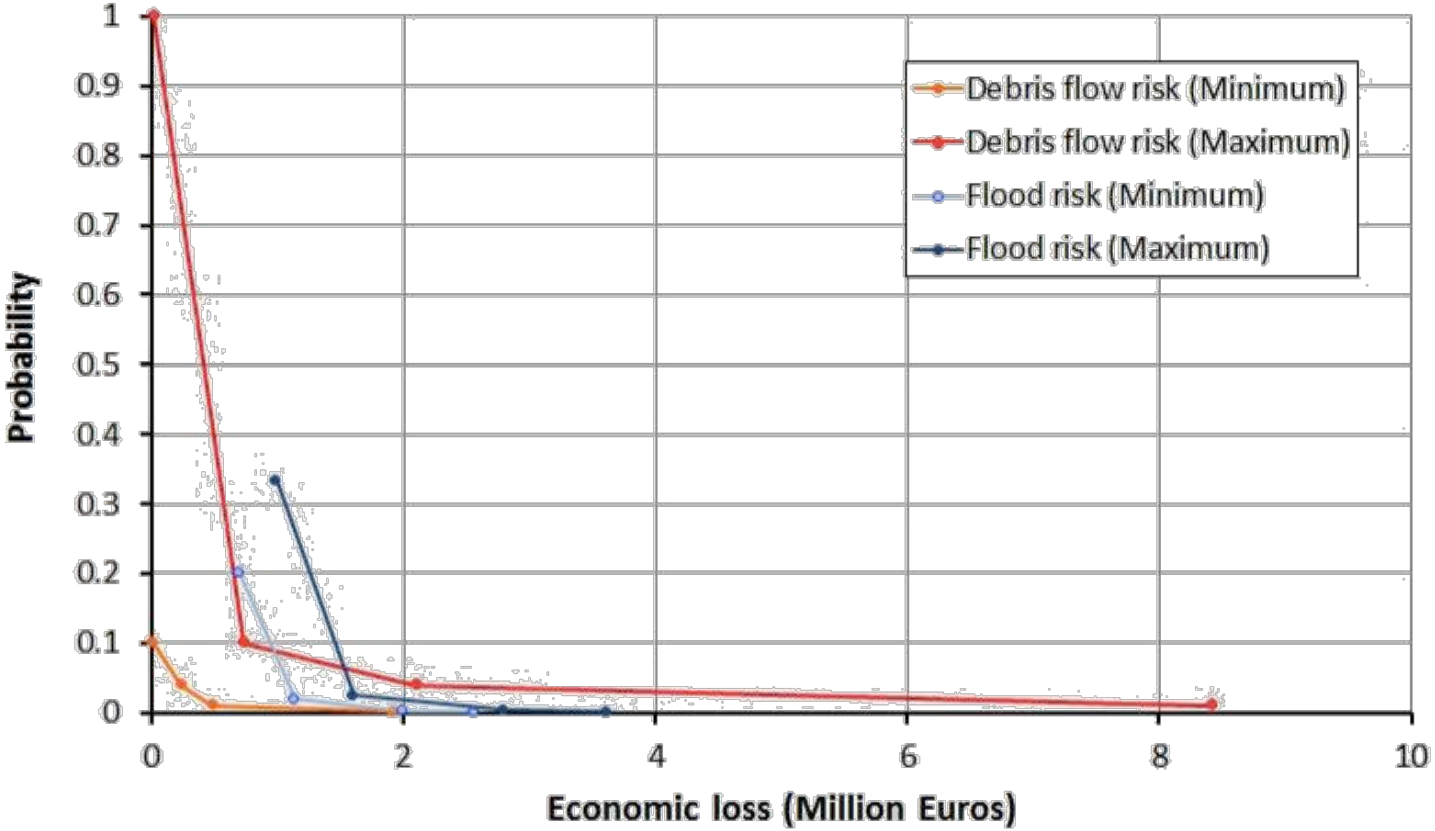

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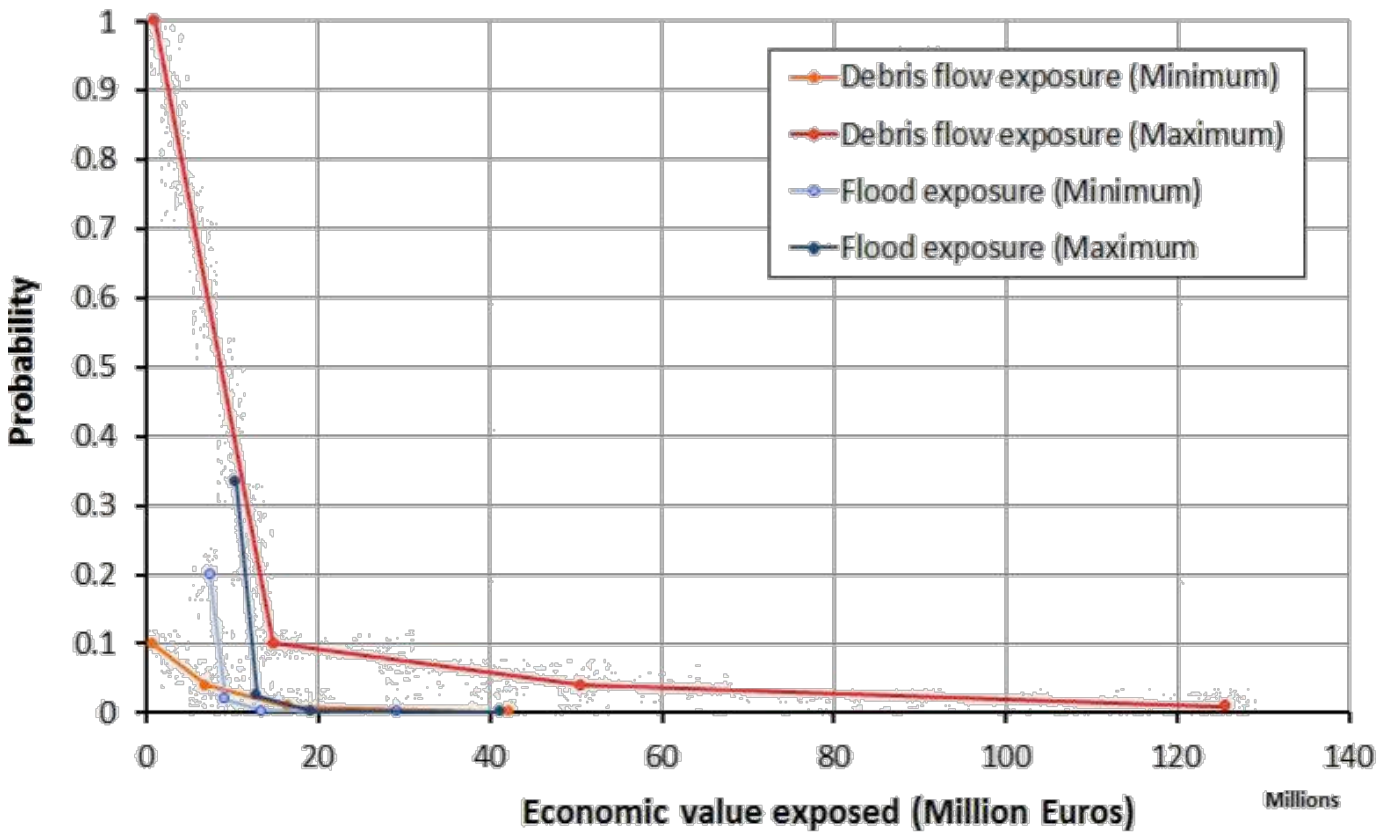
Risk Evaluation



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THANK YOU FOR YOUR ATTENTION.

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