Towards Regional Safety Assessment of Bridge Infrastructure

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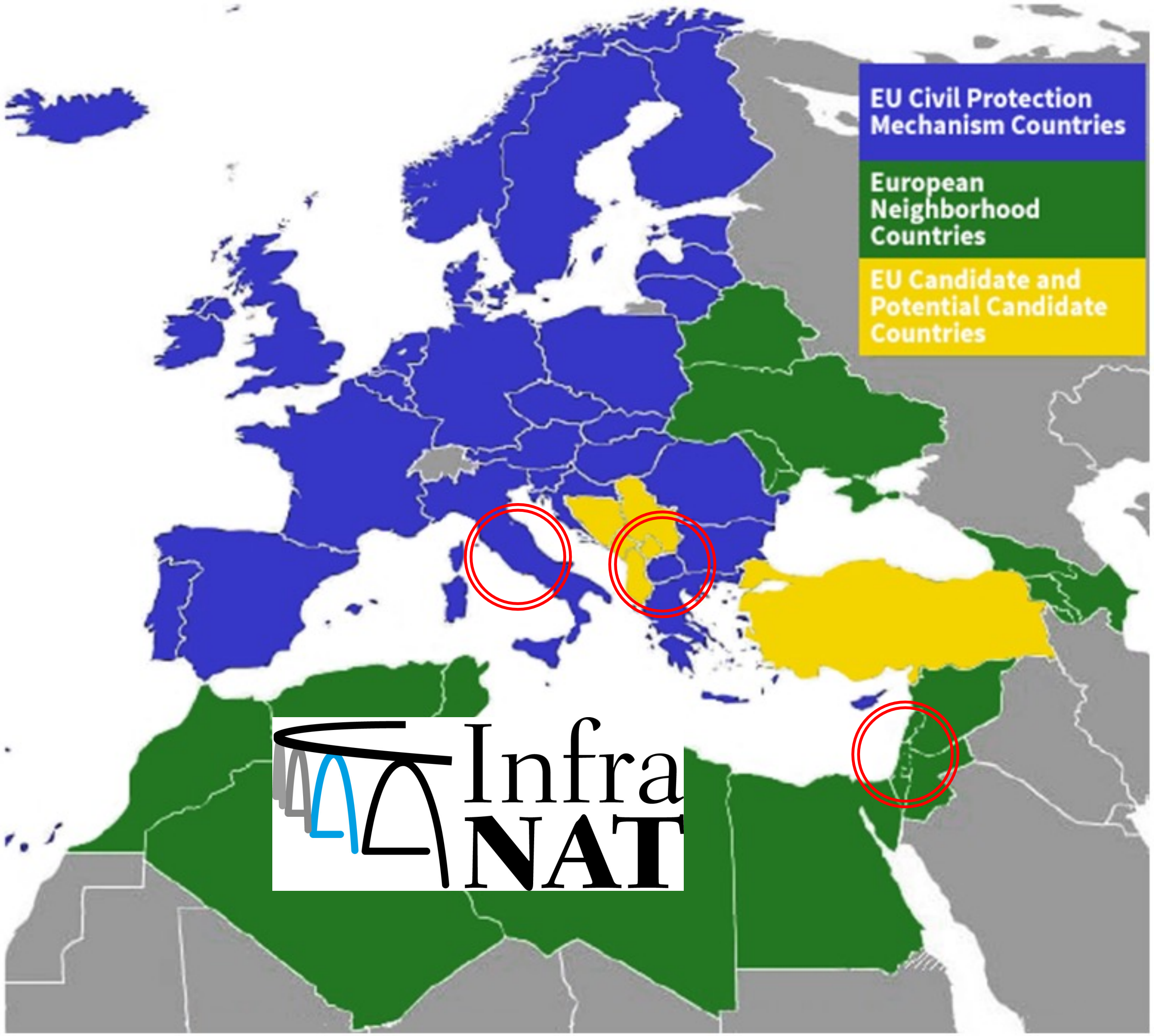
Regional risk assessment of bridges

- Risk management through adequate prioritization and preventative measures needed for large infrastructure networks
- Within risk, we consider 3 its components:
  - Hazard
  - Exposure
  - Vulnerability
- Overview of case study risk assessment of bridge infrastructure in Italy, North Macedonia and Israel as part of the project INFRA-NAT

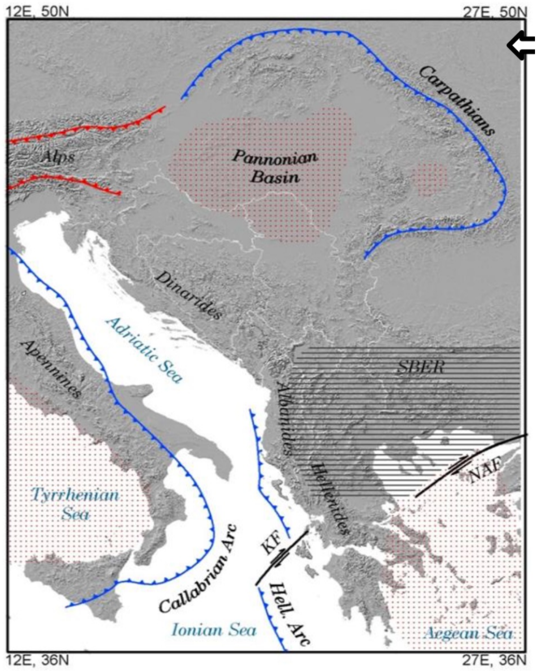


Aims of the INFRA-NAT project

- **Goal:** Increased regional safety of bridge infrastructure
- **How:** Provide **simple and accessible** tools based on existing knowledge to decision makers for resource allocation
- **Outcomes:**
  - Heightened **awareness and engagement** through workshops and training
  - Large expsoure data collection to **foster future research**
- **Specific tasks discussed here are:**
  - Critical review of existing hazard models
  - Collection and harmonisation of bridge exposure databases
  - Characterise direct physical vulnerability using existing research
  - Integration within a Web-Based Platform (WBP)

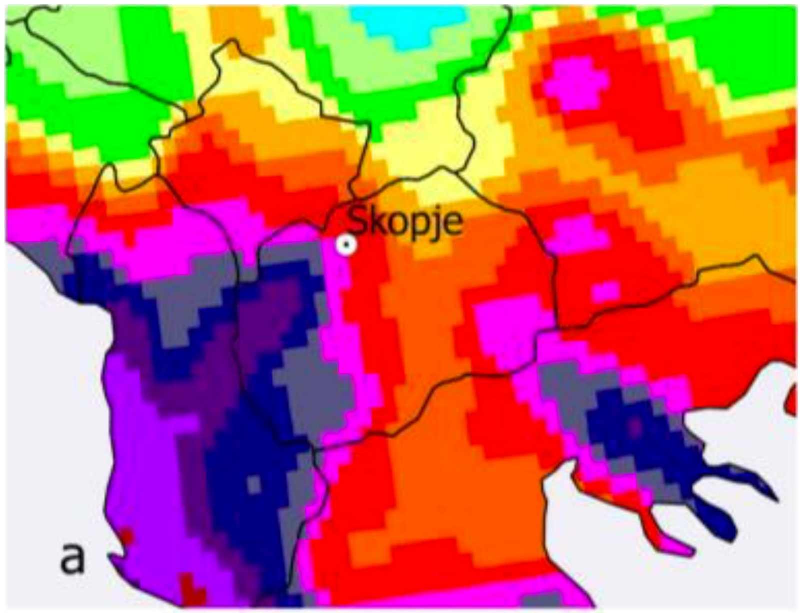
Characterising seismic hazard – North Macedonia

- The first seismic hazard maps specifically produced using PSHA were during the project “Harmonization of Seismic Hazard Maps for the Western Balkan Countries” in 2010 - BSHAP10
- This region is also covered by the SHARE model developed for Europe in 2013 - ESHM13
- A more refined model was recently developed specifically for North Macedonia by Milutinovic et al. (2016) on which basis EC8 National Annex was developed (МКС EN 1998-1/НА:2018) – MIL16



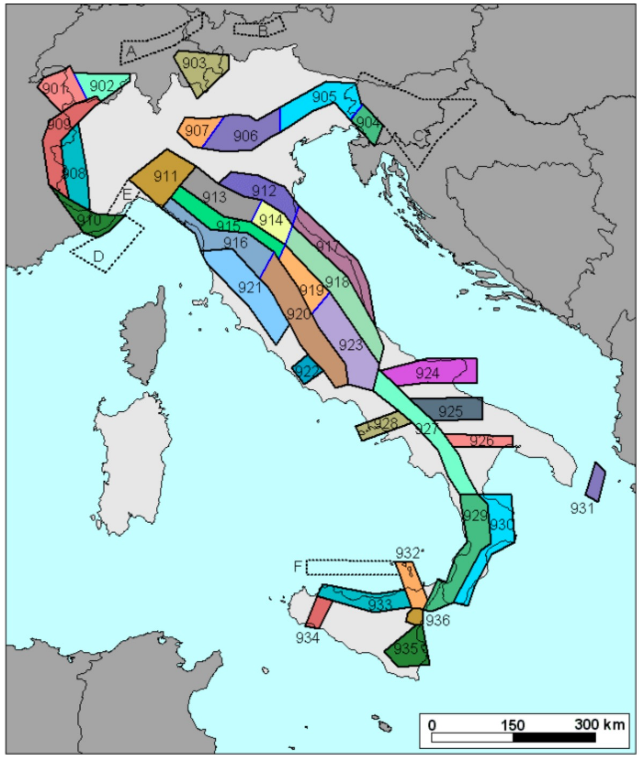
Simplified tectonic map used in BSHAP10

PGA for soil A for 475 years return period using SHARE model

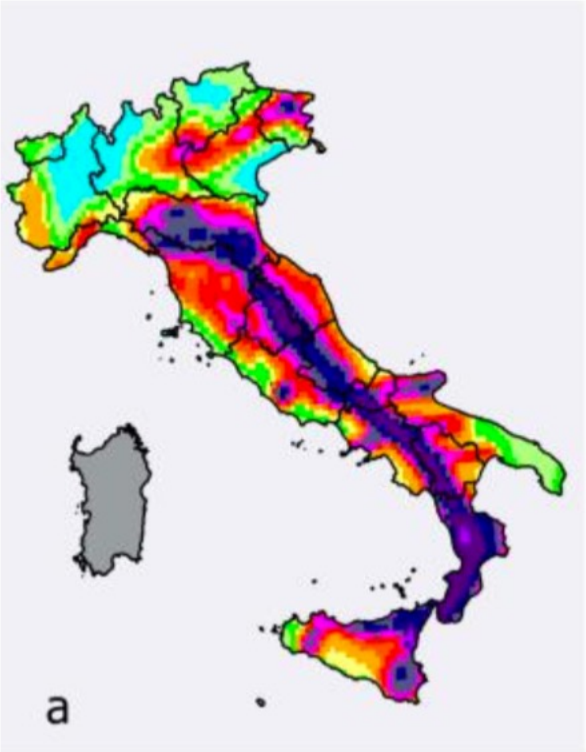


Characterising seismic hazard – Italy

- The “Mappa di Pericolosità Sismica 2004” model developed in 2004 by the Istituto Nazionale Geofisica e Vulcolonogia - MPS04
- The SHARE model developed for all of Europe in 2013 also covers the Italian territory - ESHM13



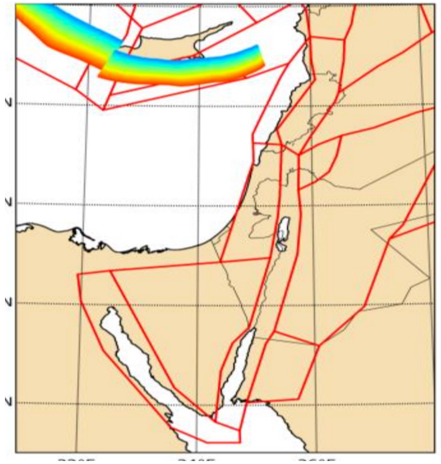
Area source model of MPS04



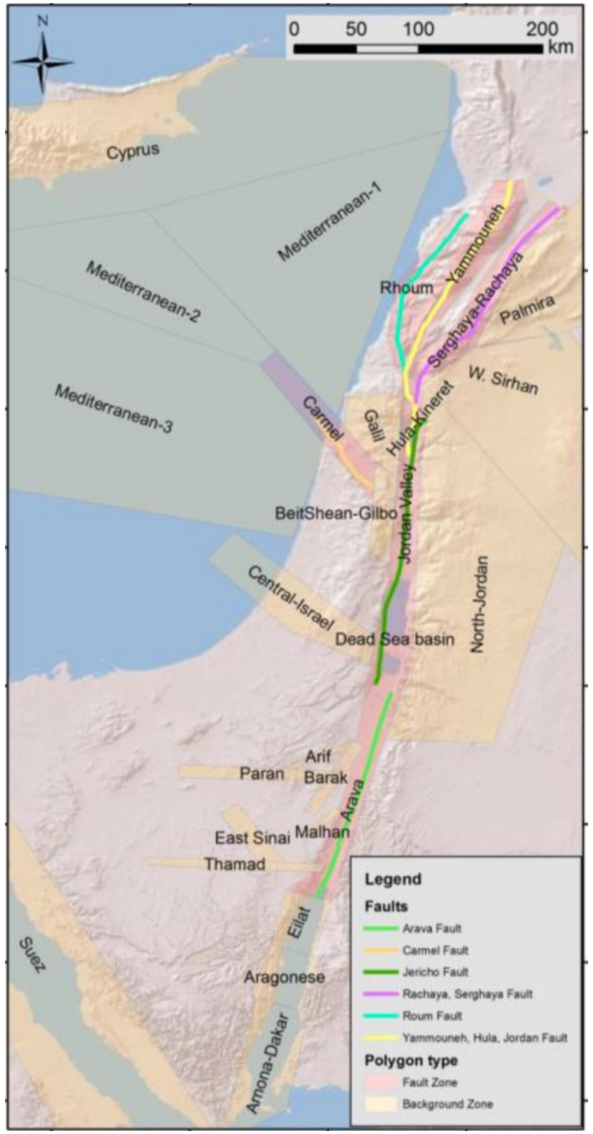
PGA for soil A for 475 years return period using SHARE model

Characterising seismic hazard - Israel

- The SI 413 hazard maps provide design spectra for the current Israeli building code – SI413
- The Middle East region model covers the Israeli territory also – EMME14
- Davis and Dor (2014) have proposed the alternative seismotectonic model because assumptions used to construct SI 413 model are obsolete – DD14
  - All seismic sources are represented as areal sources
  - Areal sources are typically used in the absence of (mapped) large faults, which is not the case of Israel



EMME14 area source models



Refined source model described in Davis and Dor (2014)

Characterising seismic hazard - summary

- In each region, a number of viable seismic hazard models are available
- Need to select one for each that fits the following criteria:
  - Follows a probabilistic approach
  - Allows for consideration of different soil types – $V_{s,30}$
  - Allows for consideration of spectral values at different periods – Sa(T)
  - Provides hazard disaggregation to facilitate ground motion selection – M, R, ε
- Based on these, one model was selected for each region

North Macedonia:

1. BSHAP10
2. ESHM13
3. MIL16

Italy:

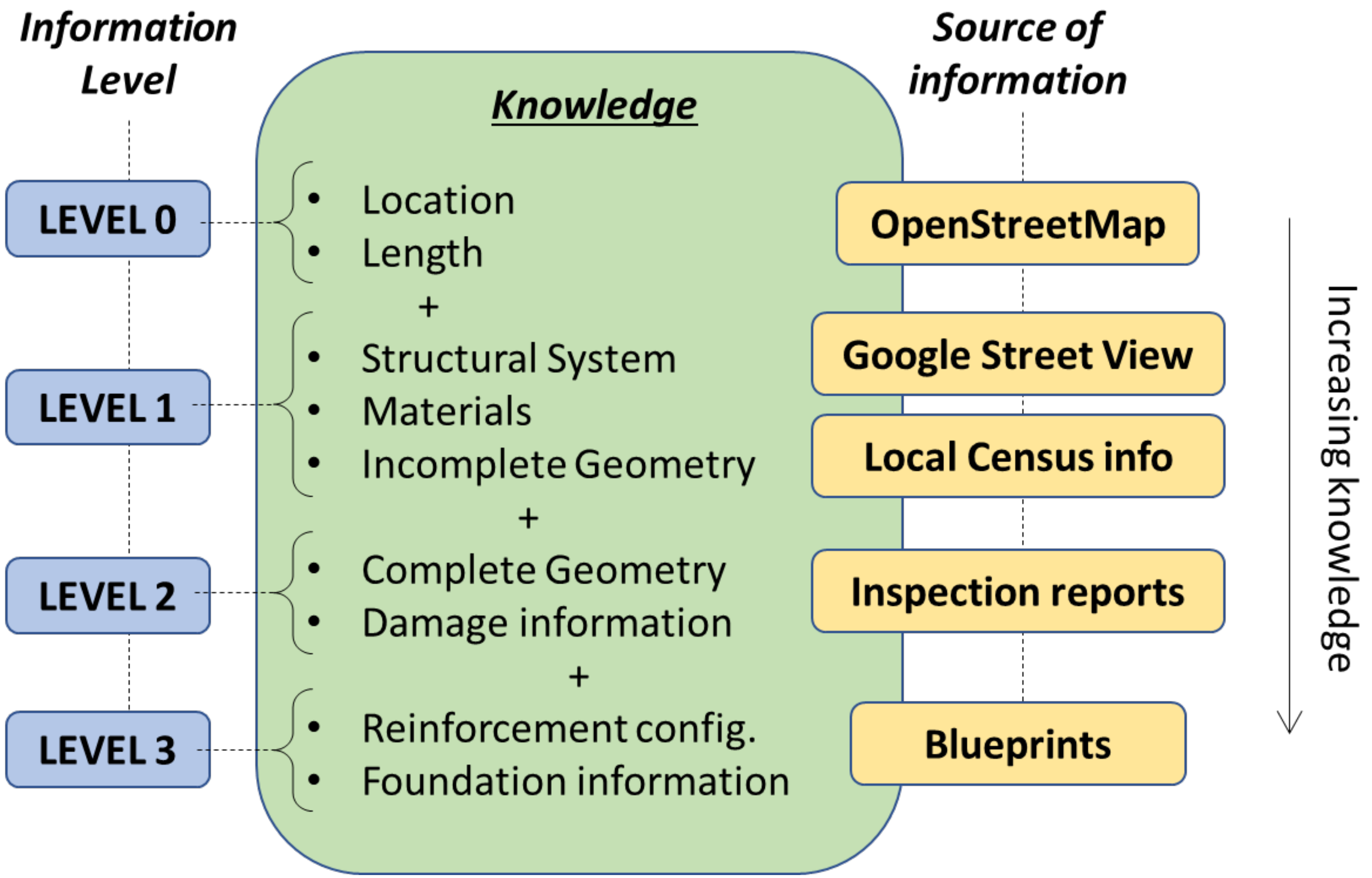
1. MPS04
2. ESHM13

Israel:

1. SI413
2. EMME14
3. DD14

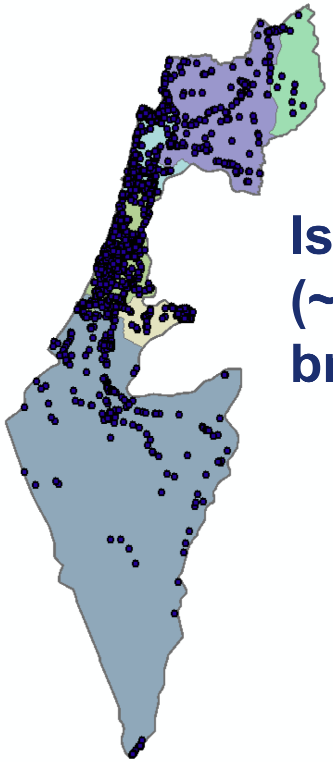
Exposure data collection - methodology

- A number of approaches were set forth to collect data
- OpenStreetMaps was used to identify the location and length (Level 0) of bridges
- This Level 0 was used to provide a broader pricture of where hazard should focus based on seismicity and soild class



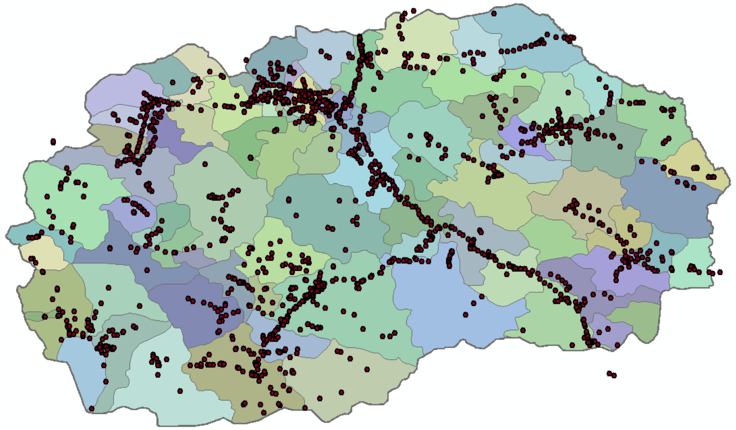
Exposure data collection – location of bridges

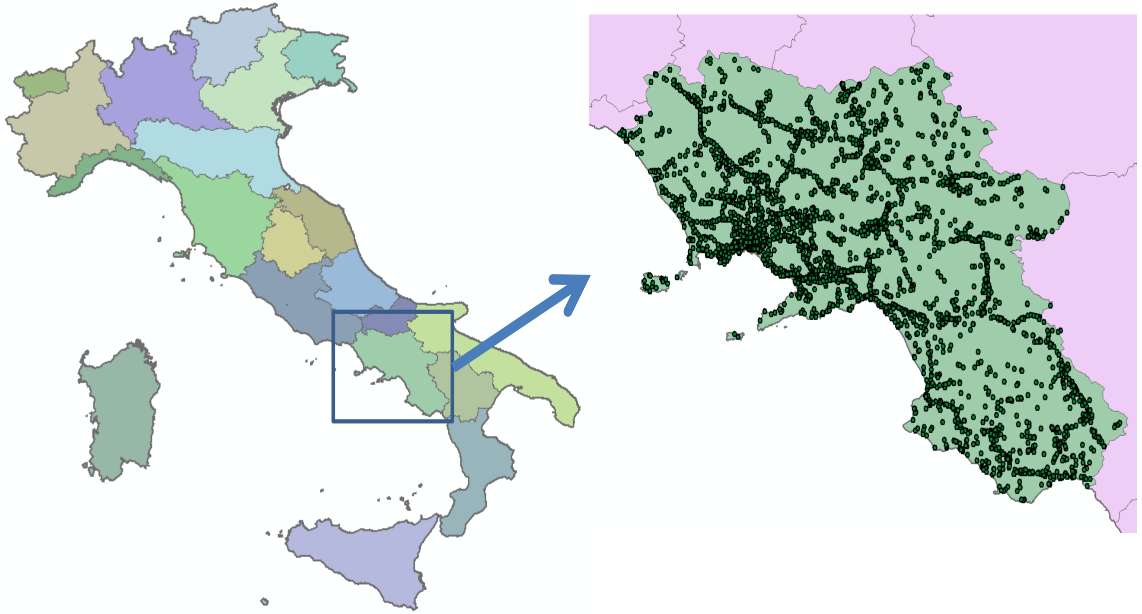
- Using this level 0 information available from OpenStreetMaps, the locations of bridges in each country was identified
- For Italy, the case study was limited to Campania to keep the sizes comparable



Israel (~2,000 bridges)

North Macedonia (~2,000 bridges)

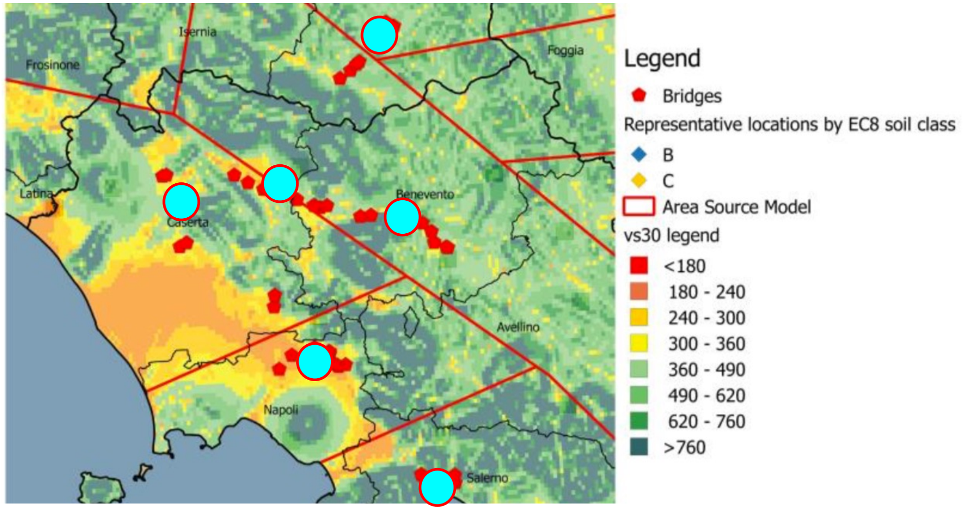


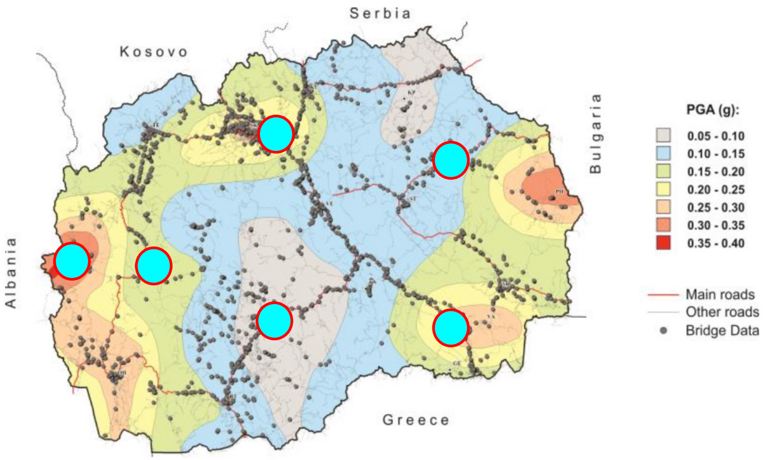


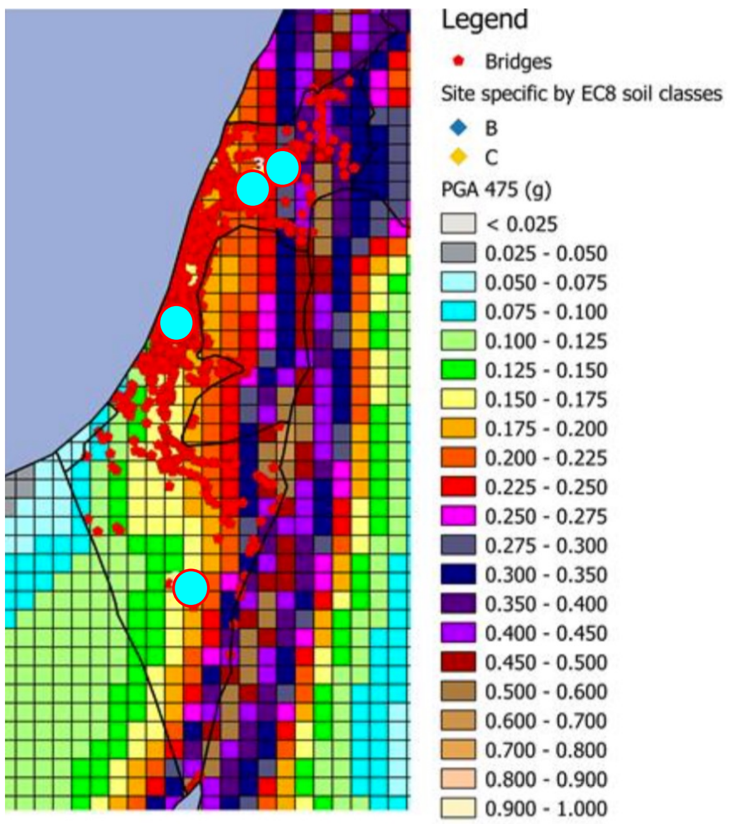
Italy – Campania region (~4,600 bridges)

Expsoure data collection – use in seismic hazard

- This information was used to characterise the seismic hazard in a number of specific sites

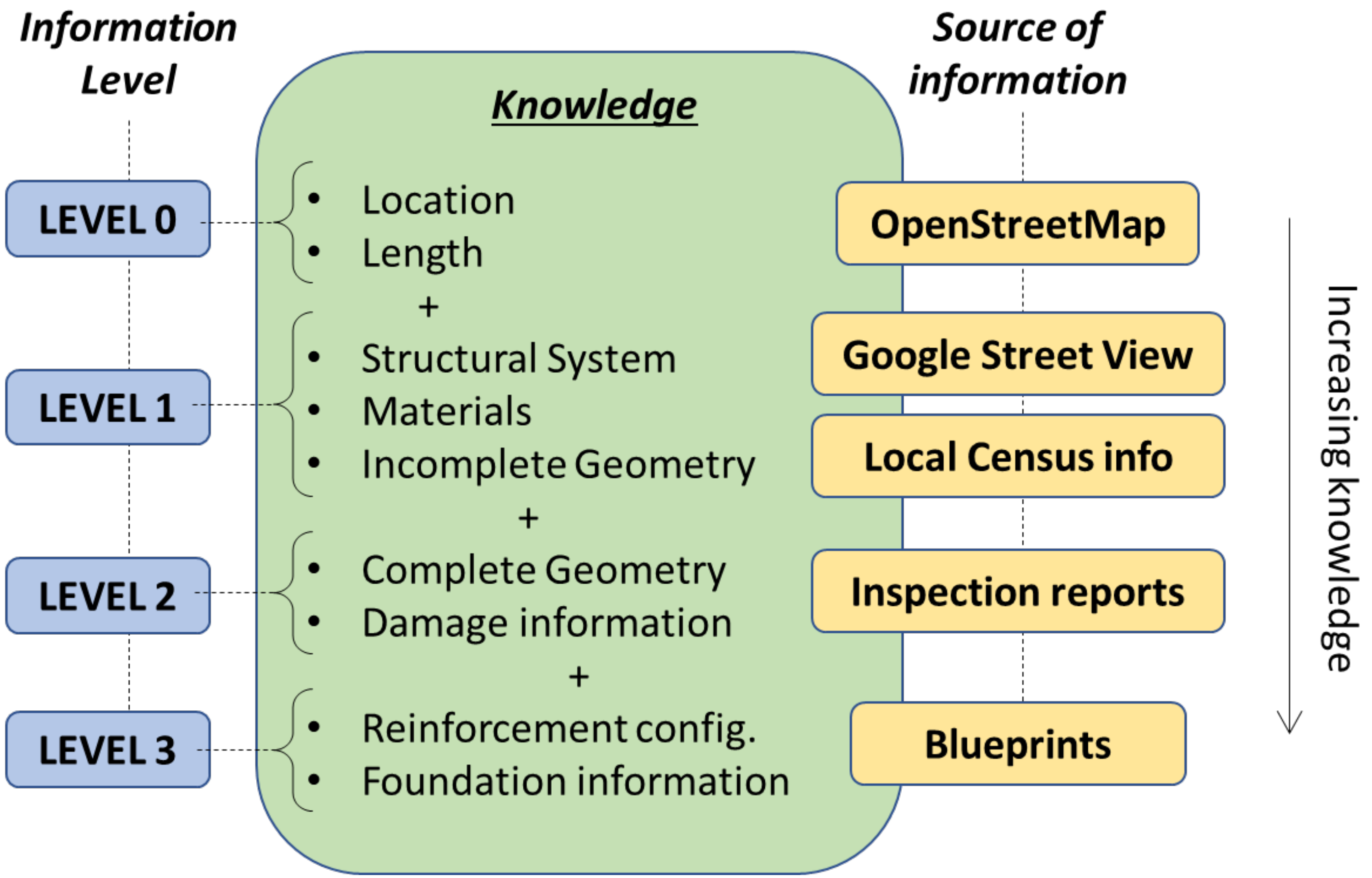






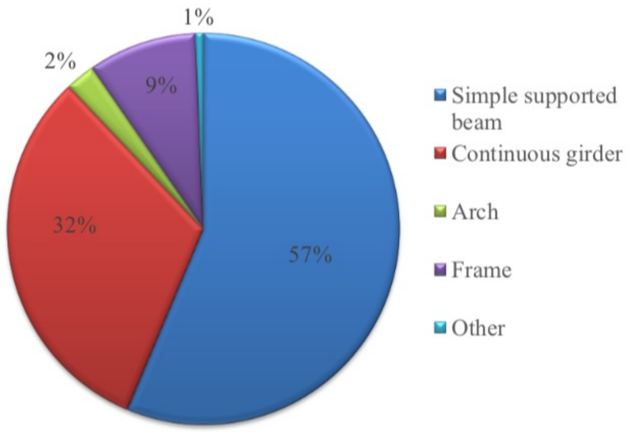
Exposure data collection - methodology

- Following on from the Level 0, more detailed information was collected
- This utilised Google Street Maps or full in-situ inspections
- These were conducted using a data collection specifically developed for bridge structures

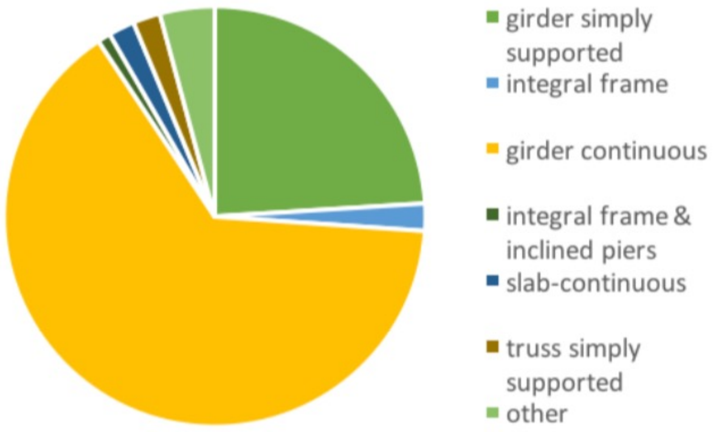


Exposure data collection - summary

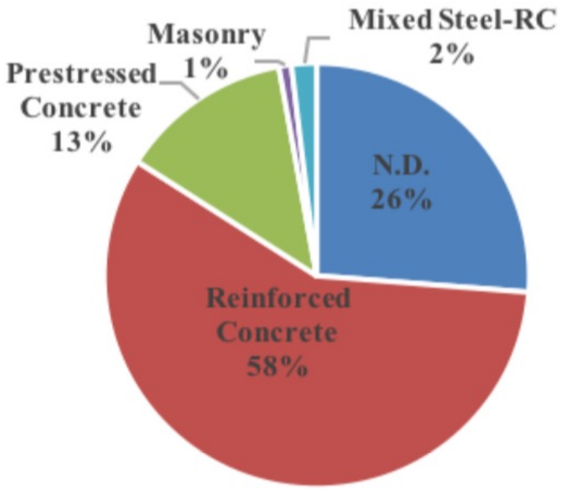
- With the various levels of information for the bridge structures, a database was constructed
- This way vulnerability functions made available on the platform could be tailored



Bridge typologies in North Macedonia



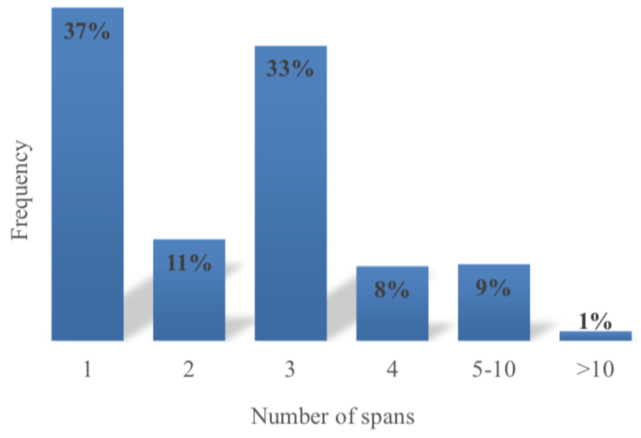
Bridge typologies in Israel



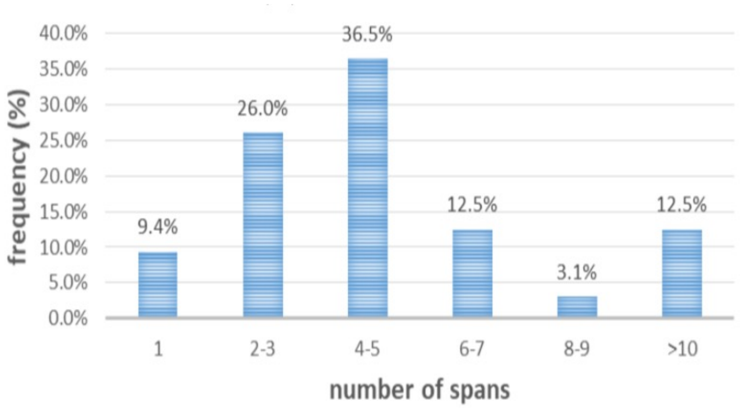
Bridge typologies in Campania, Italy

Exposure data collection - summary

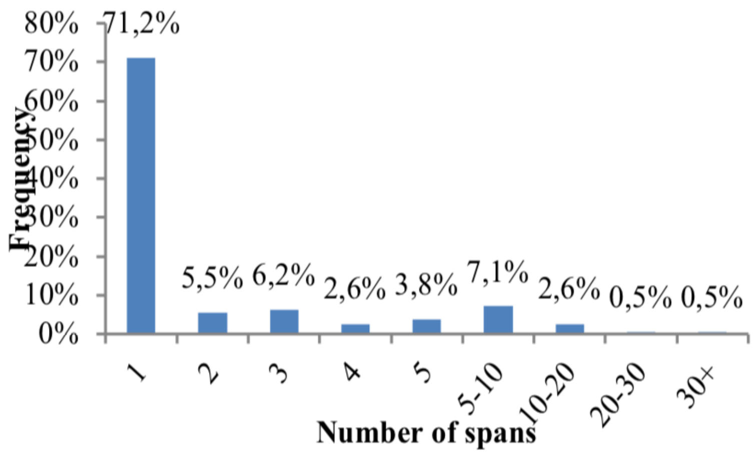
- Statistical information indicated the bridge typologies that needed to be focused on in each region
- This meant that a taxonomy definition could be developed for all the bridges in the case study regions



Spans for bridges in North Macedonia

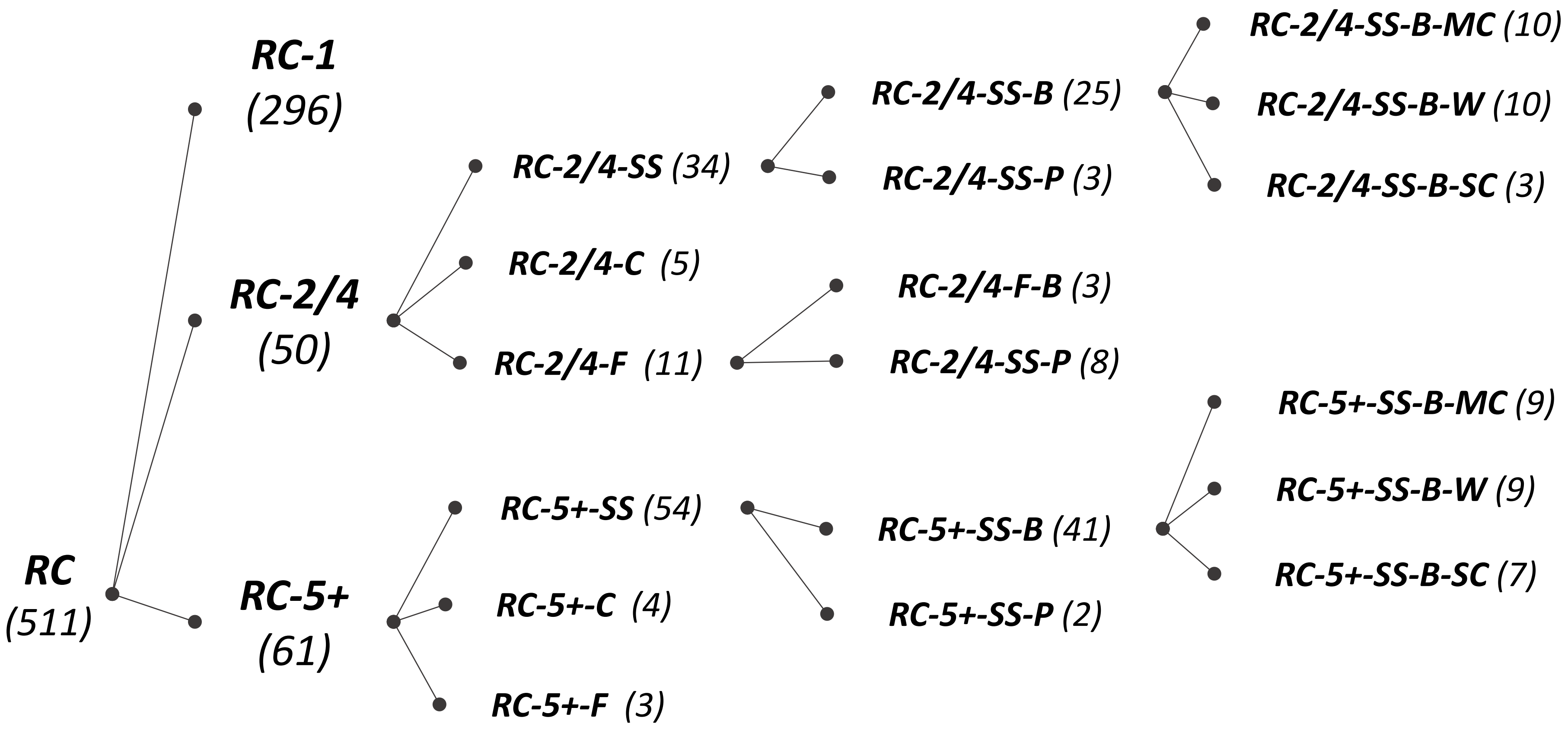


Spans for bridges in Israel



Spans for bridges in Campania, Italy

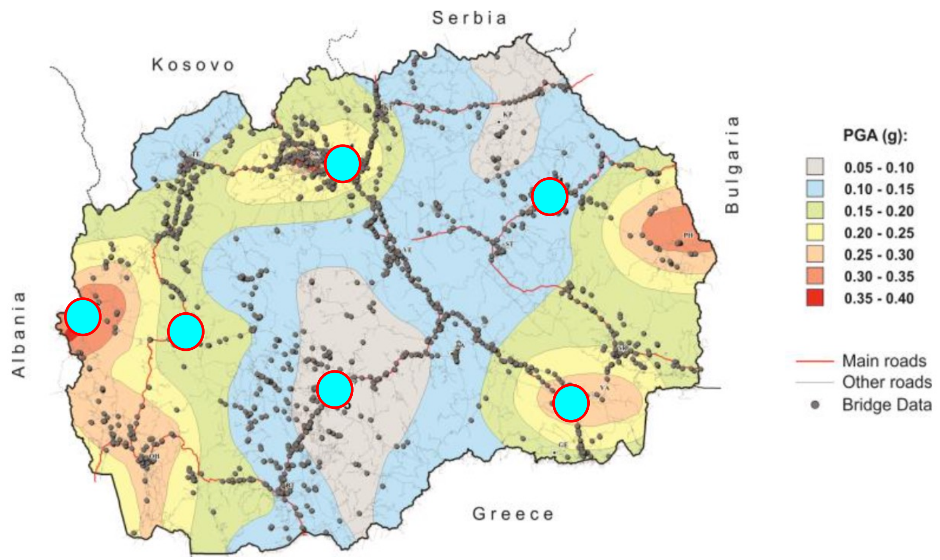
Exposure data collection – taxonomy definition

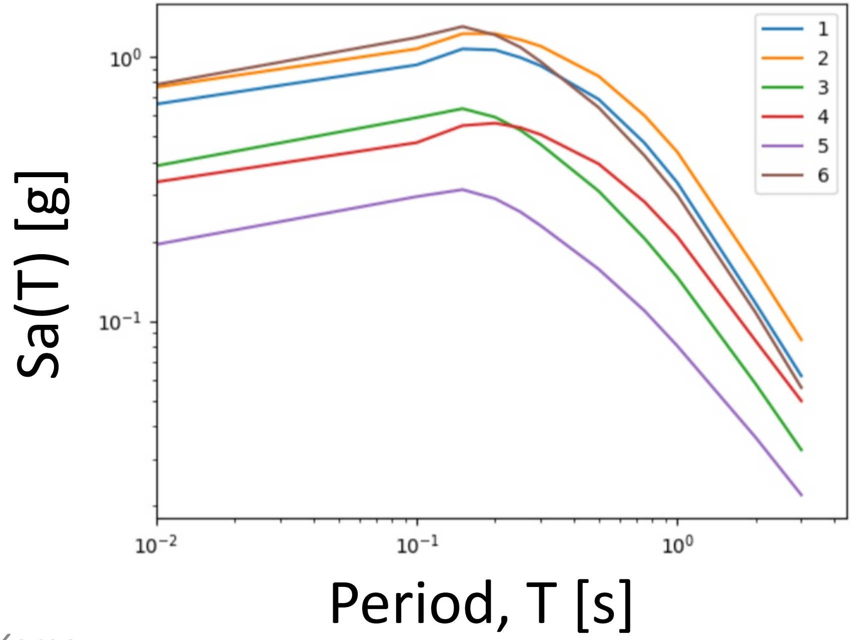


MAT	*Spans*	*Static Scheme*	*Deck Type*	*Pier Type*
RC	*1*	*S. S.*	*Beam*	*S. Column*
	2-4	*Cont.*	*Plate*	*Wall*
	5+	*Frame*		*M. Column*

Vulnerability – characterising seismic hazard

- With the bridge taxonomies and seismic hazard identified, the vulnerability can be characterised
- How to use seismic hazard – ground motions!
- For each site, ground motion selection was performed for return periods from 98 up to 9975 years
- The intensity measure used was average spectral acceleration (AvgSa)

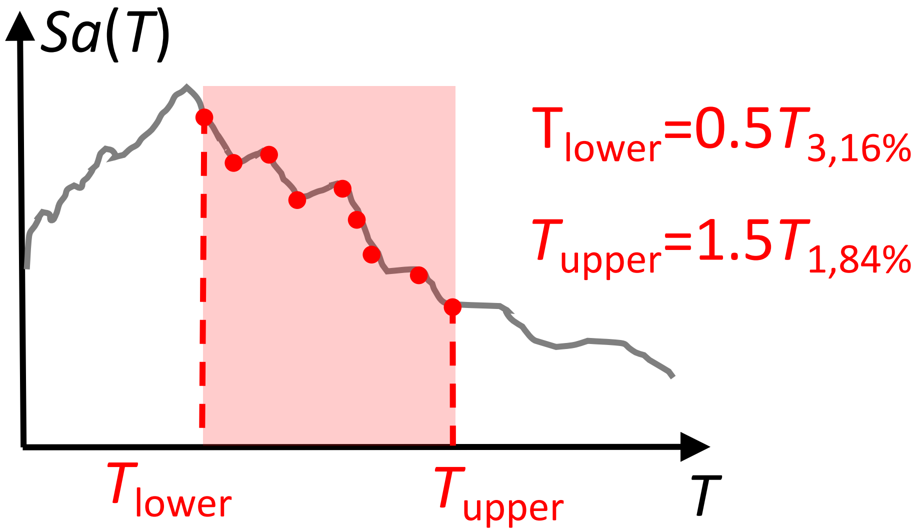


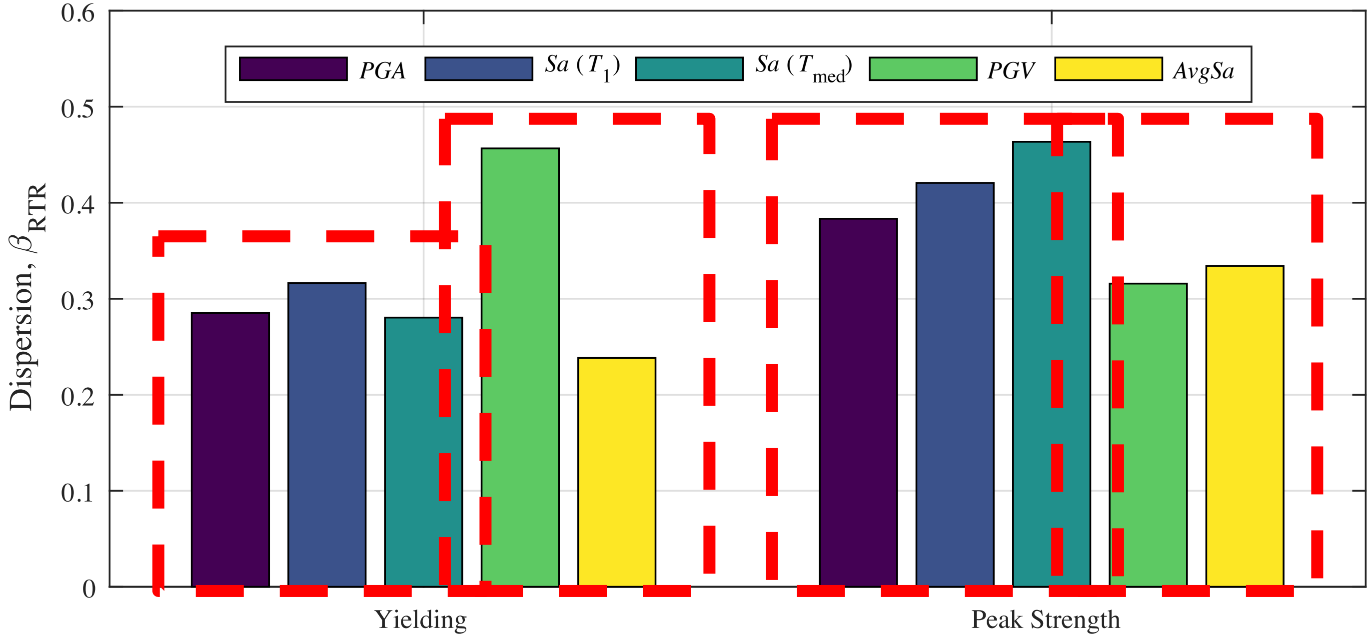


Uniform hazard spectrum for 975 years in North Macedonia

Vulnerability – characterising seismic hazard

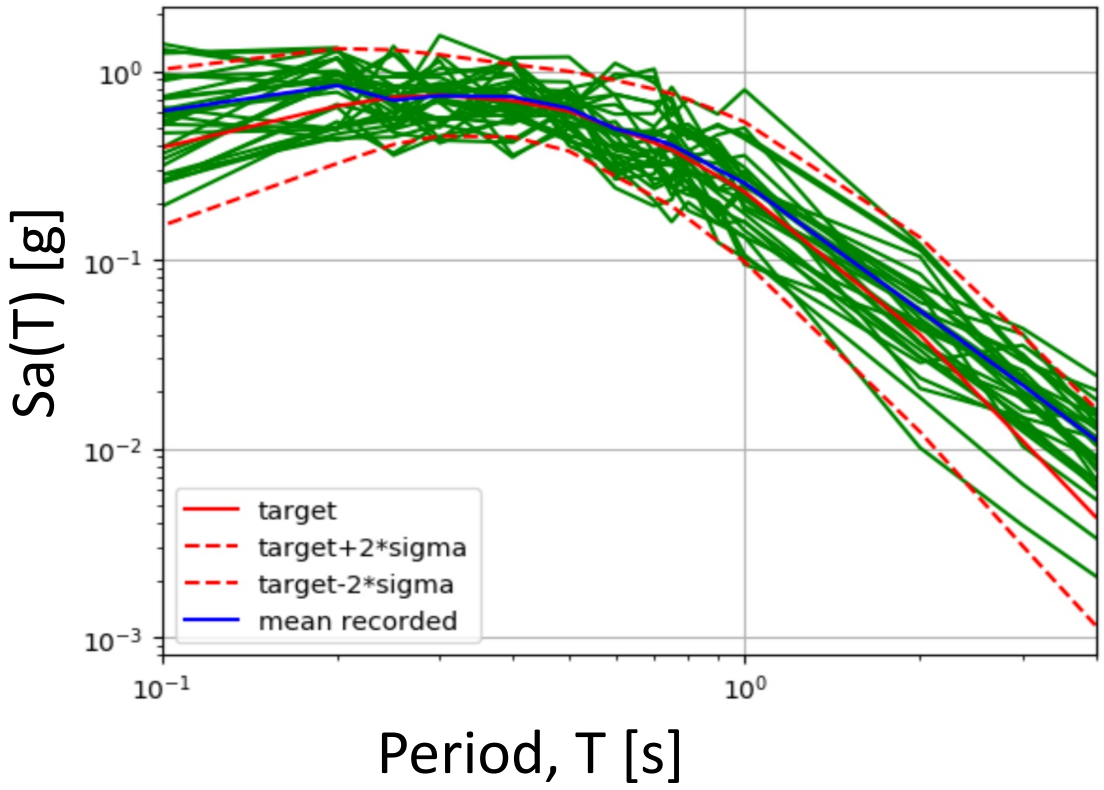
- AvgSa conditions the record selection over a period range of interest instead of a fixed period value
- Results from a recent study by O'Reilly & Monteiro (2019) have shown that for bridges:
  - *PGA*, $Sa(T_1)$ and $Sa(T_{med})$ are fair predictors at both limit states
  - *PGV* and *AvgSa* were the best ones overall





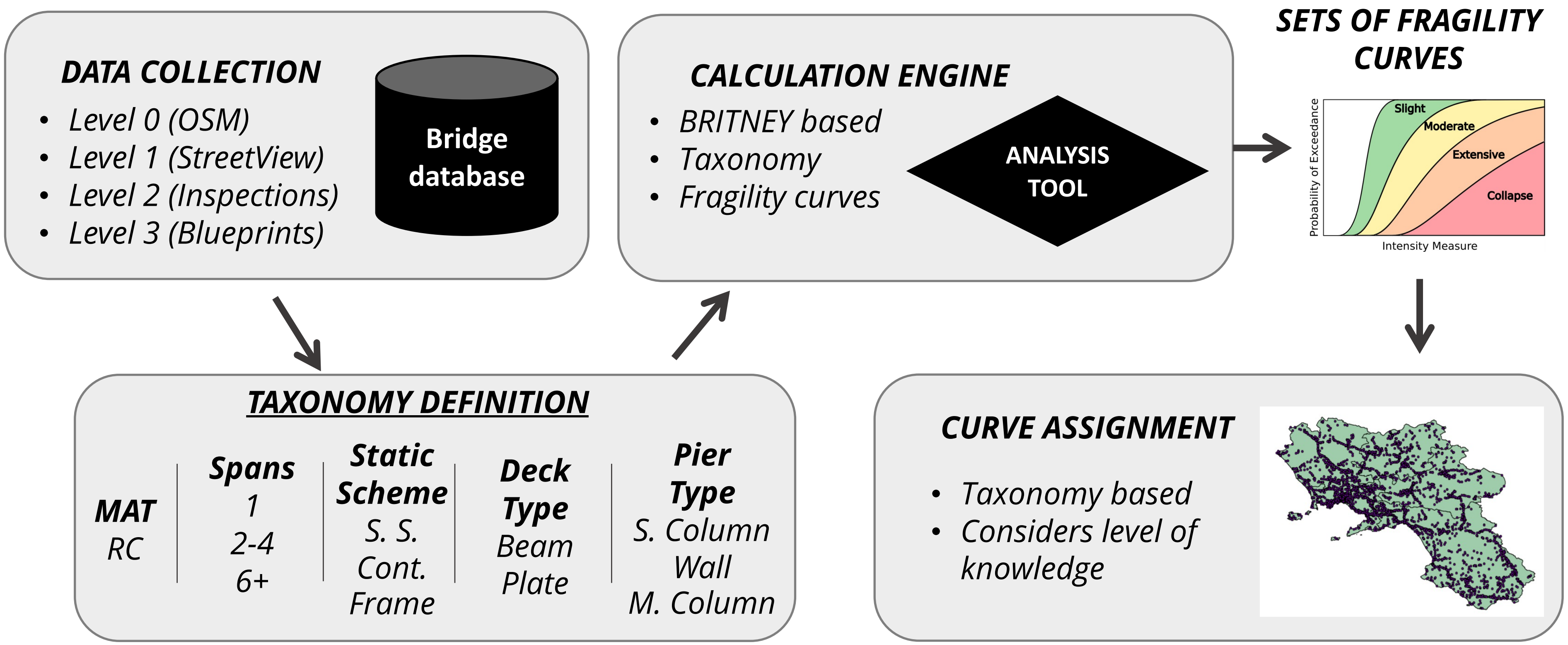
Vulnerability – characterising seismic hazard

- This has the advantage of:
  - not being structure-specific
  - not being mode-specific
  - being a more accurate quantifier of structural response
- 30 ground motion records were selected for each country, site and return period – available at www.infra-nat.eu
- Period ranges were defined using available data from bridges surveyed



Vulnerability - methodology

- For a given bridge taxonomy, its fragility curves can be derived numerically for each of the sites with the ground motions
- Depending on where it falls in the taxonomy definition map, the whole network can be assigned a set of suitable fragility functions



Risk assessment – scenario-based illustration

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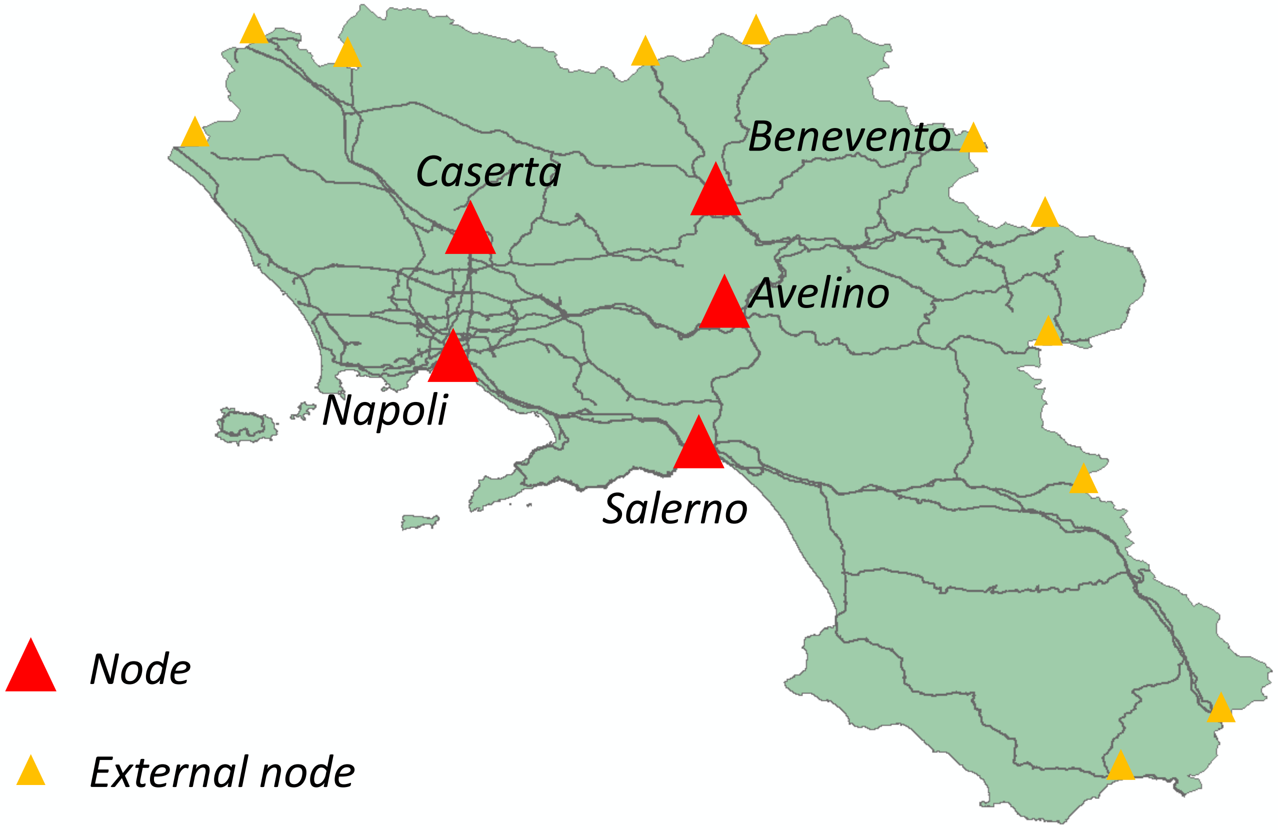
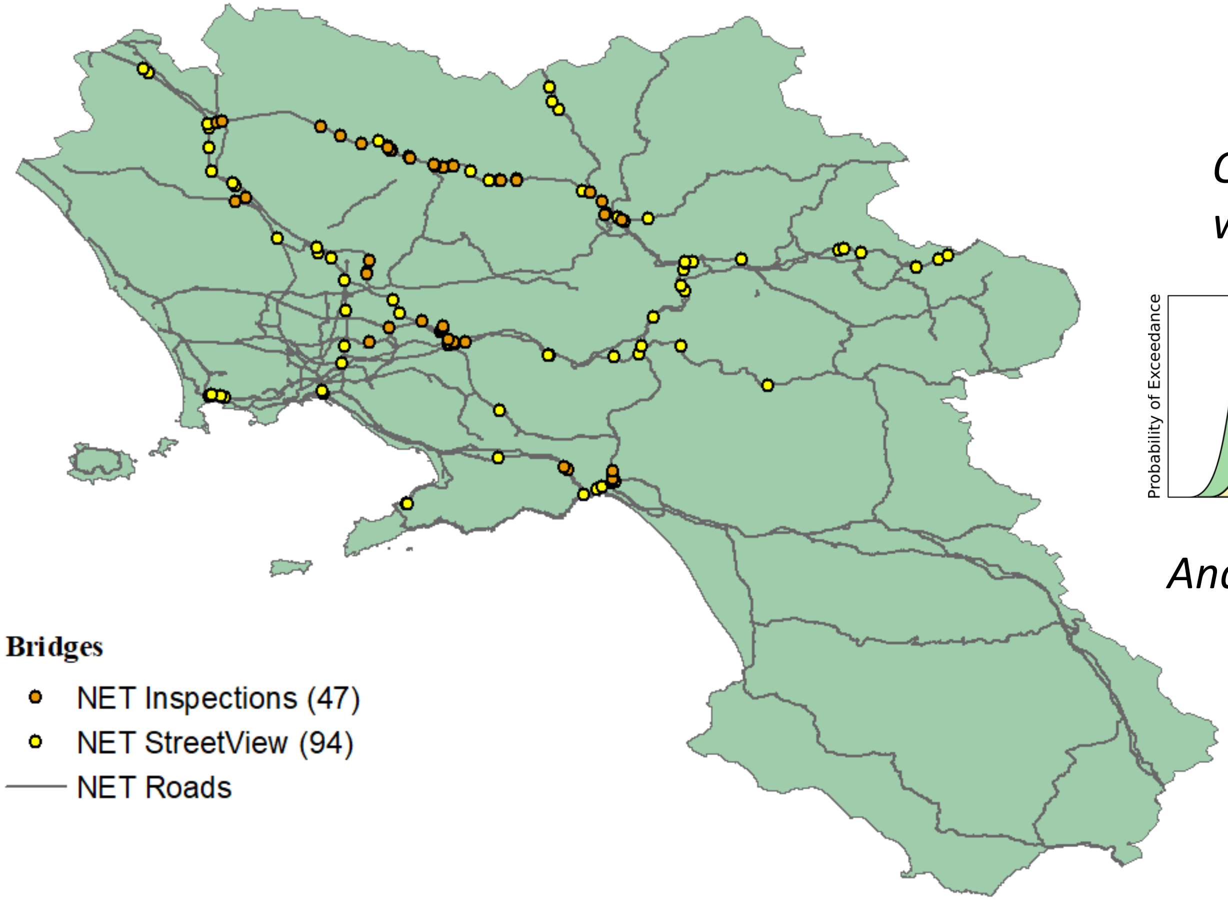
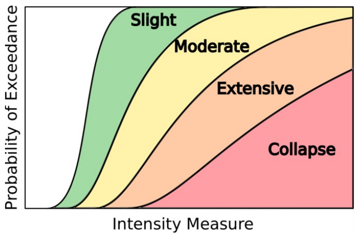


Risk assessment – scenario-based illustration

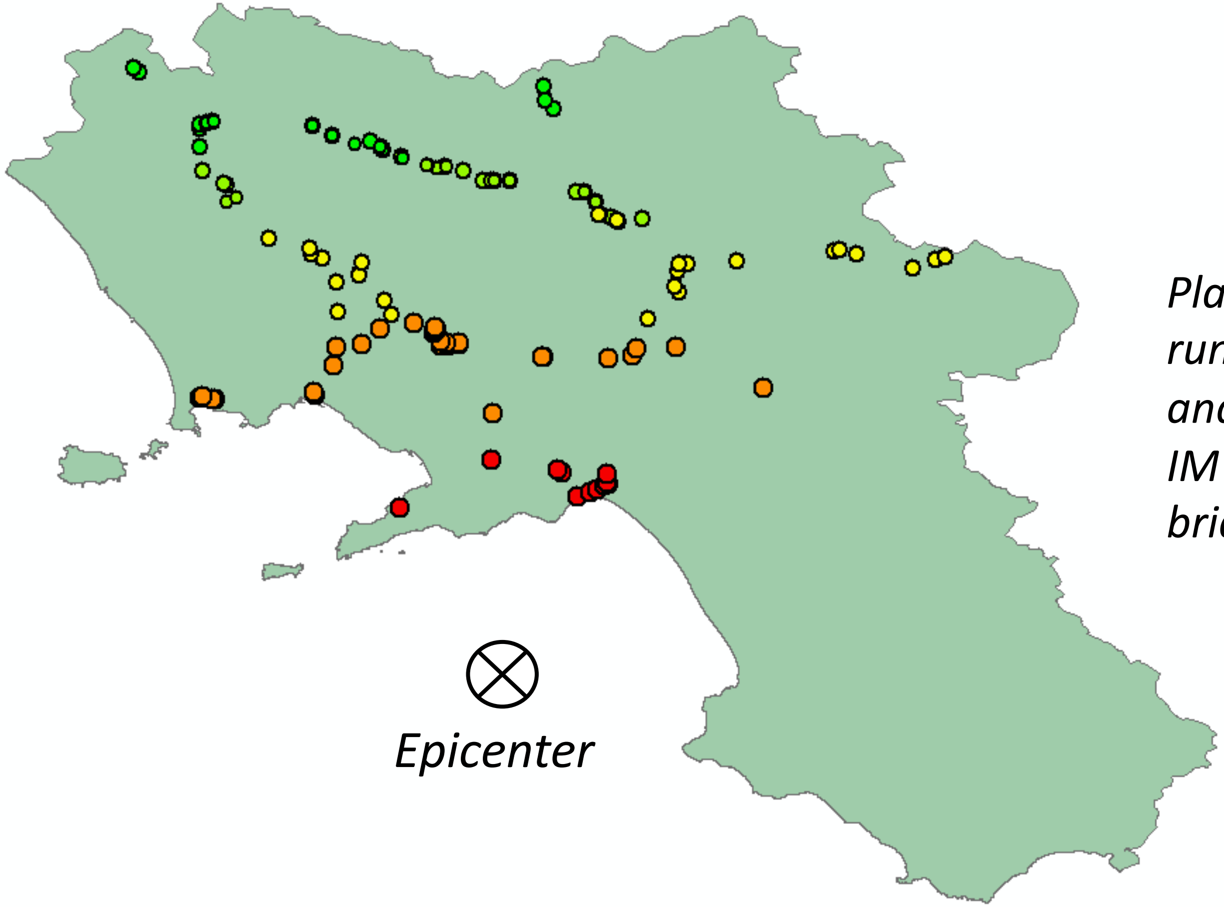


Only bridges with piers



And information

Risk assessment – scenario-based illustration



Platform will run scenario and calculate IM at each bridge location

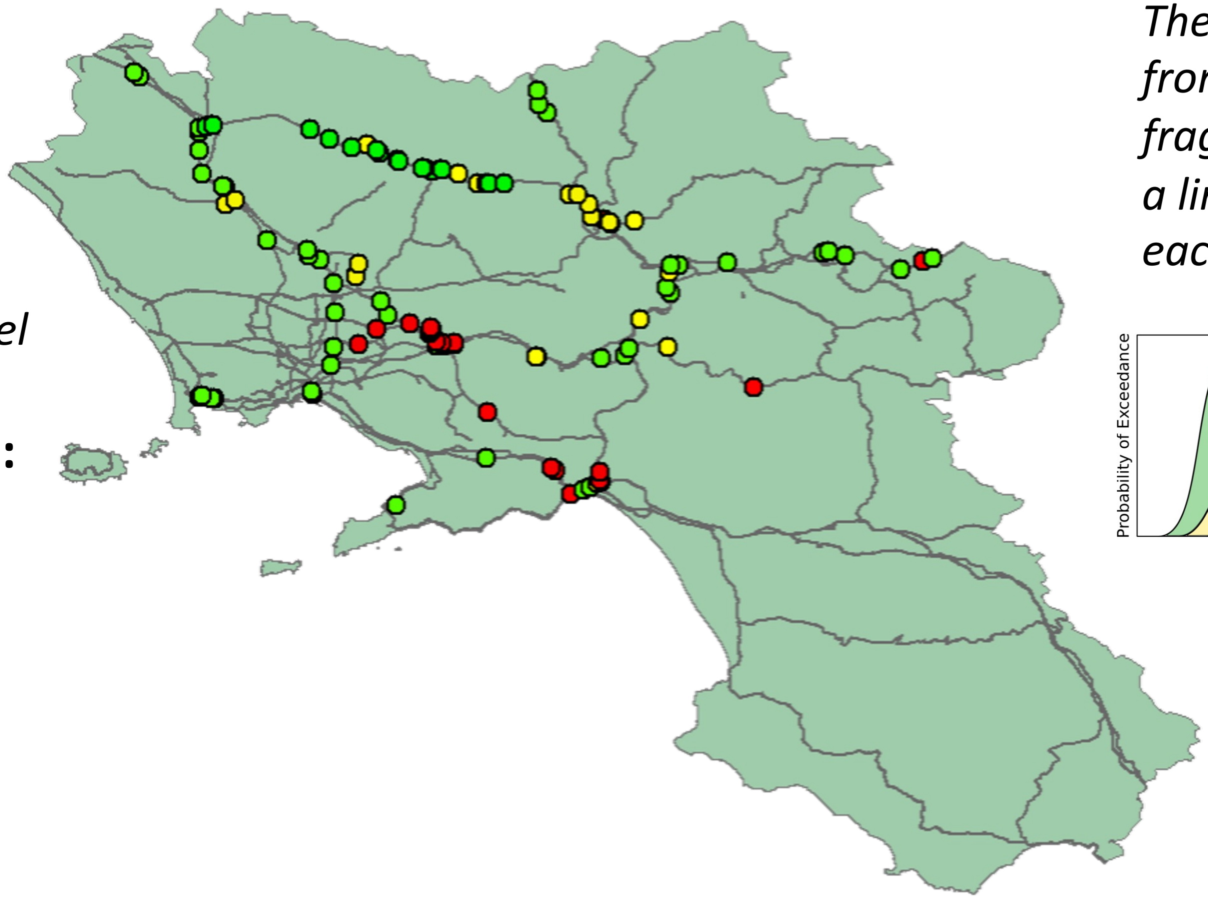
Risk assessment – prioritisation

Network Analysis:

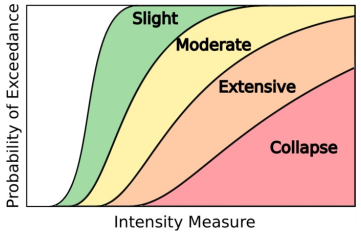
- *Modify road capacityCheck indicators (average/total travel time)*

Simple connectivity/distance:

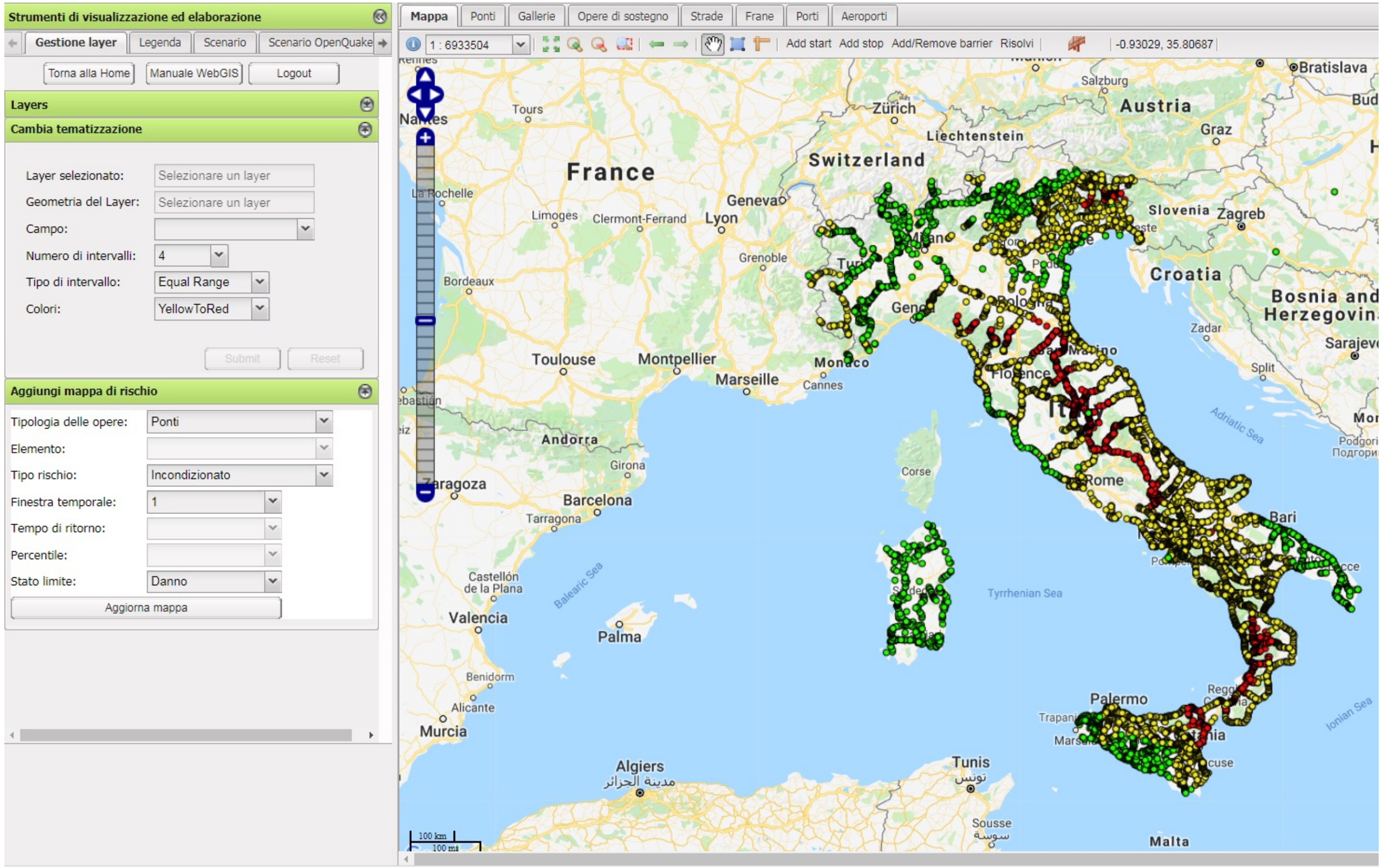
- *Re-route analysis*
- *Alternate paths*
- *Changes in travel length*
- *Connectivity changes*



Then sample from each fragility curve a limit state for each bridge



Integration in Web-Based Platform (WBP)



=Low risk

=Medium risk

=High risk

=Non-calculc. risk

To conclude

- Overview of the INFRA-NAT project
- Aims to increase regional safety of bridge infrastructure by providing simple and accessible tools to decision makers
- Some of the issues discussed here were:
  - Hazard models
  - Collection of bridge exposure databases
  - Characterisation of physical vulnerability
  - Integration within a Web-Based Platform (WBP)
- It is hoped that this research effort will lead to:
  - Heightened awareness and engagement through workshops and training
  - Large expsoure data collection to foster future research

Visit the project website:
www.infra-nat.eu

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