International Workshop on Advances in Assessment and Modelling of Earthquake Loss, Istanbul, 4th – 5th November 2019

Elements at Risk, Fragilities, Consequence Functions and Vulnerabilities

State of the practice, challenges and future directions

Helen Crowley (Seismic Risk Consultant/EUCENTRE, Pavia, Italy)

Elements at Risk – State of Practice

- Exposure models are developed to describe the spatial distribution of elements at risk (buildings, transportation networks, critical infrastructure) and their key attributes (seismic performance characteristics, monetary value, occupants, count..).

Elements at Risk – State of Practice

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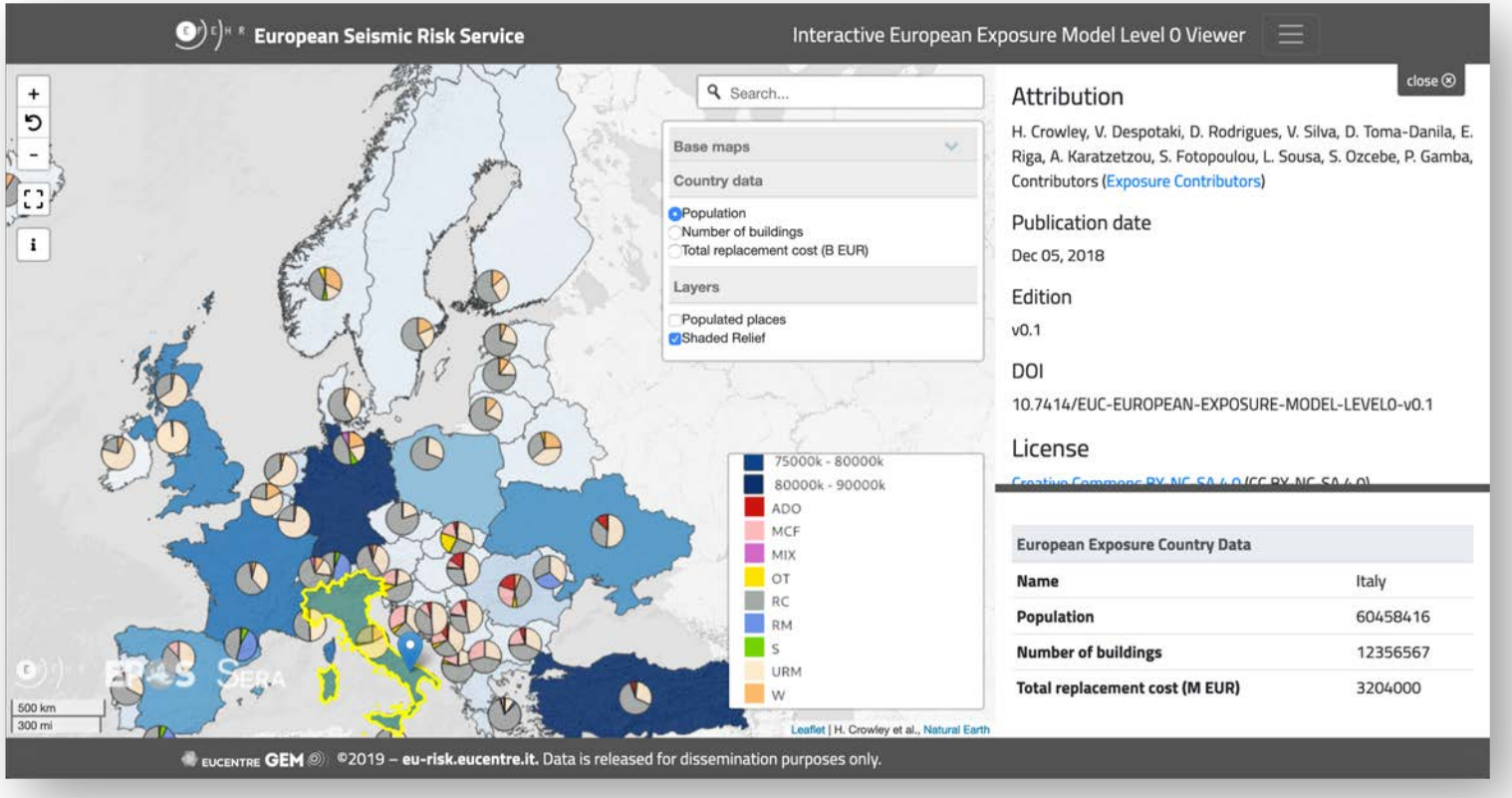
- Such exposure models can be used in the insurance/reinsurance industry for the assessment of ground up losses, or to identify the most likely building classes within a given portfolio of assets (when such information is lacking).

Elements at Risk – State of Practice

SERA
Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe

- A European model describing the spatial distribution building count, residential population, and total replacement cost for residential, commercial, and light industrial buildings is being developed for 46 European countries in the Horizon 2020 SERA project.



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Elements at Risk – State of Practice

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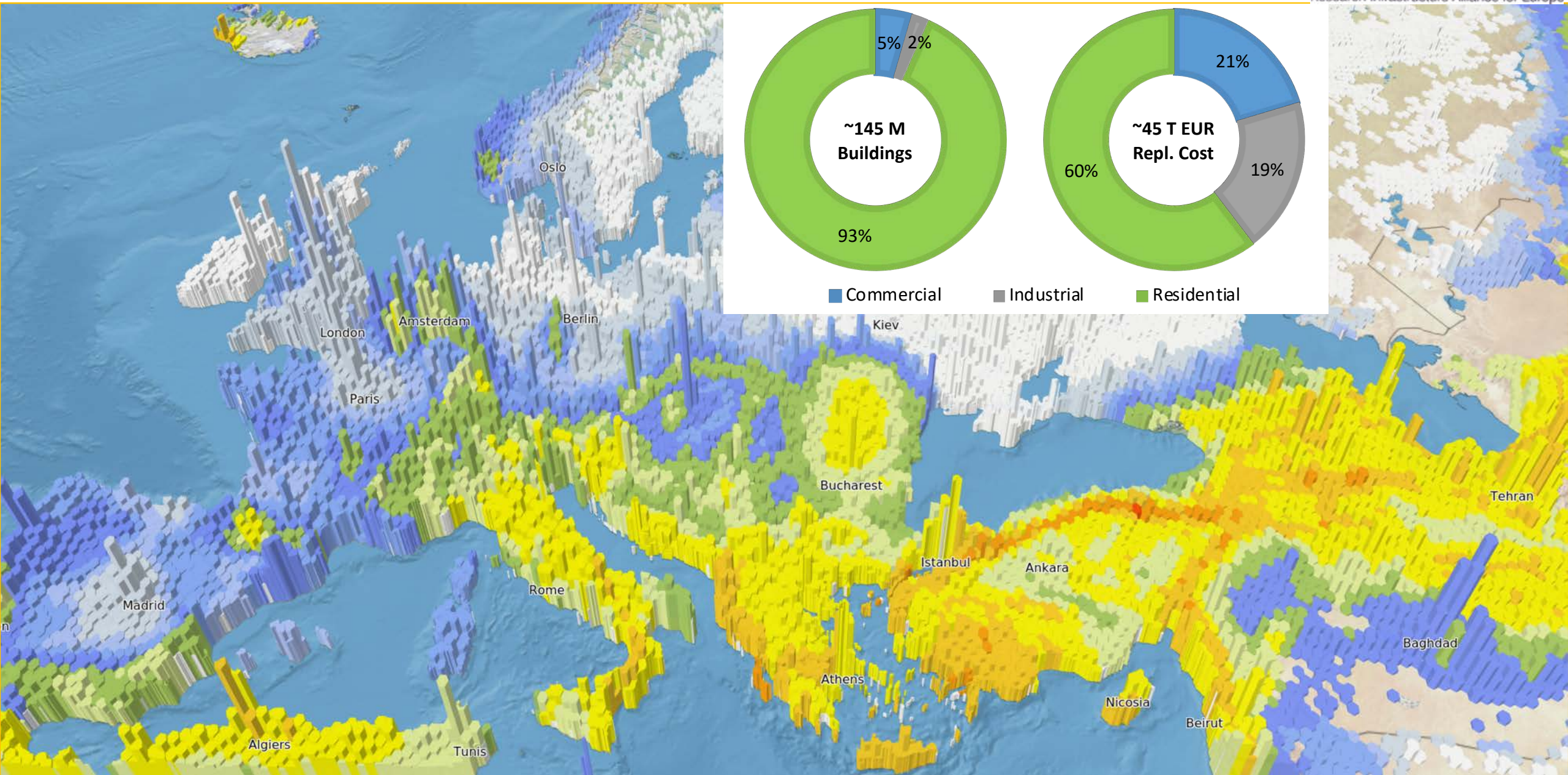

Elements at Risk – State of Practice

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eurostat

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  - academic publications (typical building classes, building surveys)
  - …judgment/feedback from local experts
    - Average replacement cost per m^2
    - Average area per dwelling
    - Number of dwellings per floor
    - Distribution of building classes (given e.g. year of construction, multi/single family dwelling, external material, number of floors)

eurostat

Elements at Risk - Challenges

- Access to proprietary data (even from a national census)
- Large amount of judgment
- Lack of reproducibility
- Uncertainties often not explicitly documented or modelled
- Static models that are not frequently (or easily) updated

Elements at Risk – Future Directions

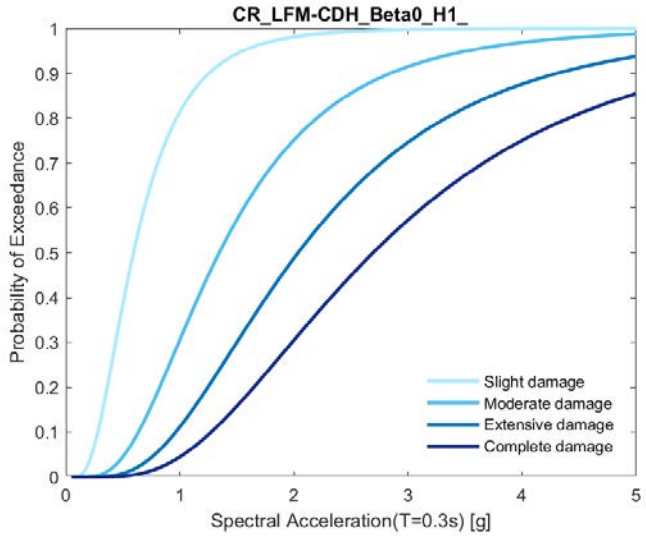
- Dynamic exposure modelling
  - Integrate big data: OpenStreetMap, satellite imagery, low-cost sensors
  - Include Structural Health Monitoring (SHM) data for real-time updating (period elongation, structural response)
  - Need to develop software, webservices and tools to automatically extract data, integrate and update the exposure model.

OSM Buildings

Feature	Value
Volume	245
N° Floors	3
Occupancy	Commercial
Type	Masonry
N° Windows	16
Basement	No
Fence	No
...	...

Fragility Models – State of Practice

- Probability of reaching or exceeding a set of damage states, given a level of ground shaking intensity (for a specific building or class of buildings).



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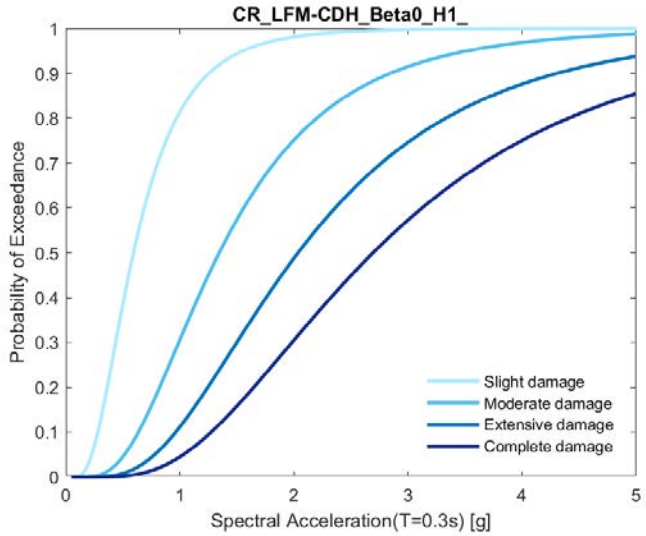
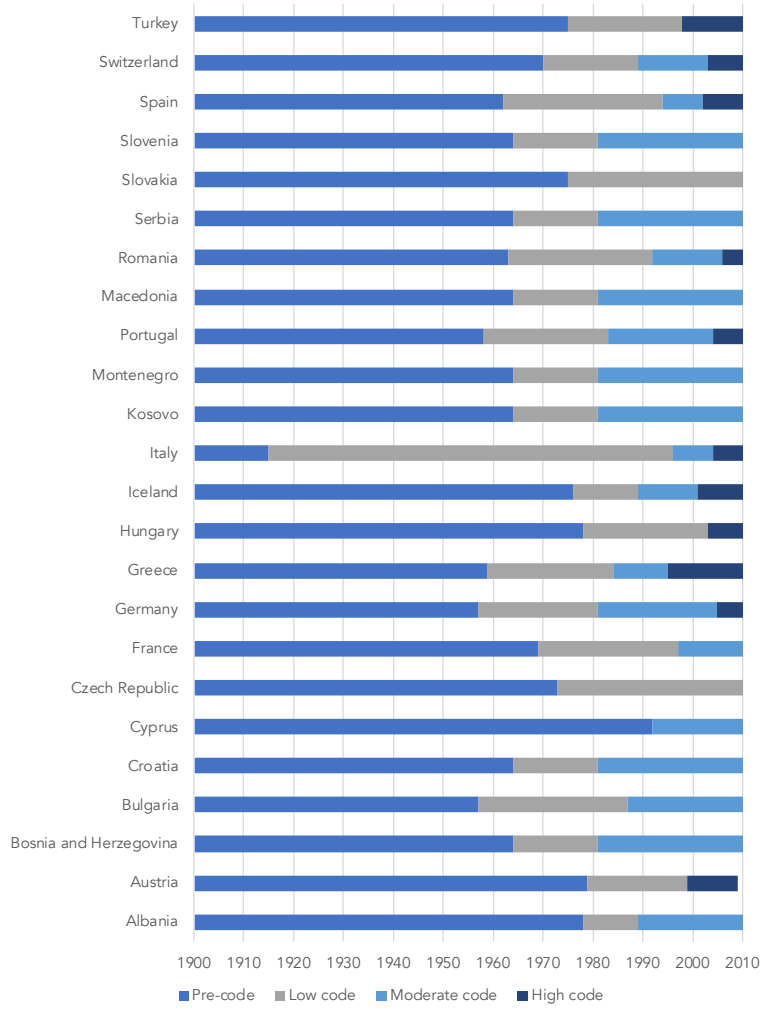


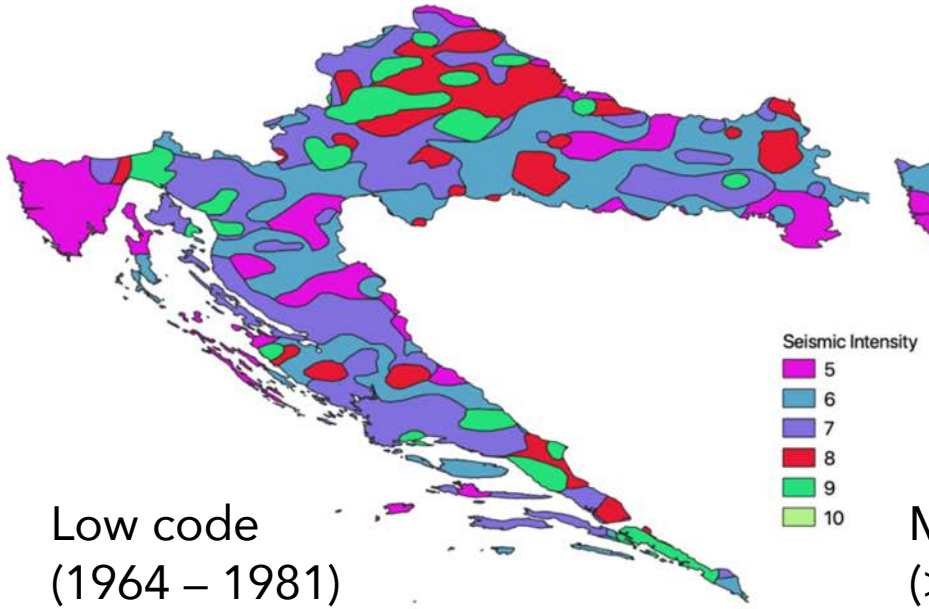
- Analytical models of buildings (or other elements at risk)
  - Account for specific characteristics (geometrical/material properties, design level, adherence to code..)
  - Hazard consistent/appropriate ground motions
  - Nonlinear dynamic analysis

Fragility Models – State of Practice

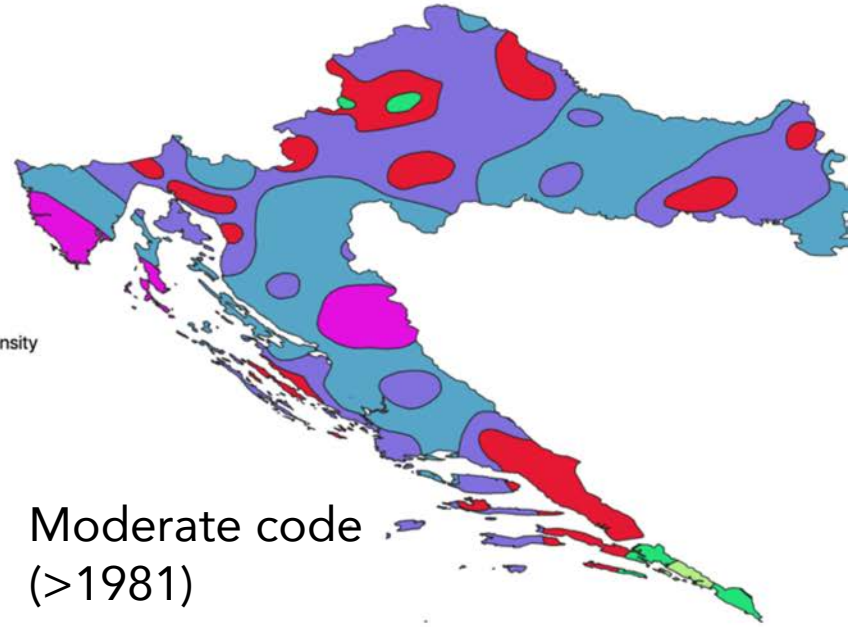
SERA
Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe

- Evolution of seismic design across Europe, digitization of zonation maps, calculation of lateral load coefficients

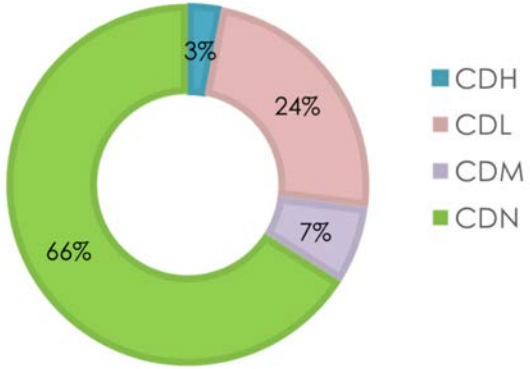




Low code
(1964 – 1981)



Moderate code
(>1981)



Design levels
4 design classes: CDN, CDL, CDM and CDH
7 **β**-values: 0%, 5%, 10%, 15%, 20%, 25%, 30%

Fragility Models – State of Practice

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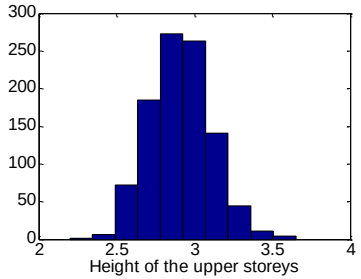
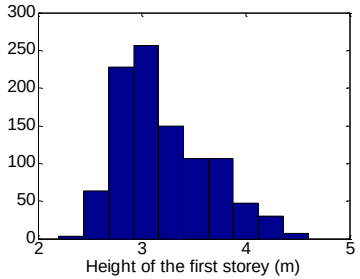
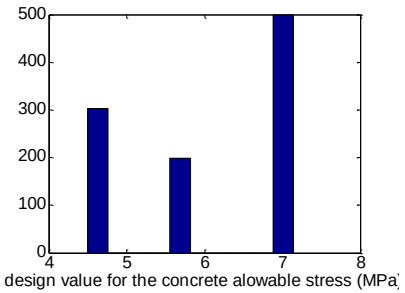
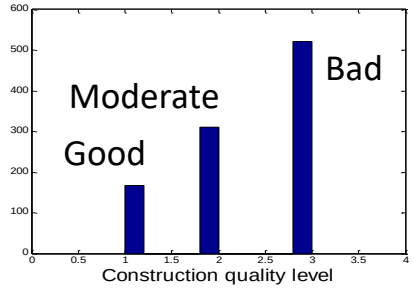
Building-to-building variability (material, geometry, ..)

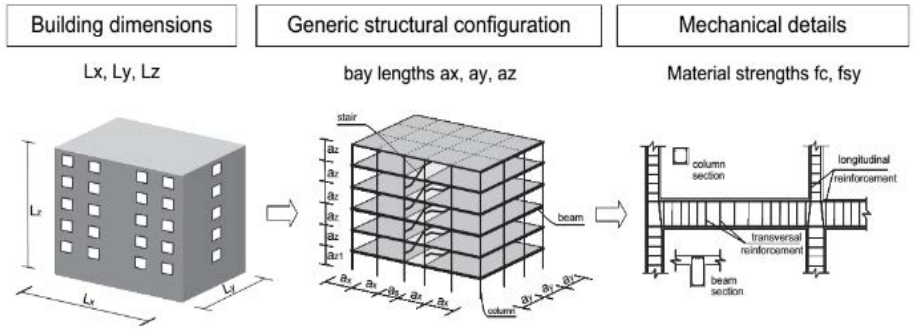






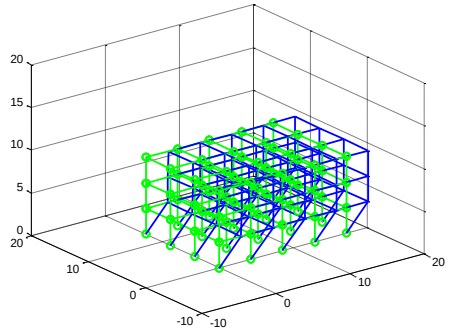


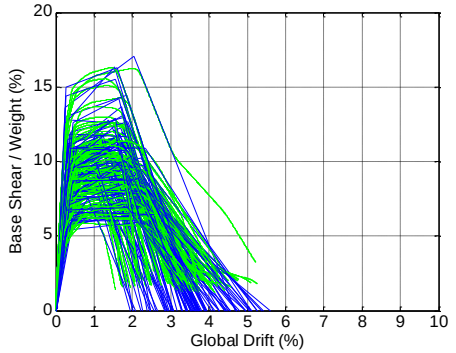
Simulated design (given design level)



Adapted from Verderame *et al.* 2008

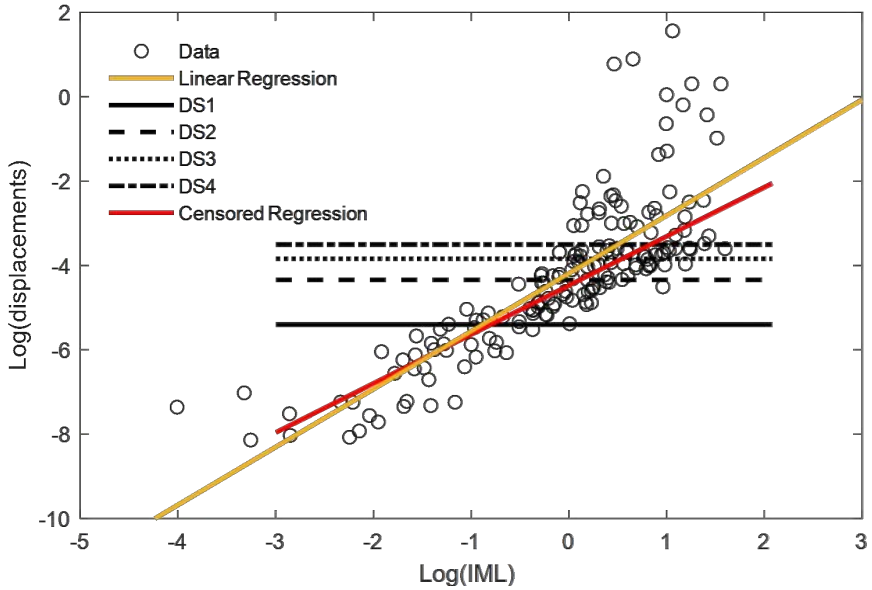
Backbone curves of designed MDOF structure



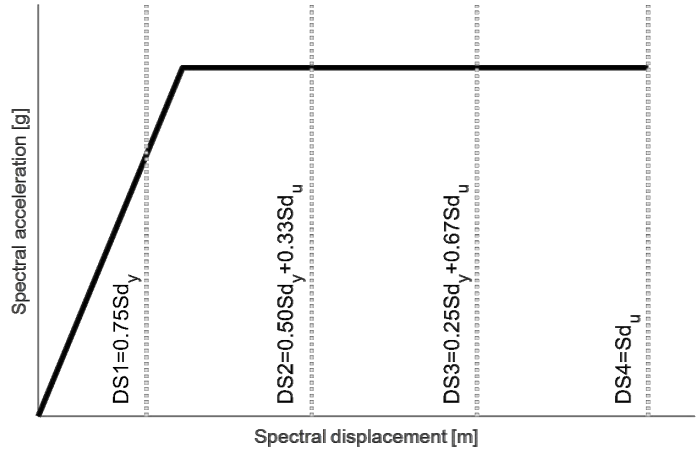


Fragility Models – State of Practice

Nonlinear dynamic analysis (MDOF transformed to SDOF or 2DOF models)

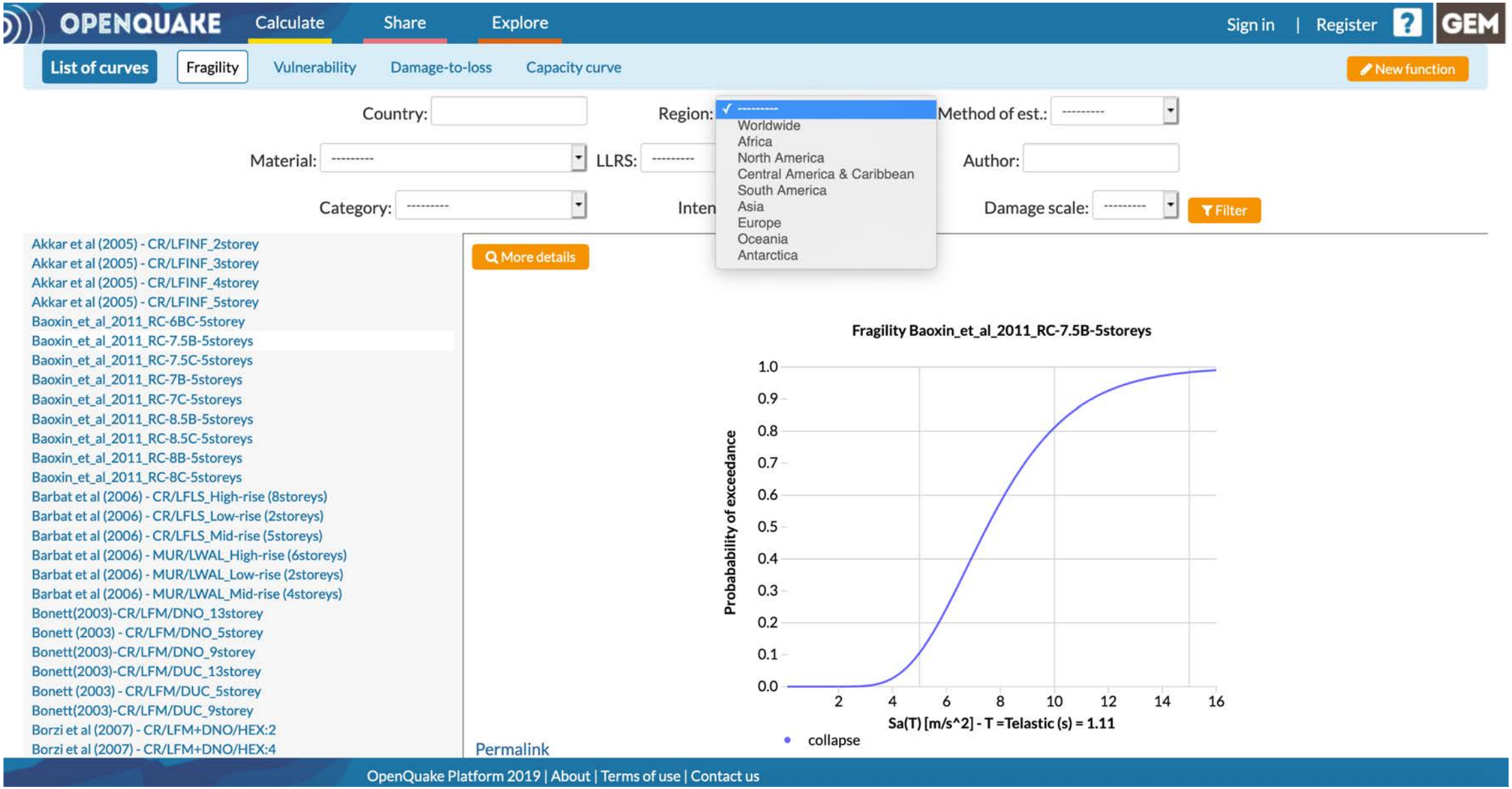


Threshold displacements for damage states



Fragility Models – State of Practice

https://platform.openquake.org/vulnerability/



Fragility Models – State of Practice

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General Information

Assessment Type: Fragility

Name: Baoxin et al 2011 RC-7.5B-5storeys

Category: Structure specific - Building

Taxonomy: CR/LFM+DUC/HEX:5/YPRE:2001/EDU+EDU2 (GEM)

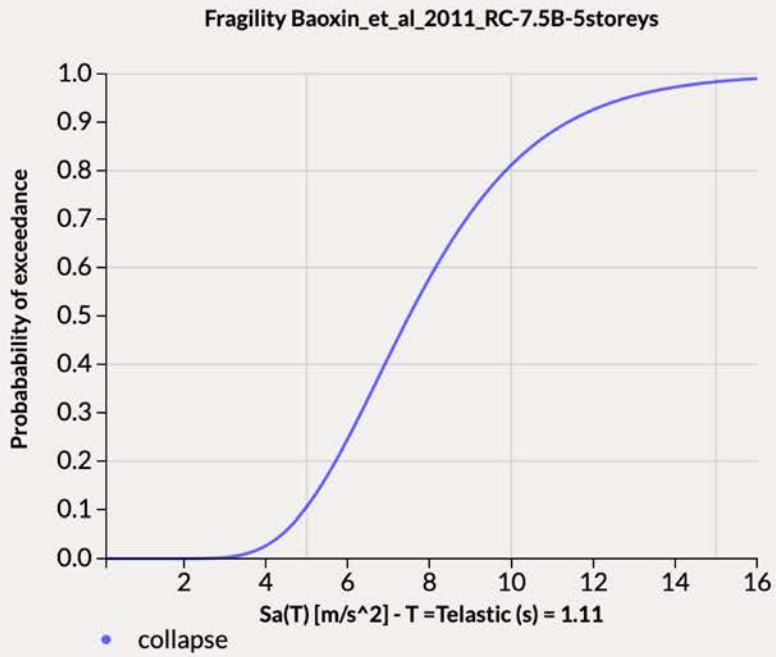
Reference: Evaluation of collapse resistance of RC frame structures for Chinese schools in seismic design categories B and C (Baoxin T., Xinzheng L., Lieping Y., Wei S., 2011) - Earthquake engineering and engineering vibration

Geographical Applicability: China

Methodology: Analytical

General Comments: The structure was designed in accordance with the 2001 Code for seismic design of buildings (GB50011- 2001) in China, for seismic design category B, and for an earthquake intensity equal to 7.5, that corresponds to 0.15 g PGA. The set of 22 far-field ground motion records proposed in ATC-63, and El-Centro ground motion record, are used as input in the IDA.

Modelling Information



Intensity Measure	Damage State
Sa(T) (m/s^2)	collapse
Mean	7.909
Standard Deviation (SD)	2.638

Fragility Models – Challenges

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➤ Current research is inconclusive on relative importance of each of these (but has probably tended to underestimate modelling uncertainty)

Fragility Models – Future Directions

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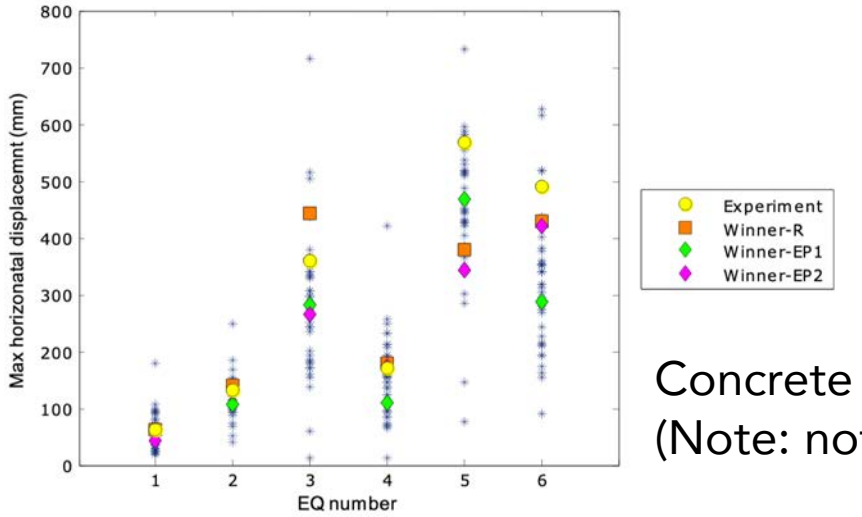


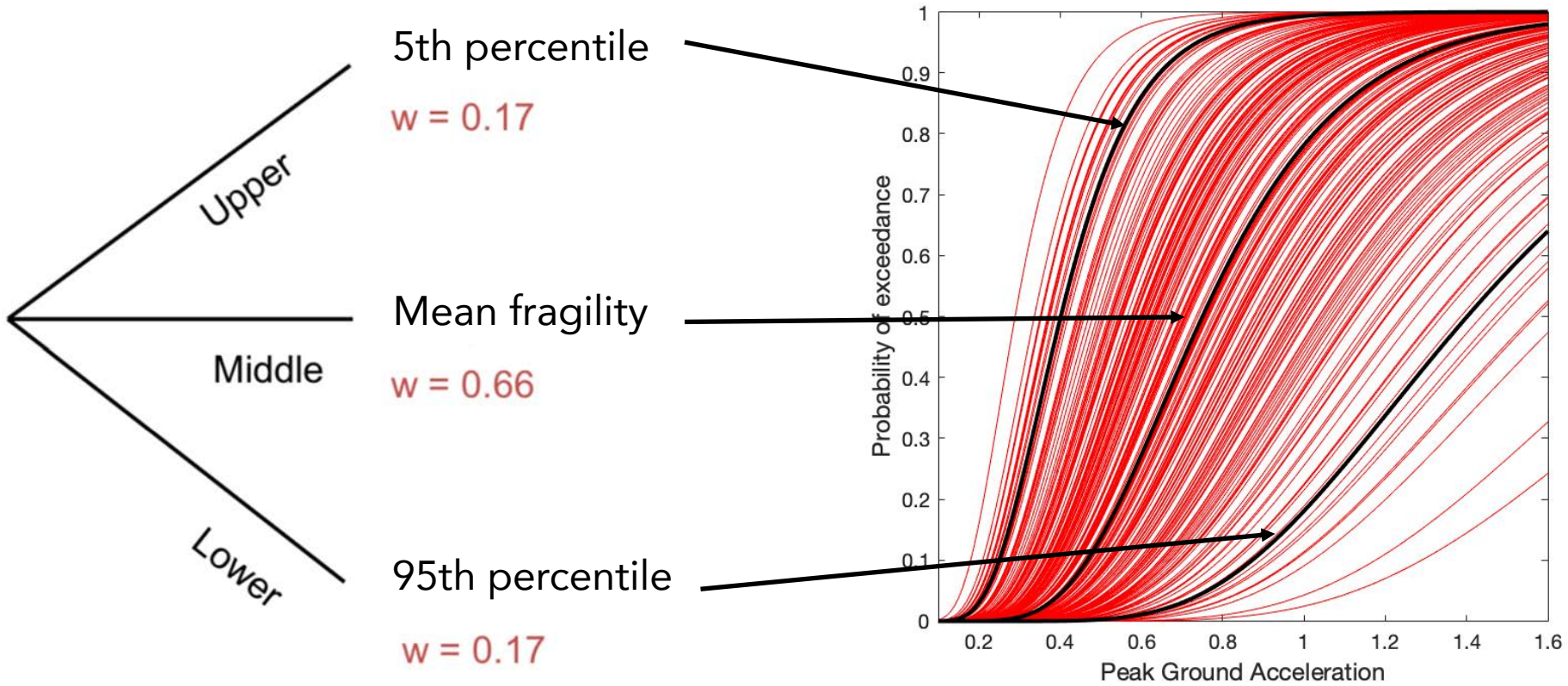
Concrete Column Blind Prediction Contest 2010
(Note: not all models shown here are necessarily 'plausible')

Fragility Models – Future Directions

- With increased access to experimental tests of components and full-scale buildings, more efforts should be made to address modelling uncertainty.
- Even when the selected modelling approach is tested/calibrated against some experimental tests, blind prediction exercises show that results from plausible models can still vary significantly.
- Sensible variations of the model should thus still be undertaken when developing fragility functions for a given structural typology (or impact should be applied *ex post* through engineering judgment, based on results of other similar studies – of which more are needed).

Fragility Models – Future Directions

- Epistemic (modelling) uncertainty should be included in the risk analysis (maybe through a backbone approach where aleatory variabilities are represented by a logic tree of limited branches)



Fragility Models – Future Directions

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- Measurements of the actual levels of ground shaking and response of the building after a significant event could also be used for a multitude of insurance related activities:
  - Rapid assessment of damage/loss,
  - Prioritisation of post-event damage inspections,
  - Parametric insurance triggers

Vulnerability Models - State of Practice

- Probability of loss, conditional on a level of ground shaking

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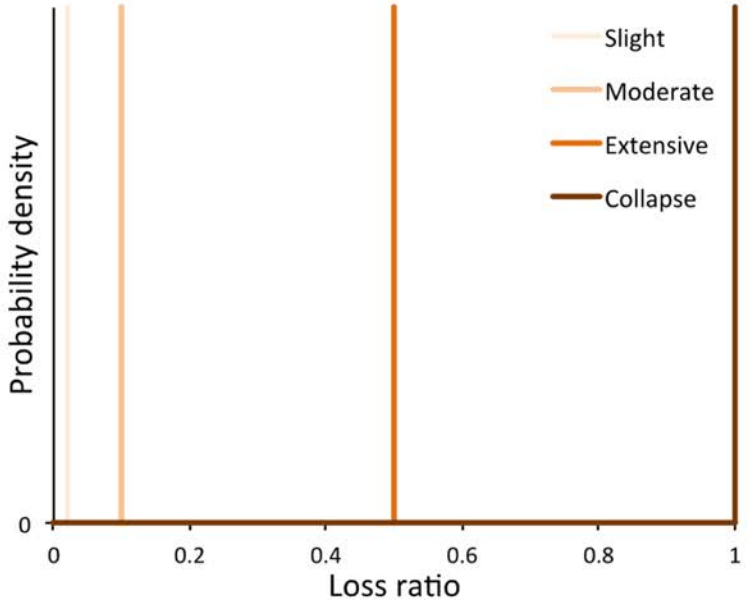
- Analytical fragility functions + (semi-empirical) consequence functions

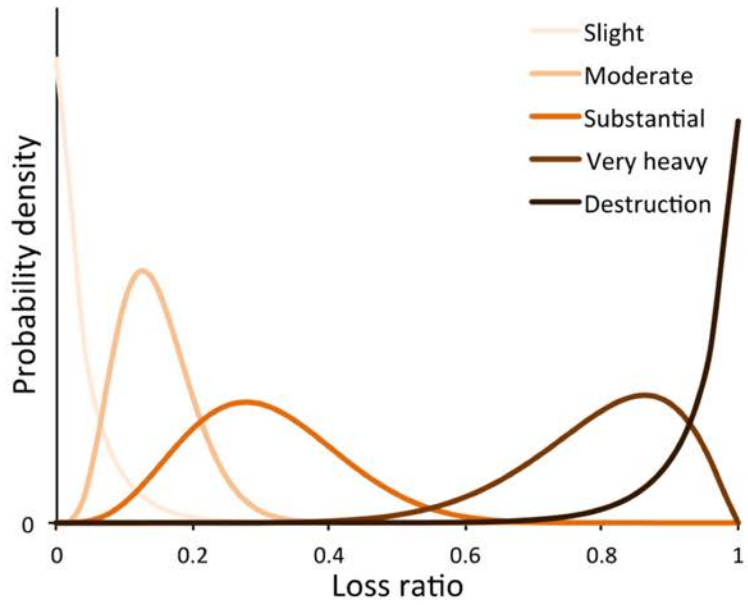
Vulnerability Models - State of Practice

- Probability of loss, conditional on a level of ground shaking
- Analytical fragility functions + (semi-empirical) consequence functions
- Consequence functions: probability of loss conditional on damage (where loss may be injuries, fatalities, repair costs, downtime..)



Deterministic model

(HAZUS – FEMA 2004)



Probabilistic model

(Dolce et al. 2006)

Vulnerability Models – State of Practice

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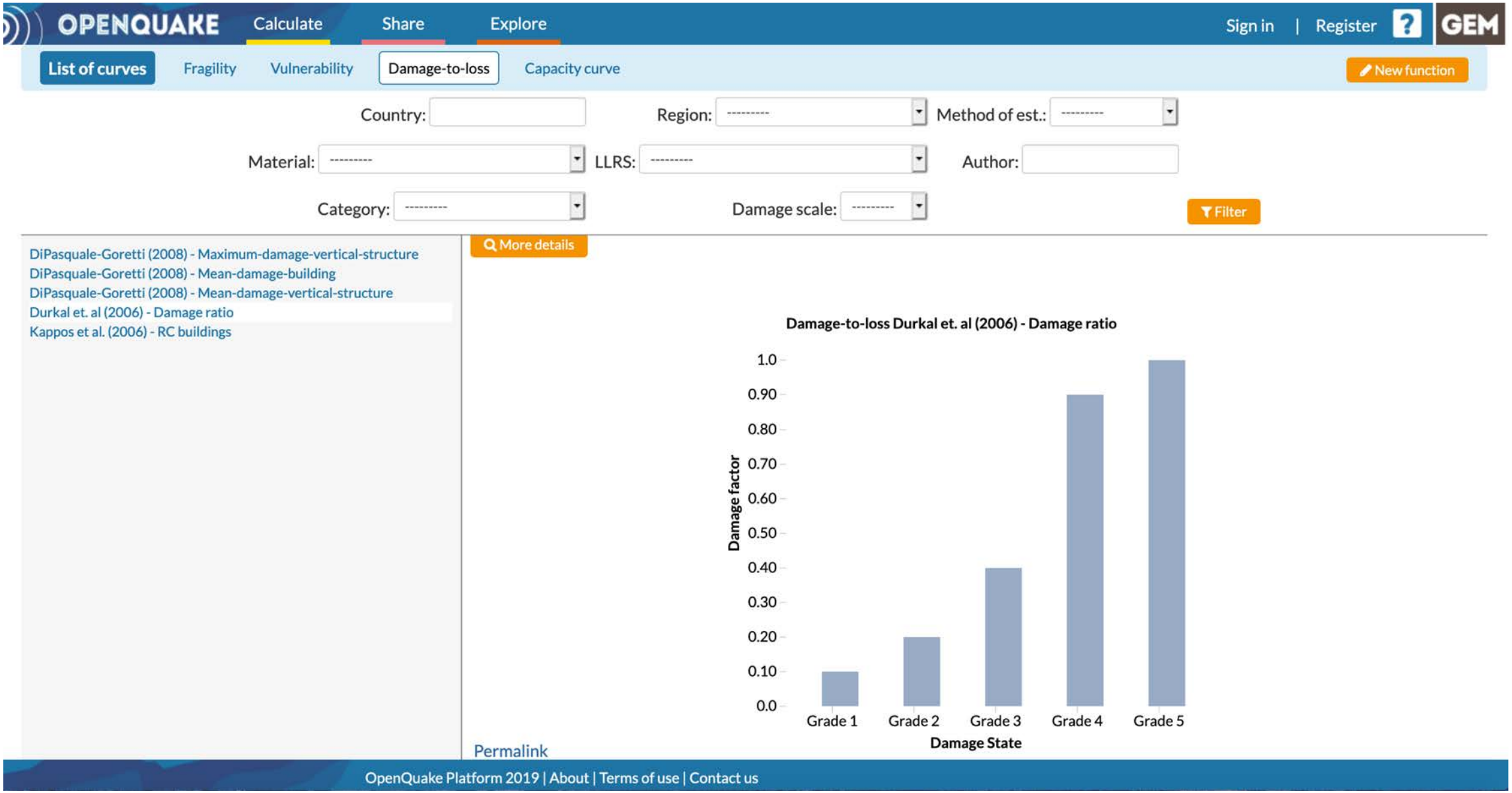

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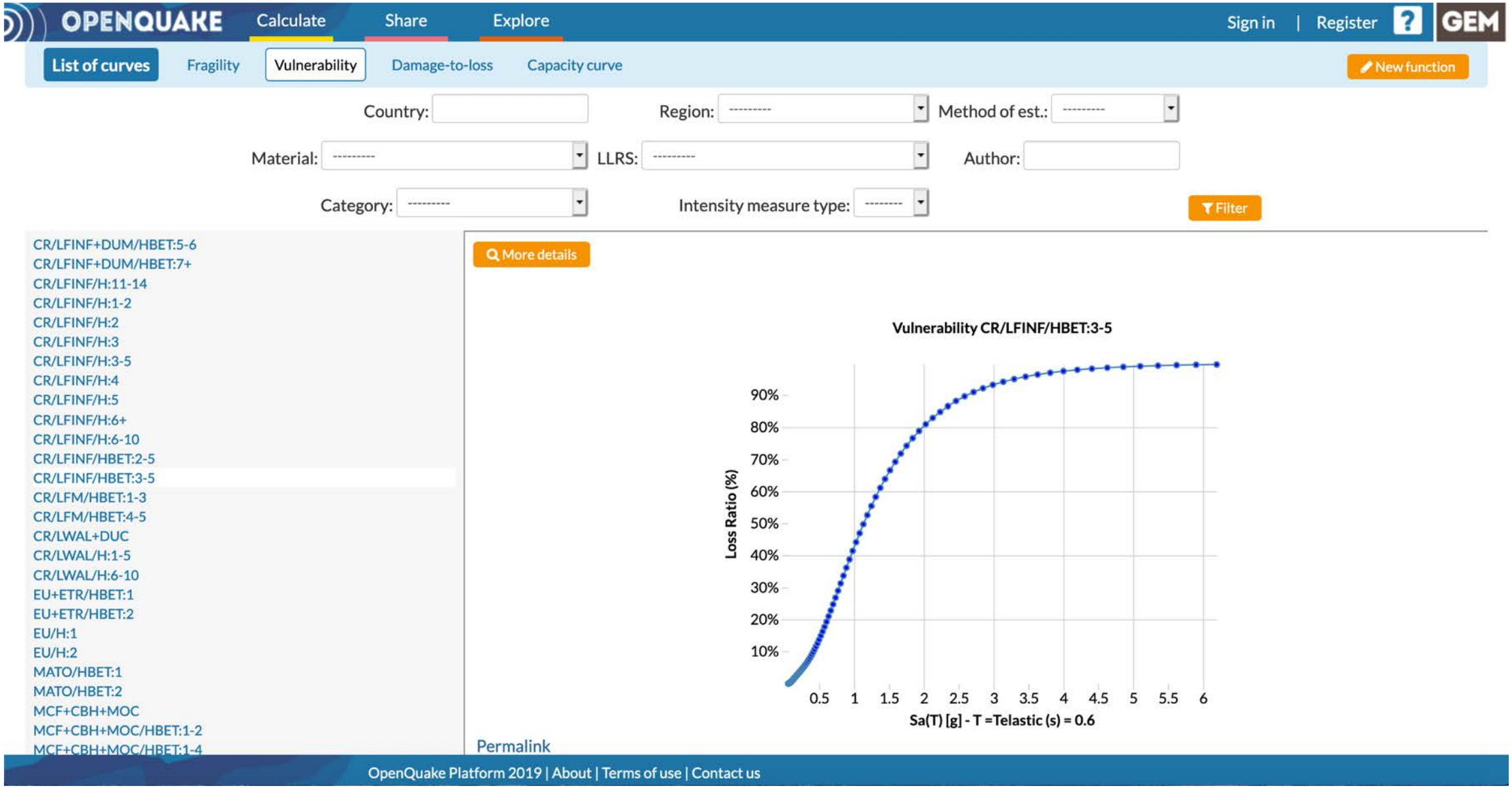

Vulnerability Models - Challenges/Future Directions

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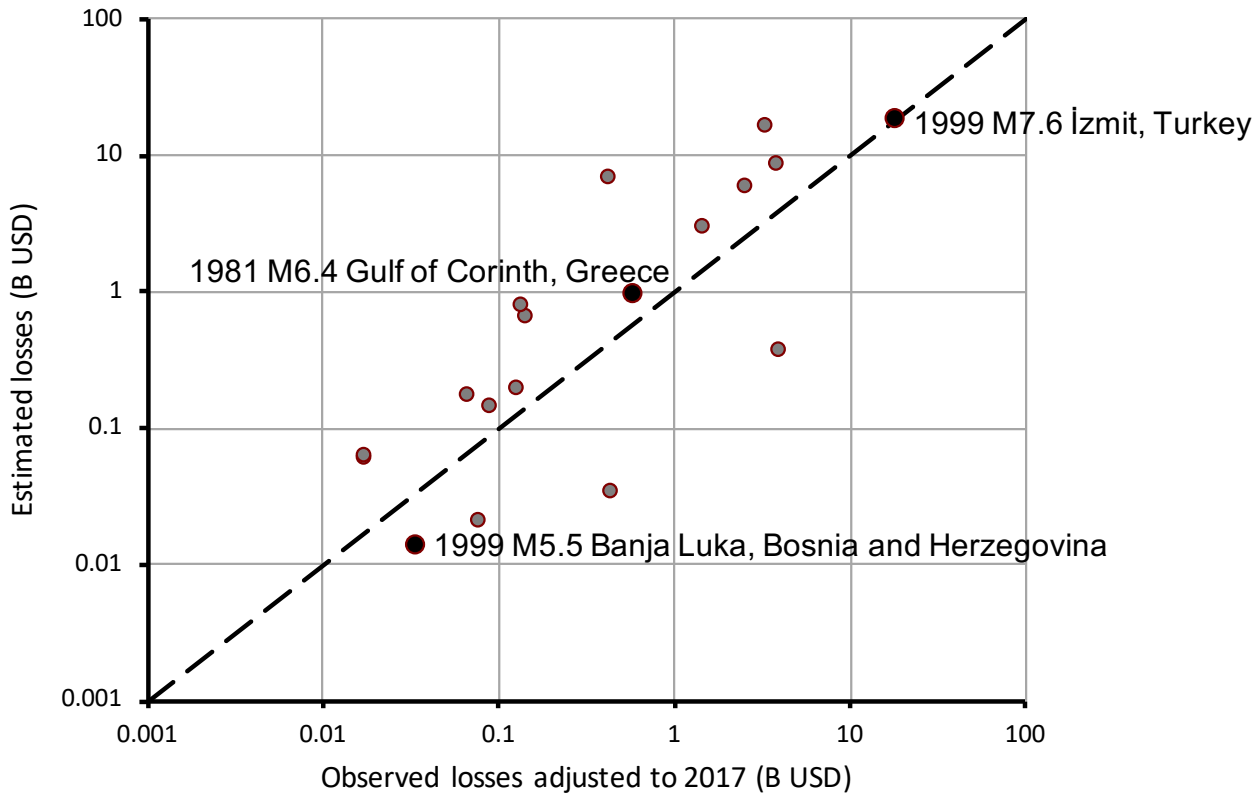

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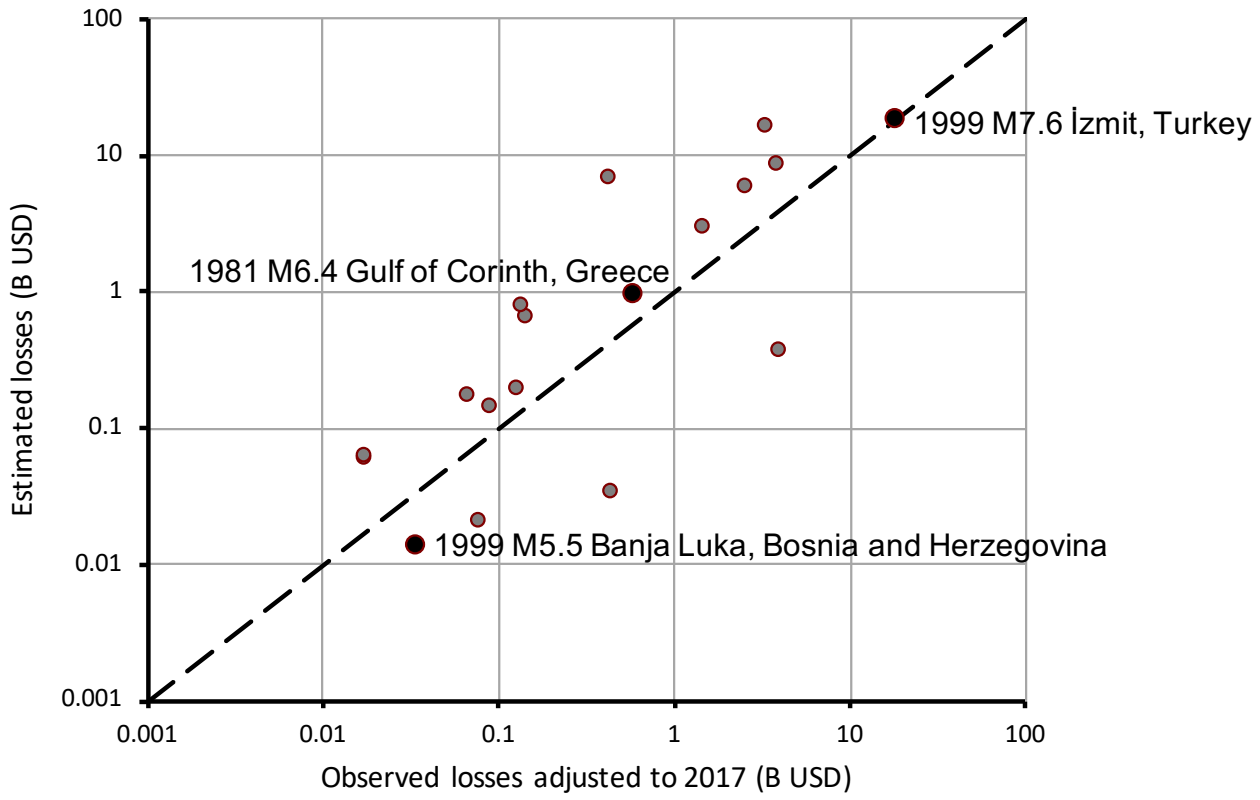
- Tools to do this automatically with the aforementioned database could be set up.



Vulnerability Models - Challenges/Future Directions

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Vulnerability Models - Challenges/Future Directions

- There is limited (reliable) data in the public domain both for developing models and testing them (in particular related to injuries and fatalities for specific building classes).
- Future efforts to standardise the collection of open and publicly available consequence data is fundamental for a better understanding of the impacts of earthquakes and for better calibration and verification of loss models.

Research Infrastructures

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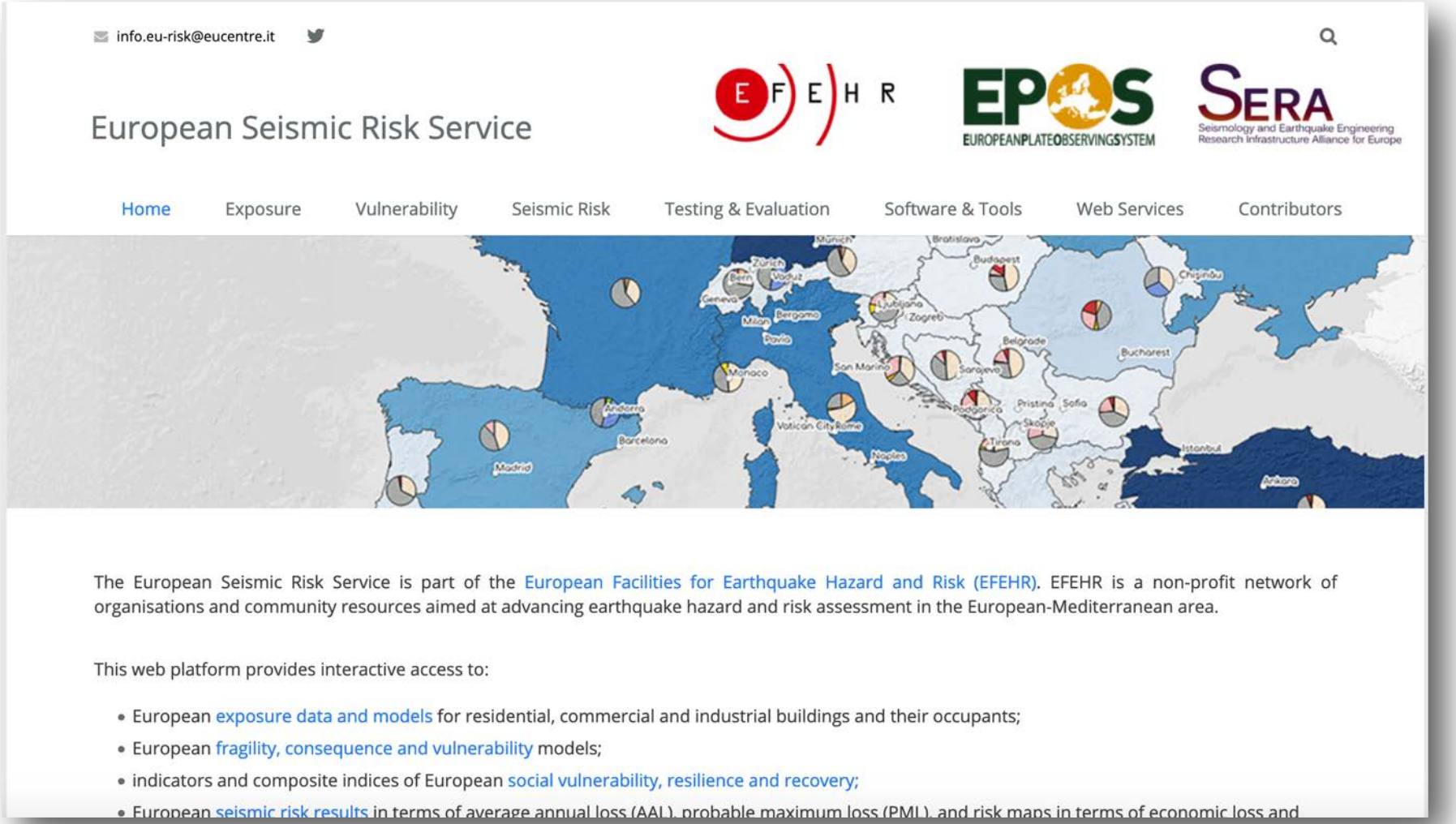
Research Infrastructures

https://eu-risk.eucentre.it



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- EFEHR provides and maintains services and data related to seismic hazard and risk (including exposure, vulnerability and risk products).
- As stakeholders of these services, we would be interested to know more about your needs, and ideas on how we might continue to sustain the costs of these services.

Thank you..

 https://eu-risk.eucentre.it

 info.eu-risk@eucentre.it / helen.crowley@eucentre.it

 @EFEHR_risk