UNIVERSITÀ DI TRENTO

Trento, 10 December 2021
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Ingegneria Sismica e Progettazione Strutturale

Probabilistic Seismic Risk Analysis for Civil Systems

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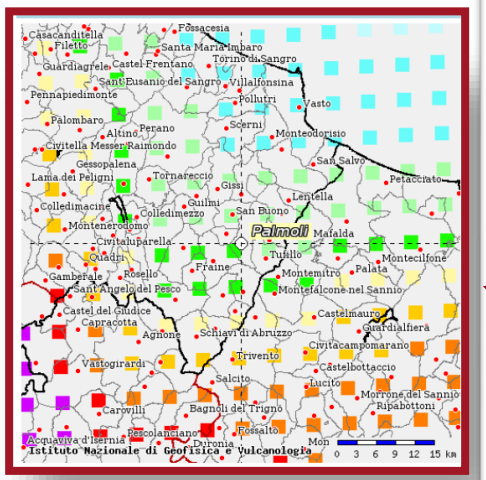
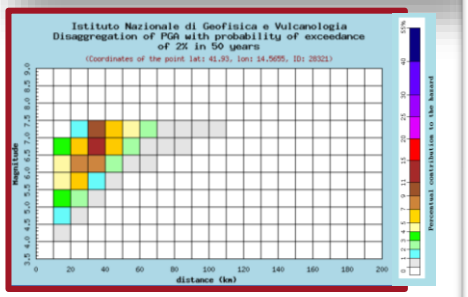
Prof. Marco Broccardo – Ph.D., M.Sc., Eng. in Civil Engineering

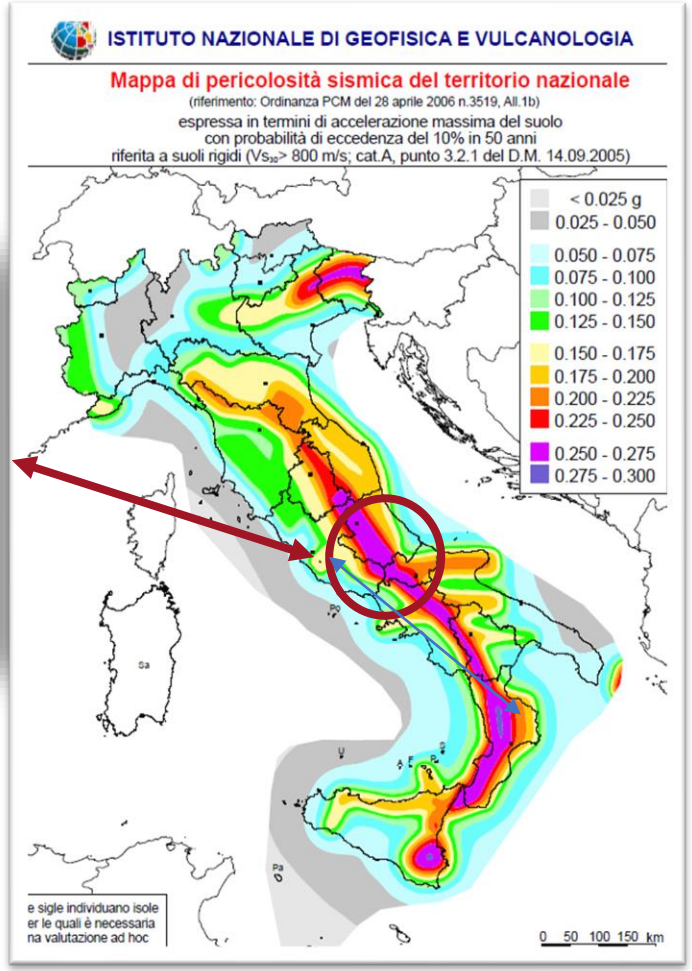
https://github.com/CNardin

Outline:

- Motivations: earthquake and losses
- Hazard curves and fragility functions
- PBEE-PEER framework
- Lecture Plan







http://zonesismiche.mi.ingv.it/

seismic risk

«Con la parola rischio si intende esprimere un concetto generale che comprende sia la probabilità di un evento, sia le conseguenze che l'evento stesso potrebbe produrre.»

Fondamenti di ingegneria sismica in 80 lezioni, A.**Parducci**, Liguori Ed.

«Risk has been defined, for management purposes, as the potential economic, social and environmental consequences of hazardous events that may occur in a specified period of time. »

Seismic risk evaluation for an urban centre, M.L.**Carreno**, O.D.**Cardona**, A.H.**Barbat**, 250th Anniversary of the 1755 Lisbon Earthquake

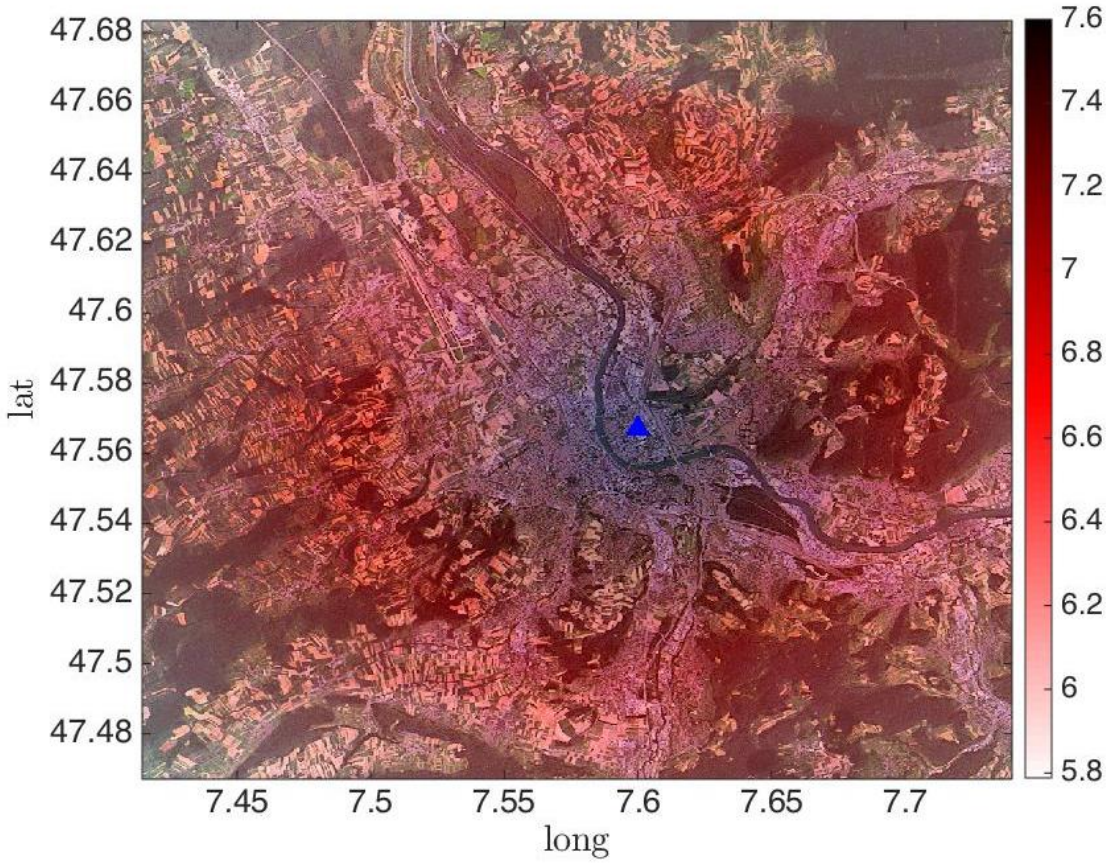
seismic risk ≠ seismic hazard

«La pericolosità sismica corrisponde alla frequenza delle intensità dei terremoti che si prevede possano interessare il territorio in questione. Può essere definita come la probabilità che un evento potenzialmente dannoso si manifesti in questo territorio entro un determinato periodo di tempo.»

Fondamenti di ingegneria sismica in 80 lezioni, A.**Parducci**, Liguori Ed.

«A seismic hazard is the probability that an earthquake will occur in a given geographic area, within a given window of time, and with ground motion intensity exceeding a given threshold. »

Probabilistic seismic hazard analysis: Early history, **McGuire,** R. Earthquake Engng Struct. Dyn., *2008*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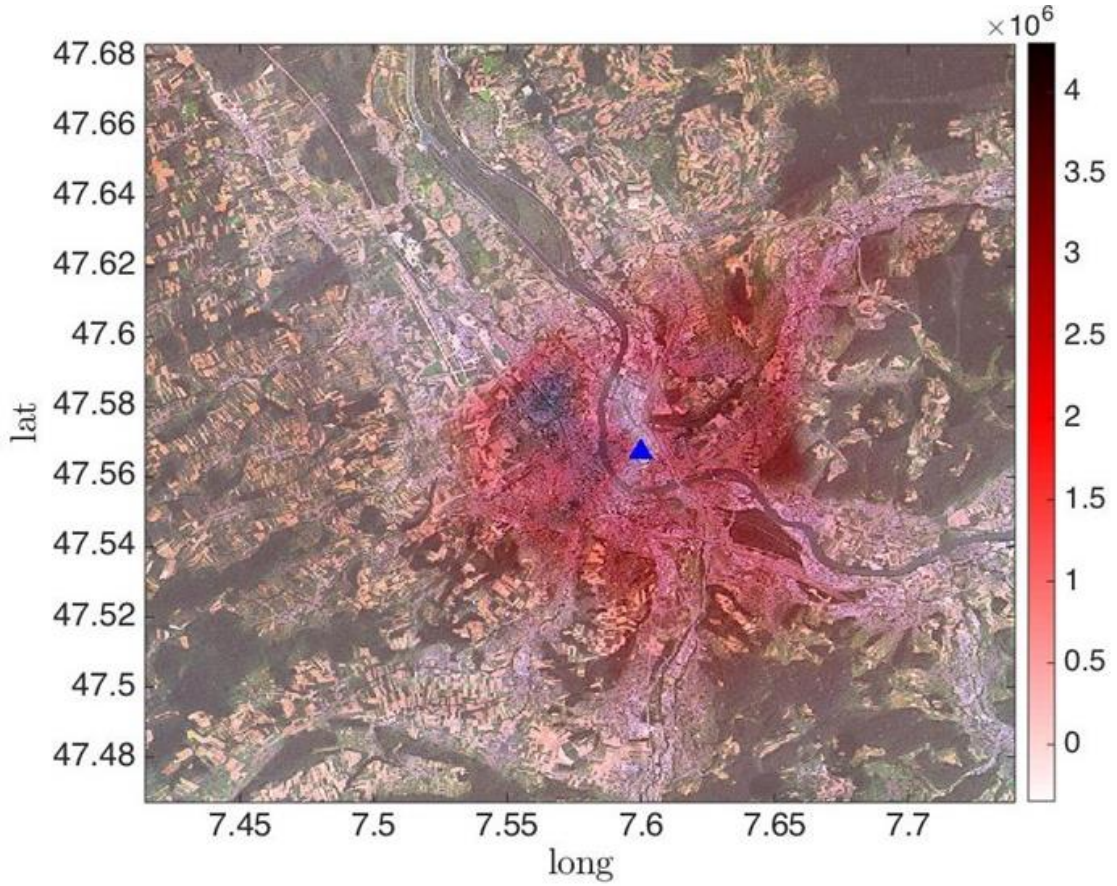
hazard map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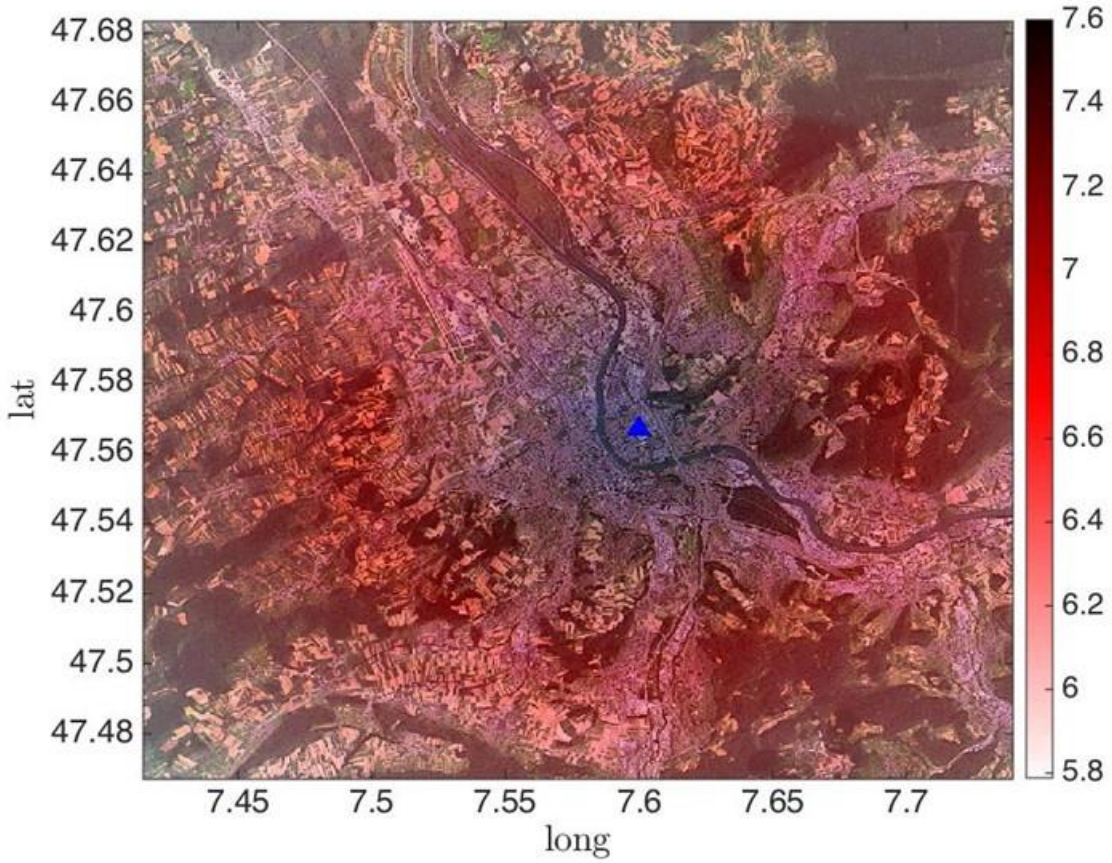
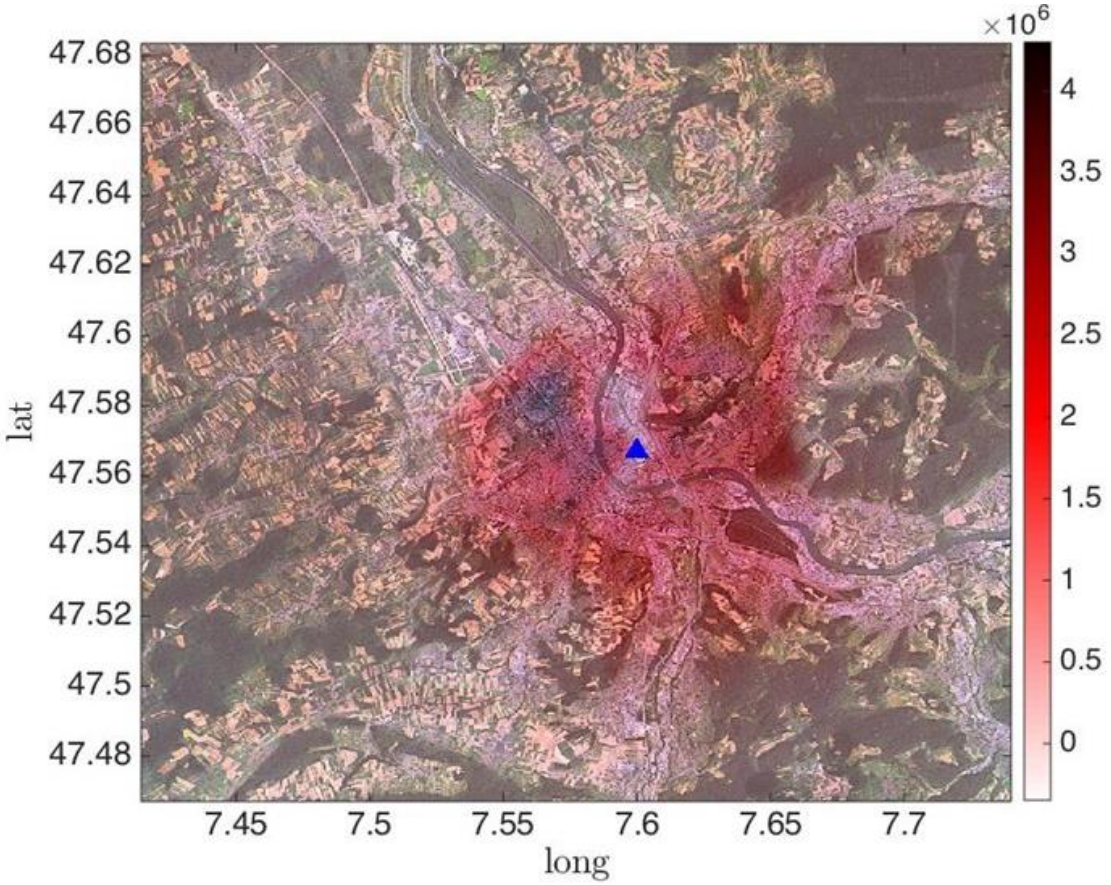
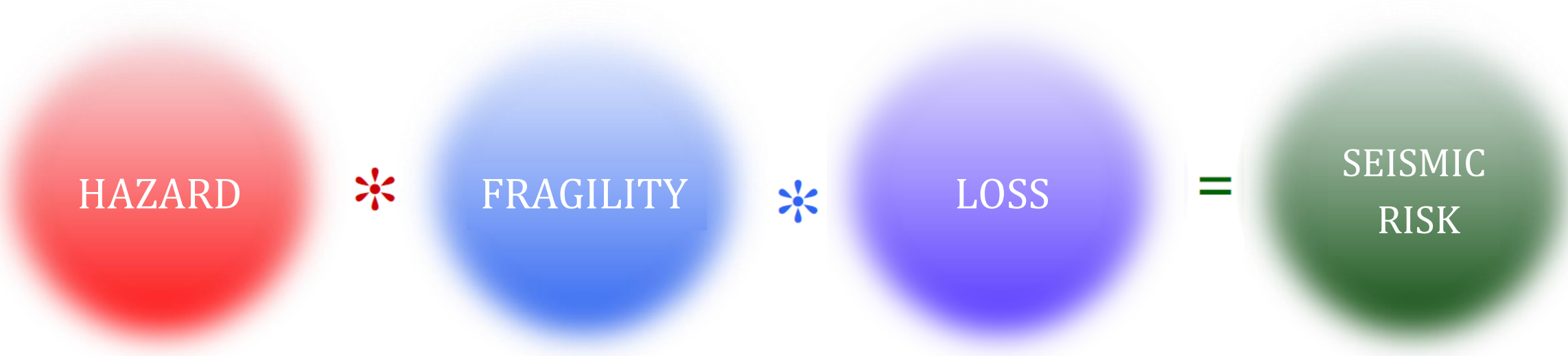
risk map

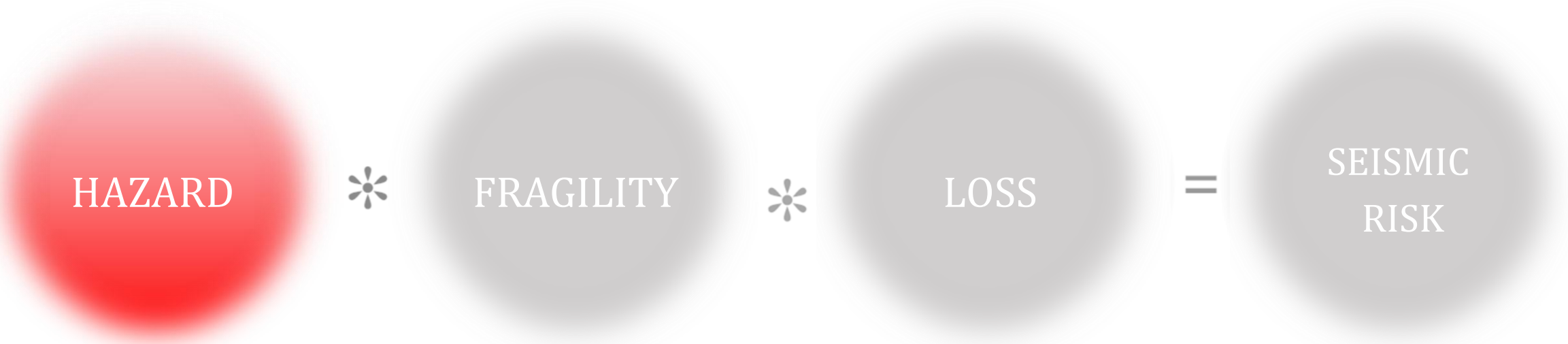


hazard map



risk map


HAZARD
FRAGILITY
LOSS
SEISMIC RISK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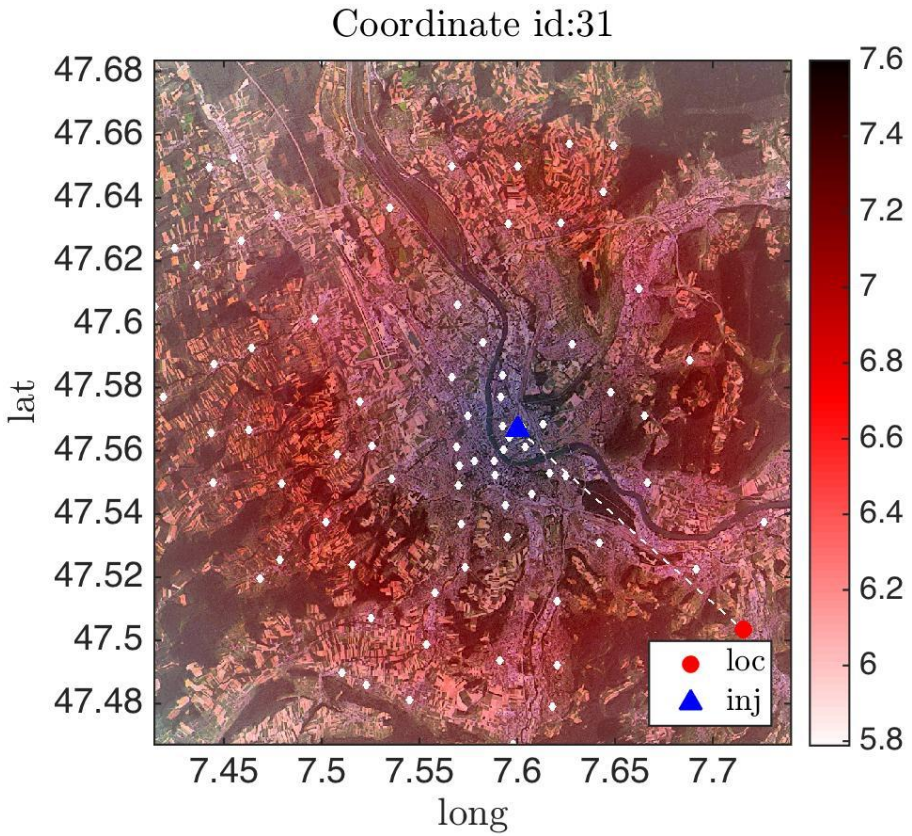
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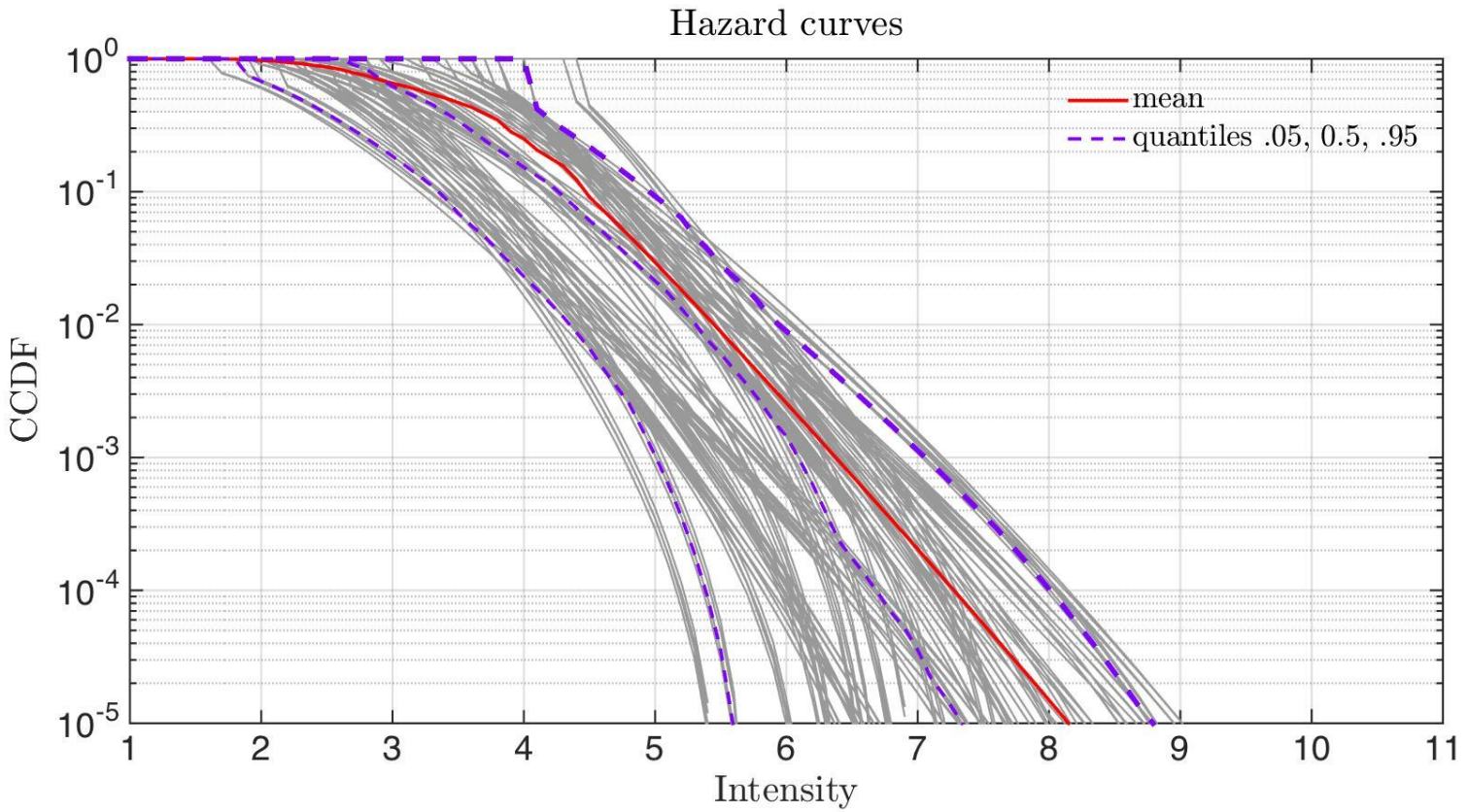
Hazard curves
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
CCDF
1
2
3
4
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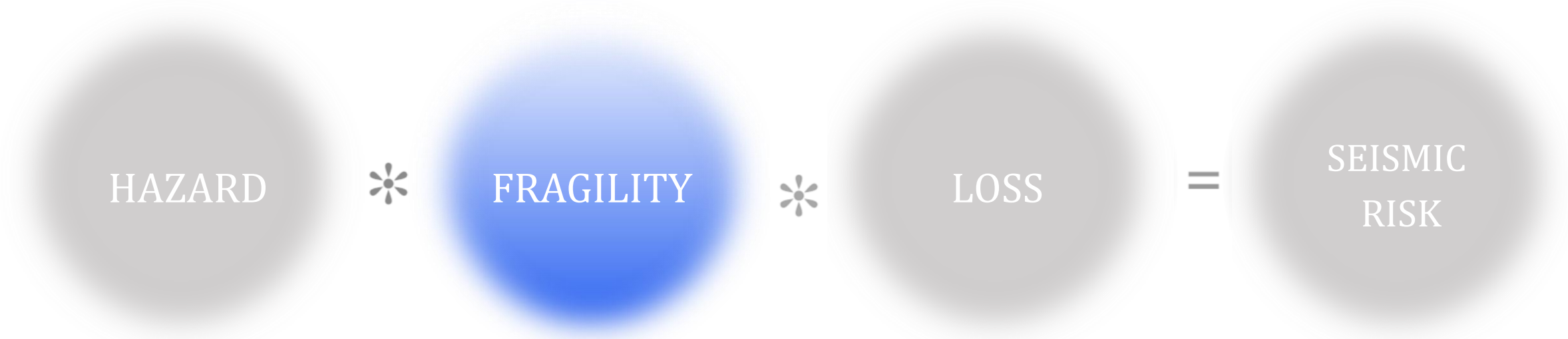
6
7
8
9
10
11
Intensity
mean
quantiles .05, 0.5, .95

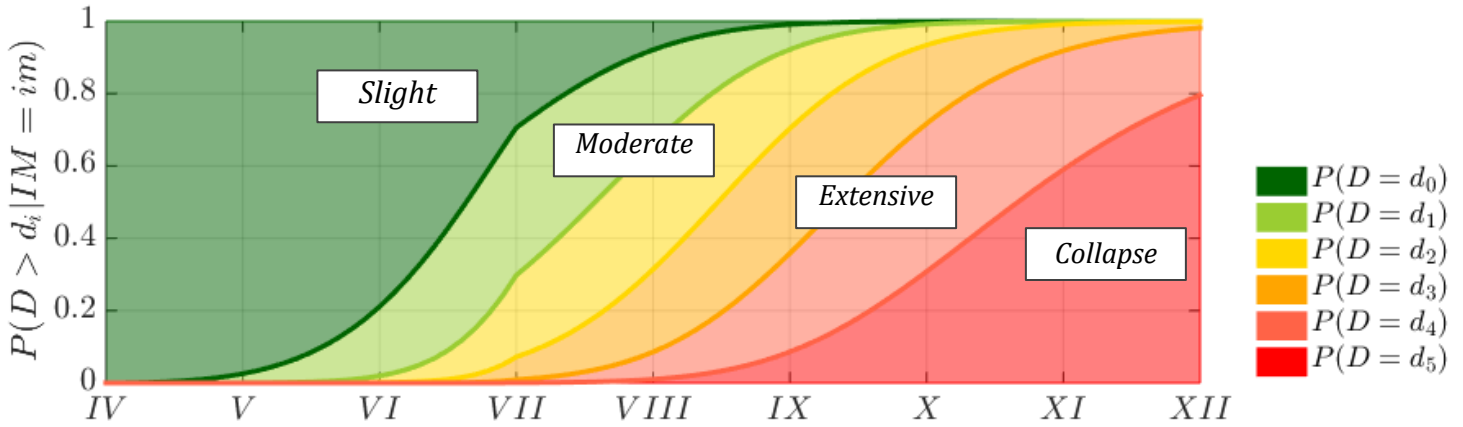

HAZARD
FRAGILITY
LOSS
SEISMIC RISK

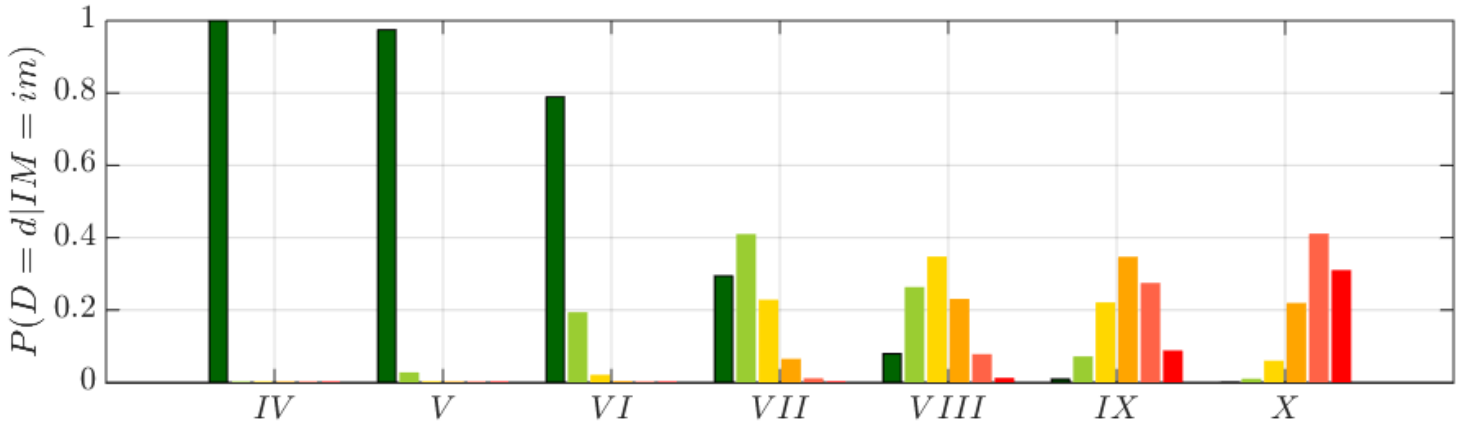
DG 1:
Slight Damage

DG 2:
Moderate Damage

DG 3:
Extensive Damage

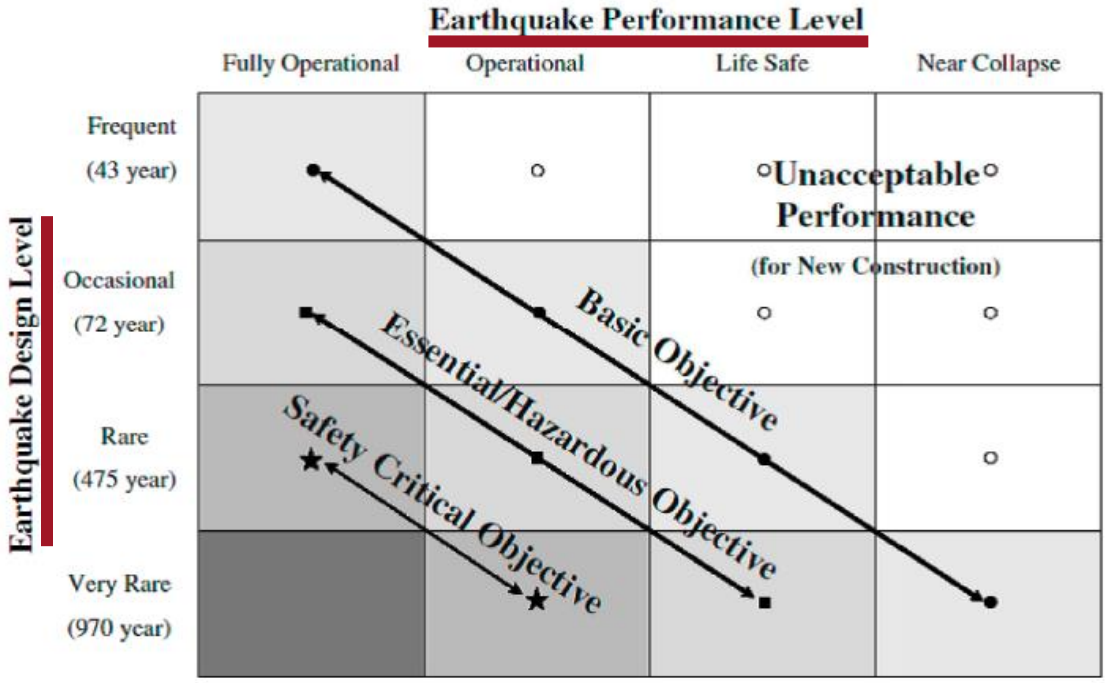
DG 4:
Complete Damage





PBEE-PEER framework

PBEE: **P**erformance **B**ased **E**arthquake **E**ngineering



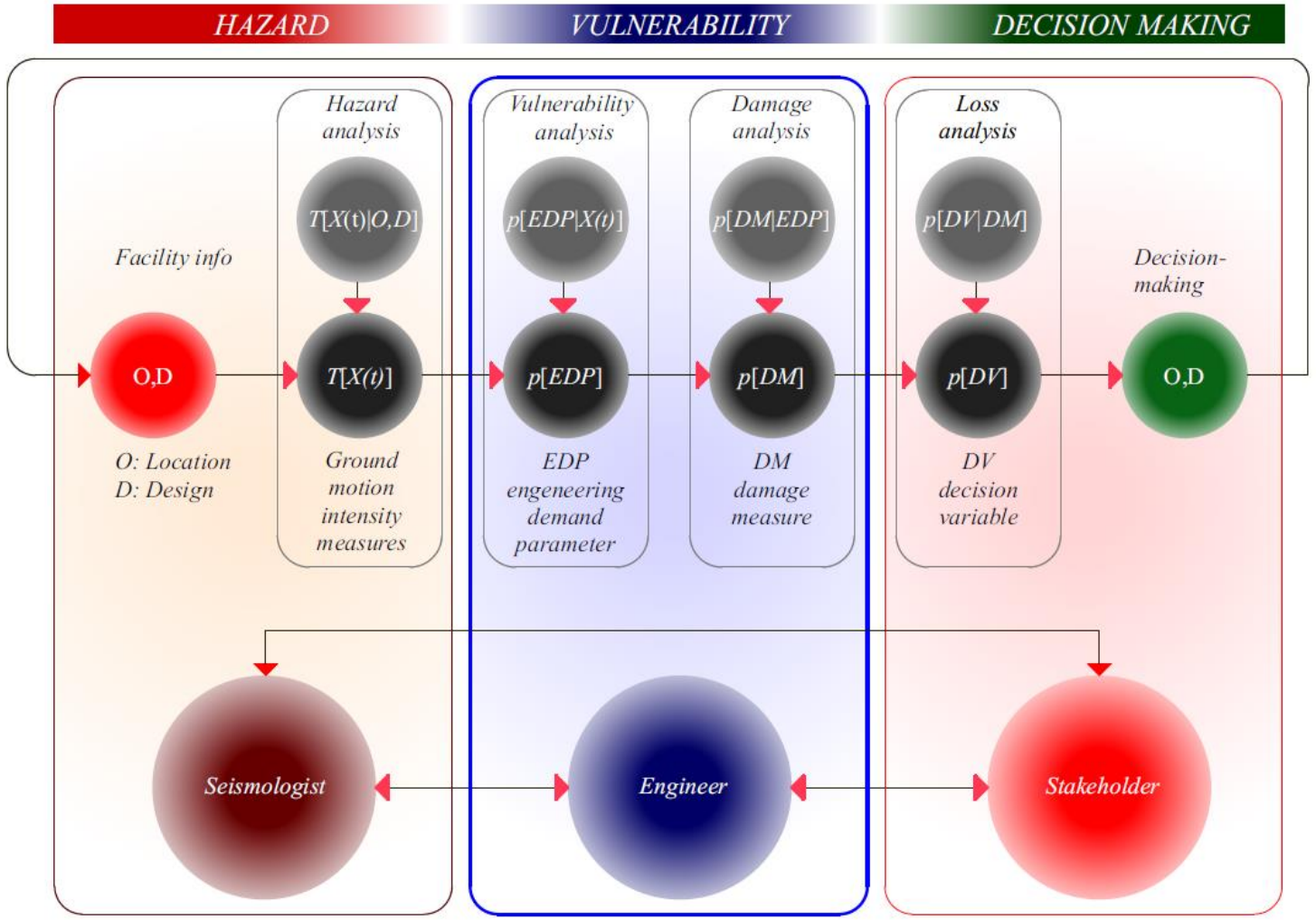
PBEE concept: seismic performance objectives *vs* seismic hazard level. ©*Poland et al.,(1995)-Vision 2000: Performance Based Earthquake Engineering of buildings. Structural Engineers Association of California, Sacramento, CA.*

The **PEER-PBEE** Framework

$$IM \longrightarrow EDP \longrightarrow DM \longrightarrow DV$$

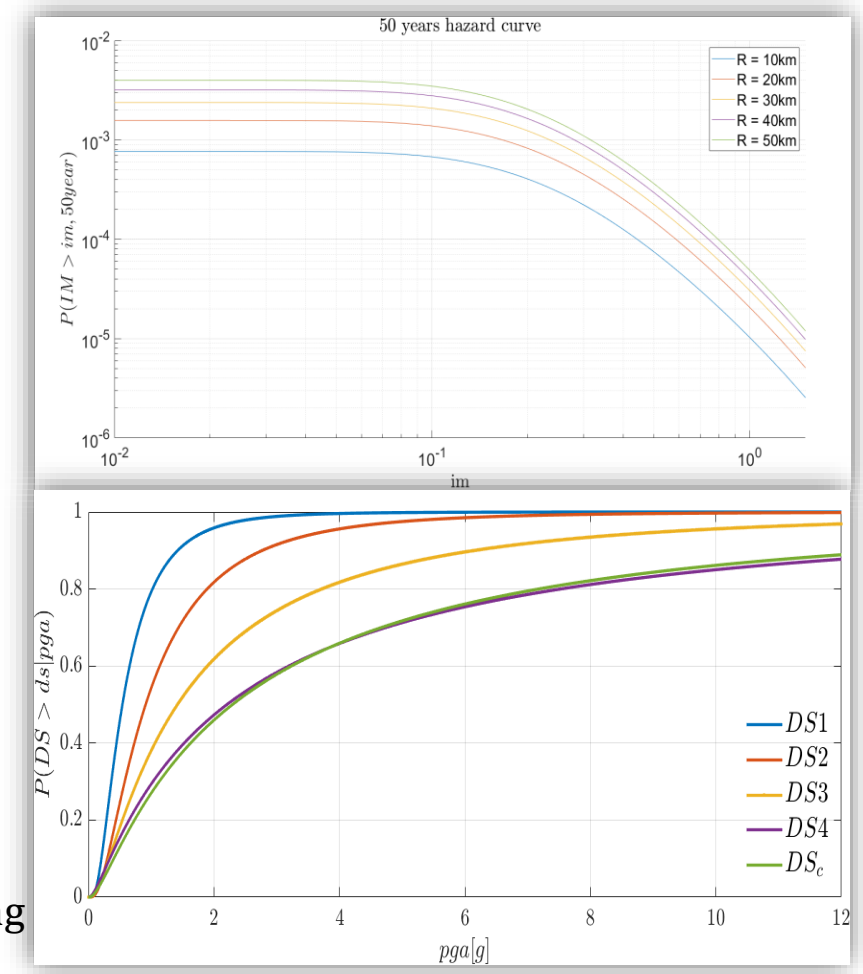
$$\lambda(dv) = \int_{d} \int_{edp} \int_{im} G(dv|d)|dG(d|edp)||dG(edp|im)||d\lambda(im)|$$

where *im* is an intensity measure (e.g., peak ground acceleration, peak ground velocity, spectral acceleration, etc.), *edp* is an engineering demand parameter (e.g., interstorey drift), d is a damage measure (e.g., minor, medium, extensive, collapse), dv is a decision variable (e.g., monetary losses, fatalities, etc.), $\lambda(x)$ is the mean annual rate of events exceeding a given threshold for a given variable x, and $G(y|x) = P(Y \geq y|X = x)$ is the conditional complementary cumulative distribution function (CCDF)


HAZARD
VULNERABILITY
DECISION MAKING
Facility info
Hazard analysis
Vulnerability analysis
Damage analysis
Loss analysis
Decision-making
T[X(t)|O,D]
p[EDP|X(t)]
p[DM|EDP]
p[DV|DM]
O,D
T[X(t)]
p[EDP]
p[DM]
p[DV]
O,D
O: Location
D: Design
Ground motion intensity measures
EDP engeneering demand parameter
DM damage measure
DV decision variable
Seismologist
Engineer
Stakeholder

Objectives & Lecture Plan:

- (1h30) Element of statistics and probability (M.Broccardo)
  - i. Set theory
  - ii. Random variables
  - iii. Probability distributions
- (1h00) Probabilistic seismic hazard (C.Nardin)
  - i. Definition and time scales
  - ii. Models of earthquake occurrence and hazard integral
  - iii. LAB → PSHA with MatLab
- (2h00) Vulnerability (M.Broccardo, C.Nardin)
  - i. Logistic regression models
  - ii. Fragility functions: methods and applications
  - iii. LAB → Computation of probability of damage state of a building



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