Advancements in Risk- and Loss-Based Methodologies for Large-Scale Assessment of Non-Ductile Infilled Reinforced Concrete Buildings

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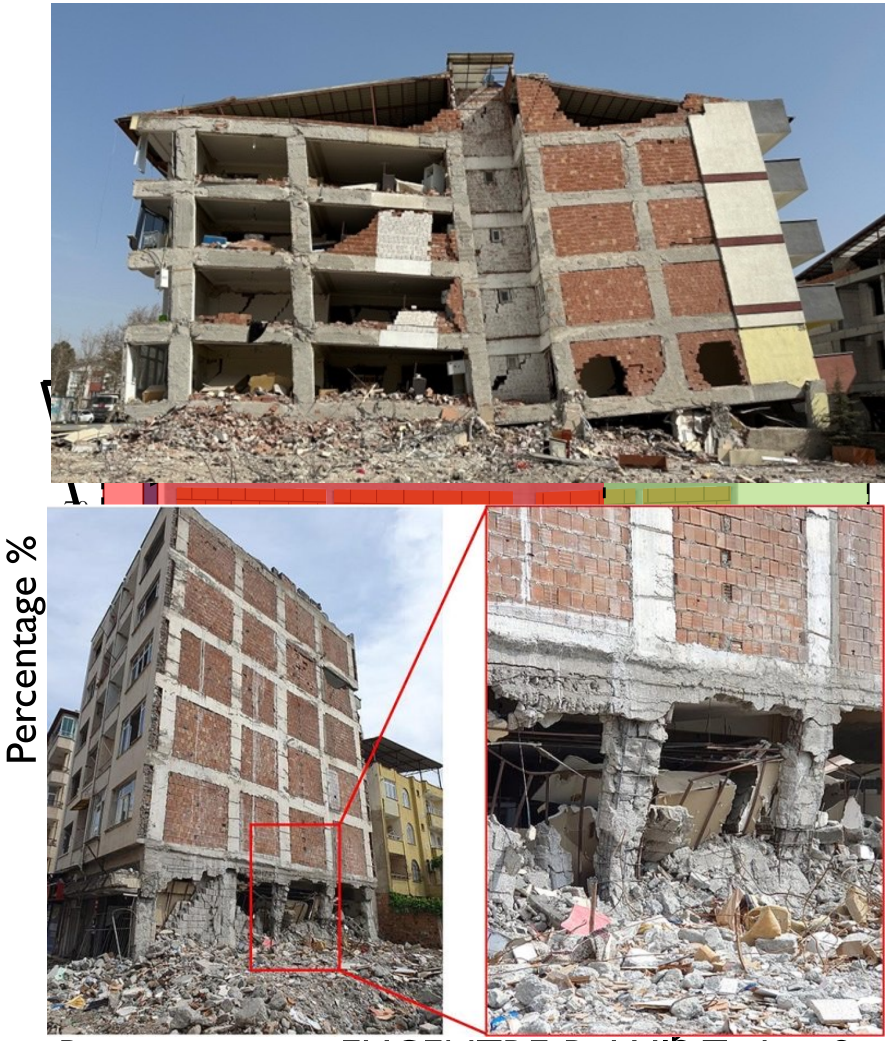
Introduction

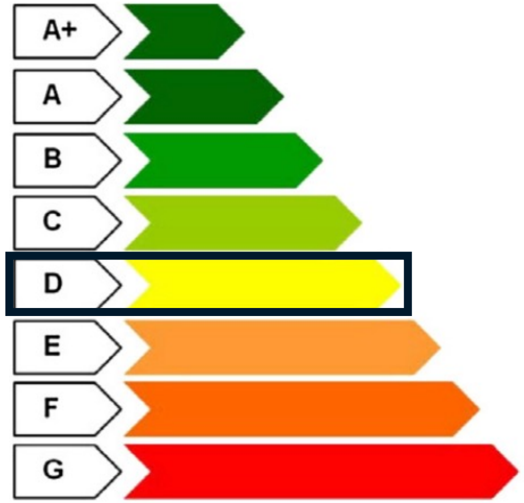
- Infilled RC buildings occupy a significant portion of the regional building stock
- The majority of Italian RC buildings were constructed before the introduction of modern seismic codes:
  - Before 1970s: Gravity loads (GLDs)
  - 1970s – 1980s: ELF method (SSDs)
  - URM panels were considered as non-structural elements
- Post-earthquake reports highlighted the vulnerability of the existing regional building stock to ground-shaking events



Joint Reconnaissance EUCENTRE-ReLUIS, Turkey-Syria Earthquake 2023 - Final report

Introduction

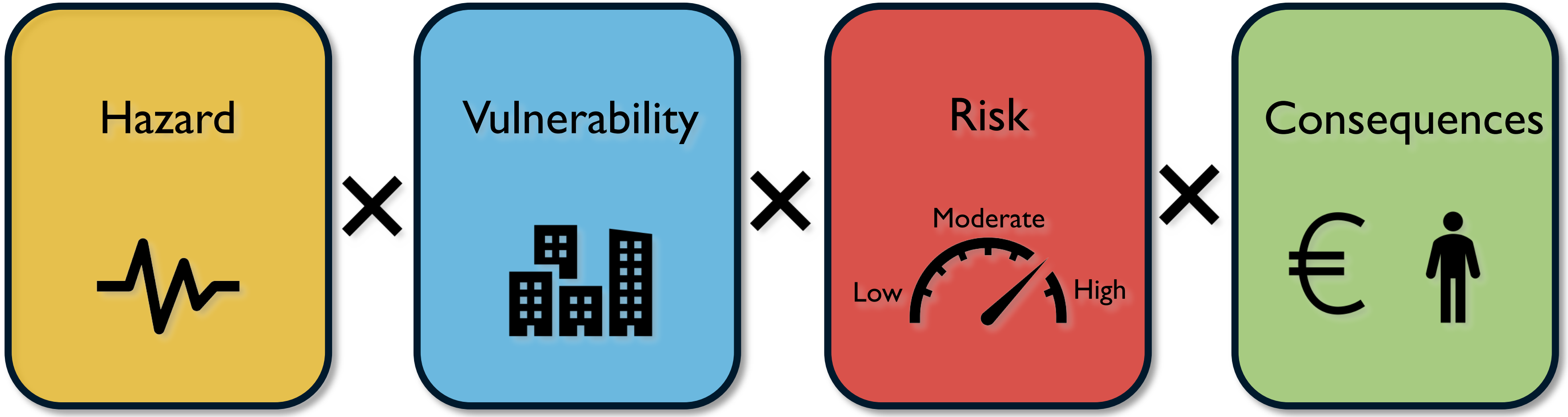
- Urgency for risk classification methodologies for informed decision-making to carry out building safety tagging and prioritization of retrofitting actions
- In Italy, *Sismabonus* is an incentive that allows you to deduct the expenses incurred to carry out seismic risk reduction work, improving the seismic class of the property that is the subject of the intervention



- *Decreto Ministeriale. [2017] Linee Guida per la Classificazione del Rischio Sismico delle Costruzioni - 58/2017, Il ministero delle infrastrutture e dei trasporti, Rome, Italy.*
- *Decreto Legge [2020] Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonche' di politiche sociali connesse all'emergenza epidemiologica da COVID-19 – 34/2020, Rome, Italy*

What do we propose?

- A fast, simple and reliable decision-support methodology for the building-specific loss assessment of non-ductile infilled RC structures (PB-Loss)
- Enables practitioners to deal with sophisticated concepts behind modern PSA simplistically
- PB-Loss integrates:
  - Open-access tools and models for the characterization of seismic hazard
  - Strength-deformation relationships and robust approximations for the quantification of seismic vulnerability
  - High-fidelity mathematical models and state-of-the-art methods for the estimation of seismic risk and losses

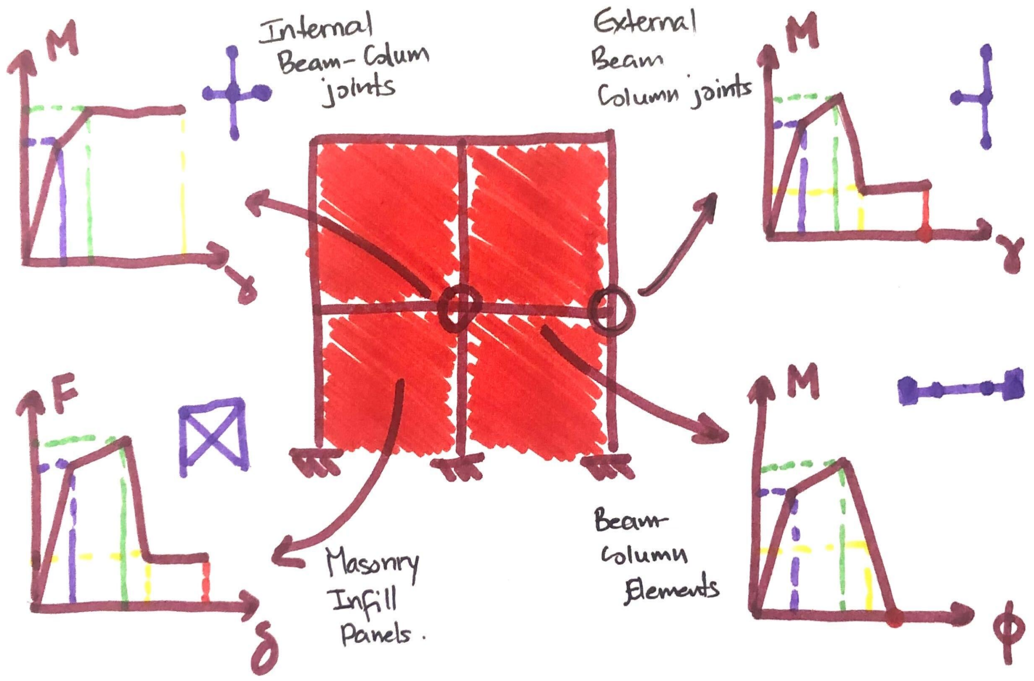


Fundamental components of performance-based earthquake assessment

Development of a database for infilled RC archetype building numerical model

Nafeh, A.M.B. & O'Reilly, G.J.,

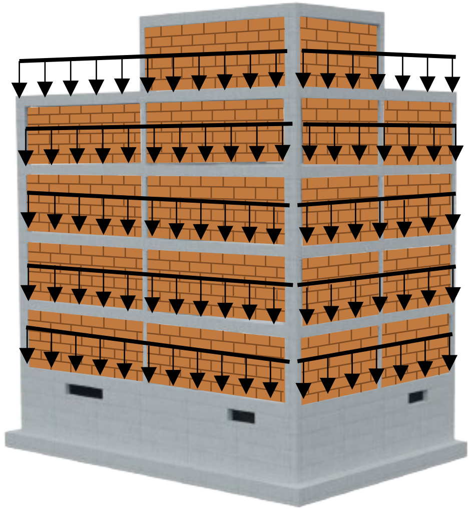
- *Unbiased simplified seismic fragility estimation of non-ductile infilled RC structures, Soil Dynamics and Earthquake Engineering, Volume 157, 2022, 107253, ISSN 0267-7261, https://doi.org/10.1016/j.soildyn.2022.107253.*



Database of Archetype Numerical Models

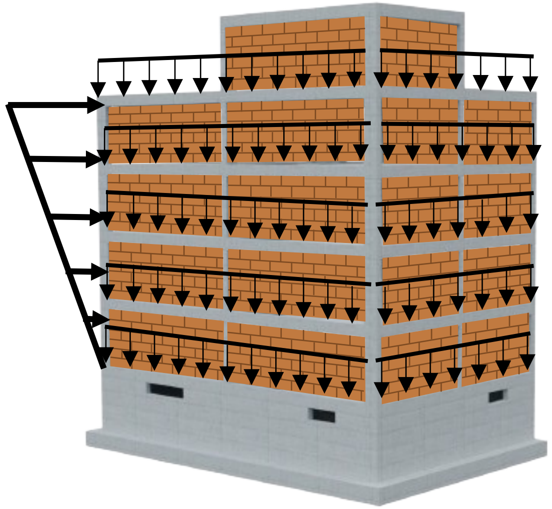
- Design space considerations through identification of the geographic construction practice

Pre-1970s (GLD)



- Gravity loads only
- Allowable stress method (RD 2229/39)
- Smooth rebars with a low yield strength (≈ 325 MPa)
- Concrete with low compressive strength (≈ 25 MPa)
- Low shear reinforcement ratios
- Inadequate detailing of beam-column joints
- Frames spanning in one direction

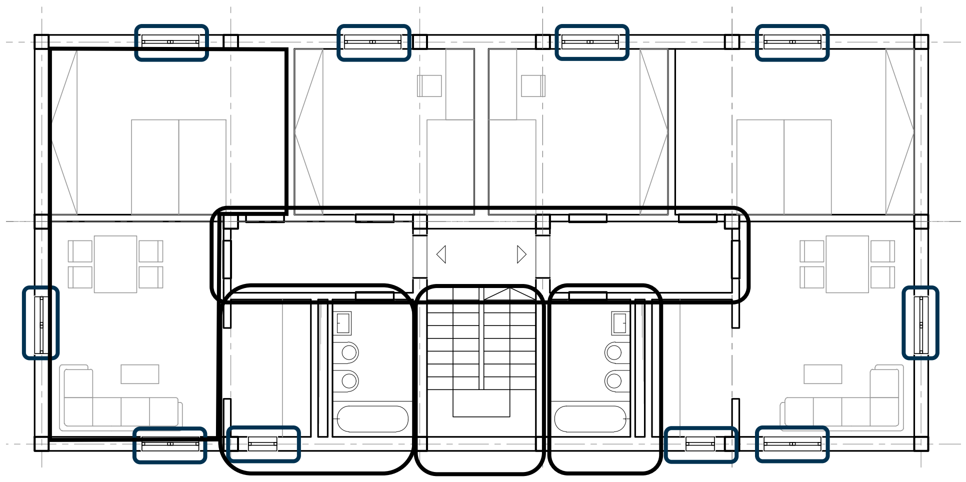
- ELF method (Seismic coefficient 5-10%)
- Allowable stress method
- Deformed rebars with typical yield strength (≈ 430 MPa)
- Concrete with moderate compressive strength (≈ 28 MPa)
- Low shear reinforcement ratios
- Frames spanning in one (or both) direction



1970s-1980s (SSD)

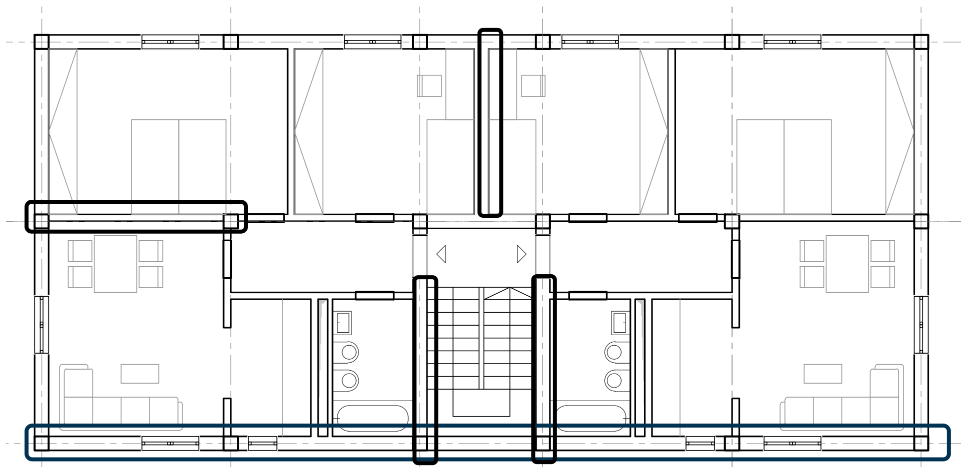
Database of Archetype Numerical Models

- Geometric configuration and architectural features selected to reflect the function and form of the Italian design space over different building periods
- Expert architectural judgment following numerous consultation with practitioners and architects
- Features include:
    - Narrow hallways and corridors in dwellings, generally 150 cm wide
    - Adjacent kitchens and bathrooms
    - Plumbing fixtures (e.g. bathtubs, sinks and bidets) installed based on optimized space allocation
    - Adequate separation of the day and night living spaces
    - Windows with widths in multiples of 45 or 60 cm
    - Staircase width not exceeding 3 m (i.e. wide enough to allow the passage of two people) and landings depth not exceeding 1.3 m



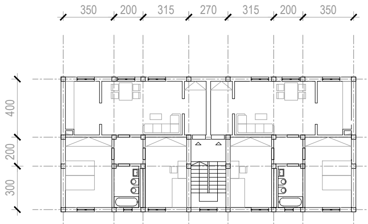
Database of Archetype Numerical Models

- Geometric configuration and architectural features selected to reflect the function and form of the Italian design space over different building periods
- Expert architectural judgment following numerous consultation with practitioners and architects
- Features include:
  - Double-leaf masonry infills for thermal and acoustic insulation and fire-retarding
  - 24 cm infill panels for perimeter walls of the façade
  - 30 cm infill panels for the separation of dwellings and encasing of the staircase
  - 80 mm single-leaf masonry infills for Internal partitioning

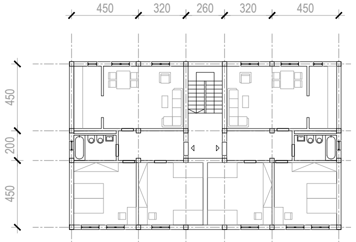


Database of Archetype Numerical Models

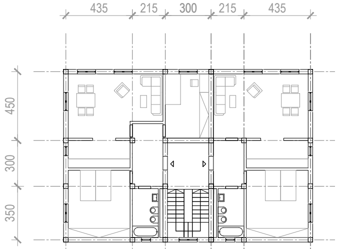
Architectural Layouts



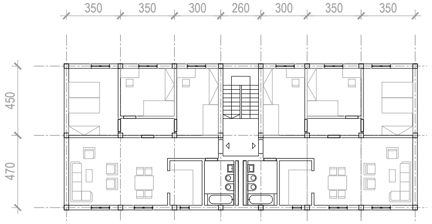
Archetype A



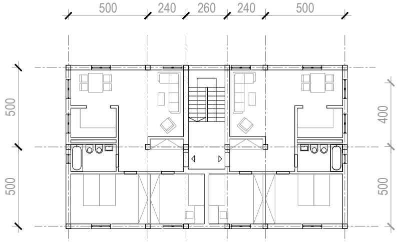
Archetype B



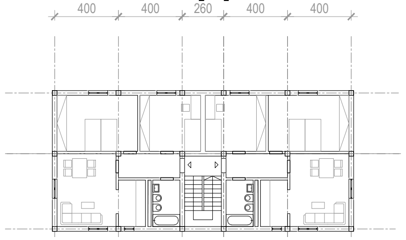
Archetype C



Archetype D



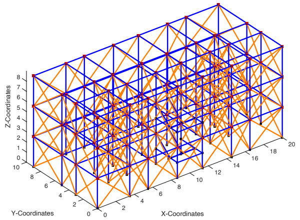
Archetype E

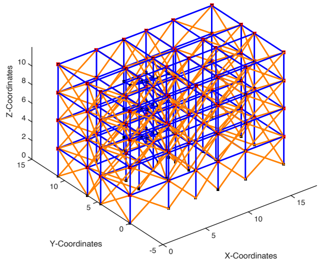


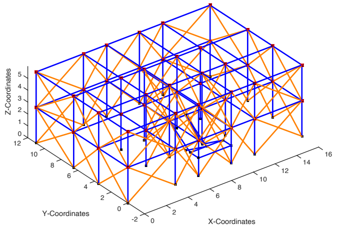
Archetype F

Archetype G

Numerical Models


Archetype A


Archetype B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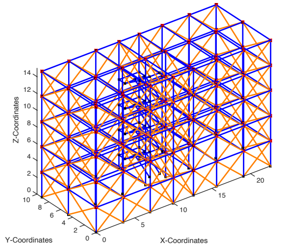
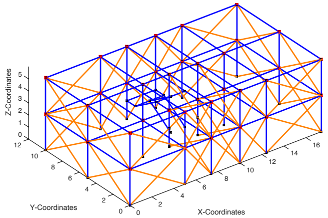
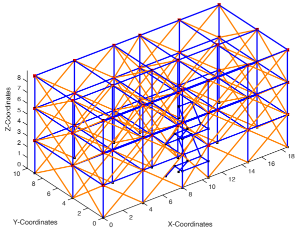
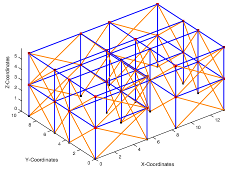

Archetype D


Archetype E


Archetype F


Archetype G

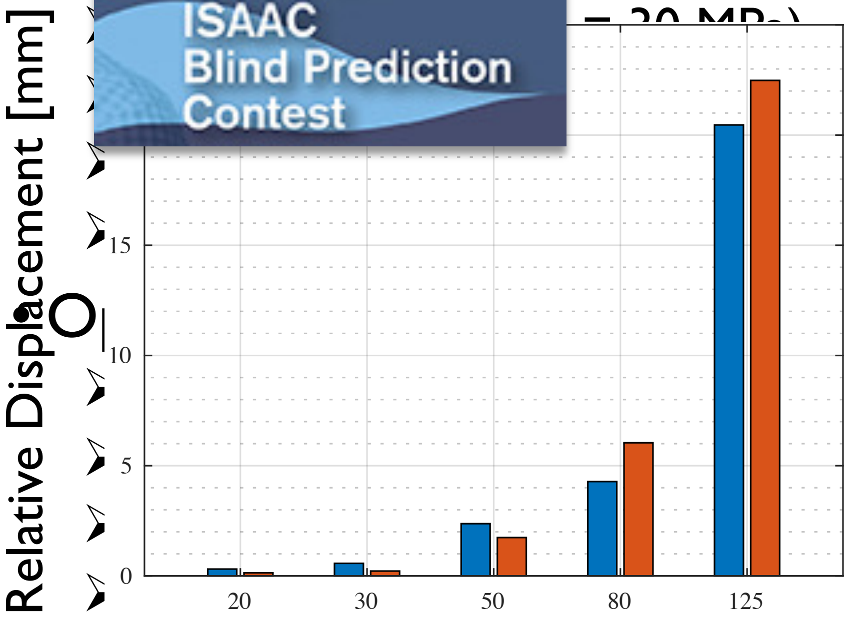
Database of Archetype Numerical Models

- Database Availability
  - Open-access and available on GitHub: https://github.com/gerardjoreilly/Infilled-RC-Building-Database
  - Versatile and customizable
  - Hazard-consistent ground-motion records representative of
    - ➢ Low Hazard (Milano)
    - ➢ Moderate Hazard (Napoli)
    - ➢ High Hazard (L'Aquila)
    - ➢ Conditioned on *Sa*(T=0.2-0.6s)
    - ➢ Conditioned on Sa_{avg} (T=0.2-0.6s)
  - Master files for running
    - ➢ Static and quasi-static procedures: SPO and CPO
    - ➢ Nonlinear time-history analyses: IDA and MSA

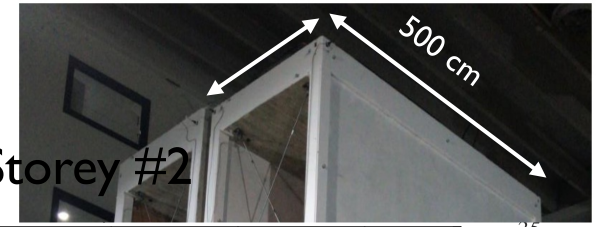
Validation via Blind Prediction Contest

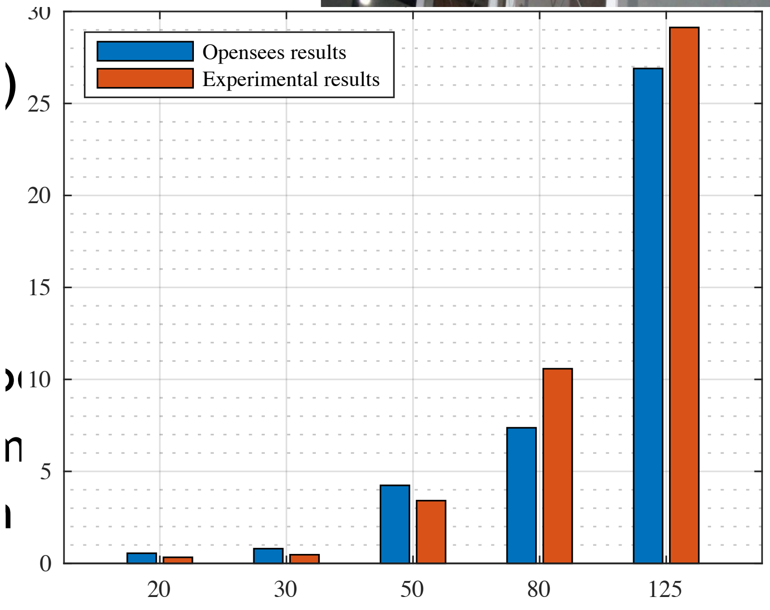
RC building

20 MPa, F_u = 450 MPa)

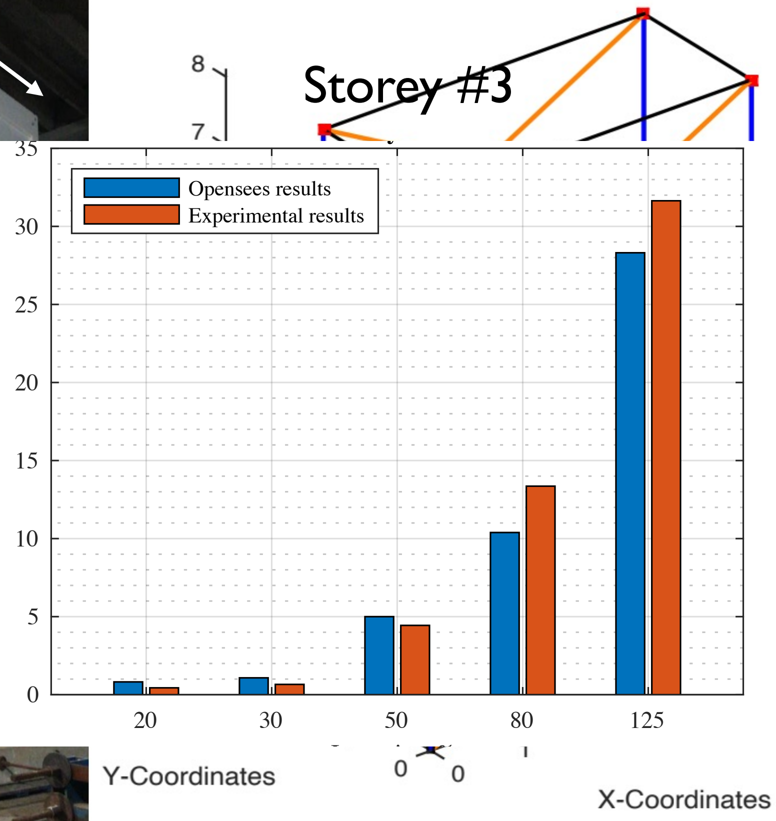


Storey #2





Storey #3



Intensity %

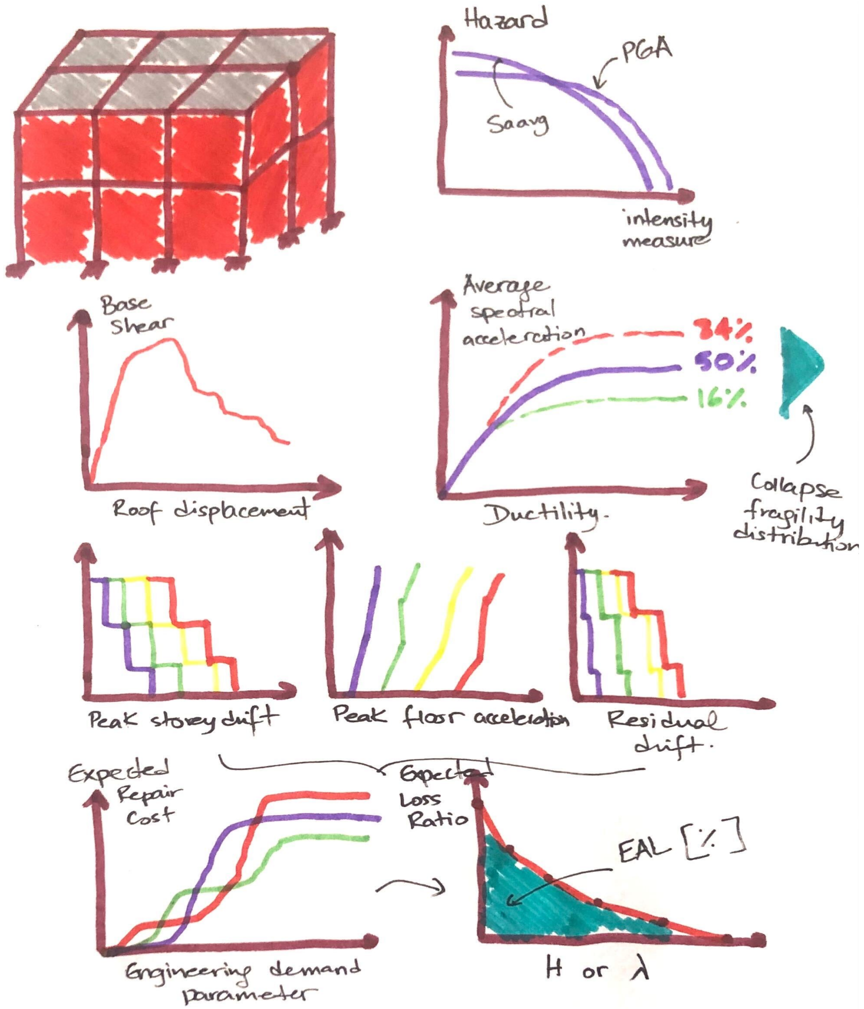
Experimental Setup

OpenSees Model

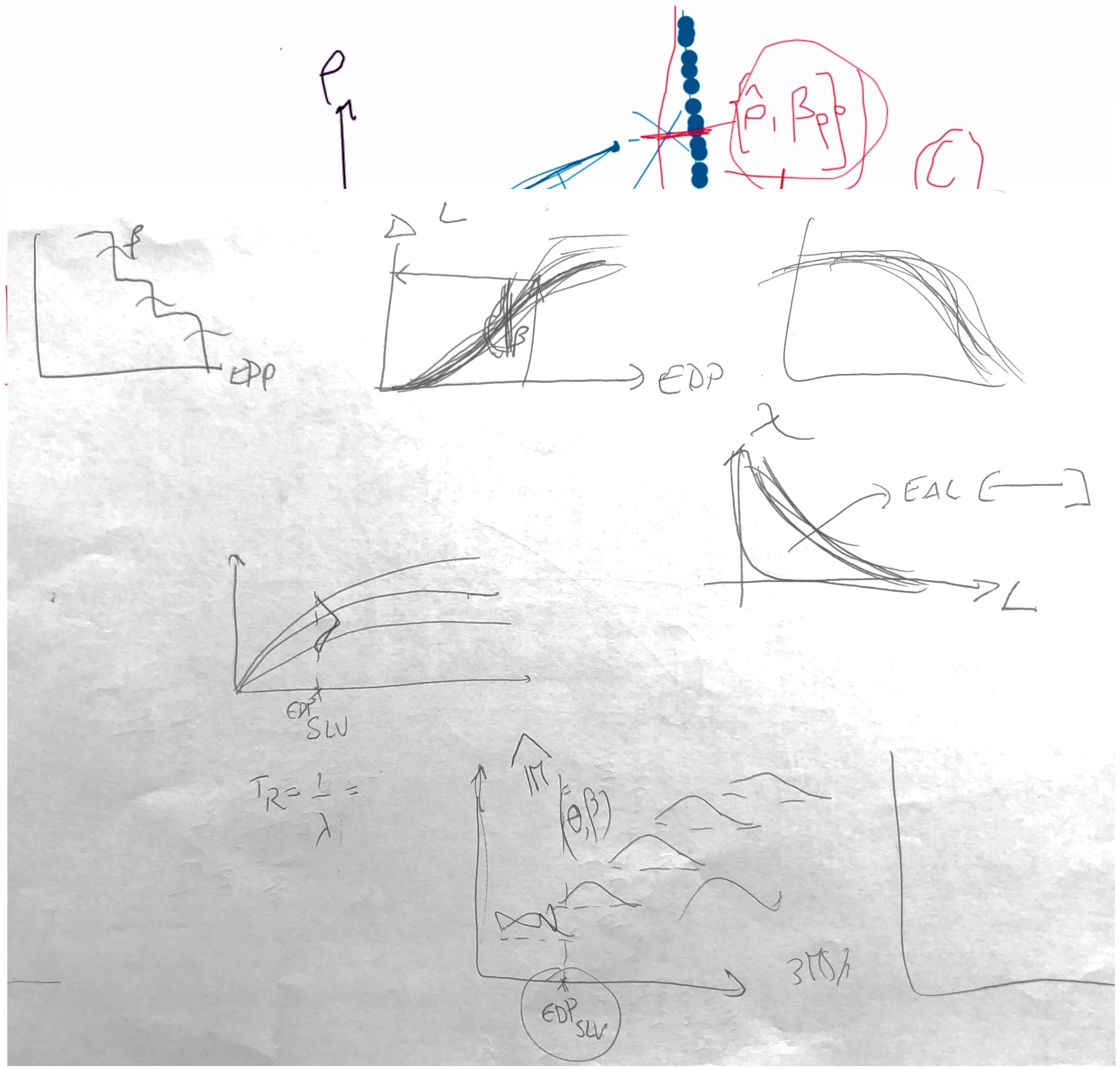
Simplified Loss-Based Approach for the Seismic Risk Classification of Existing Infilled RC Buildings (PB-Loss)

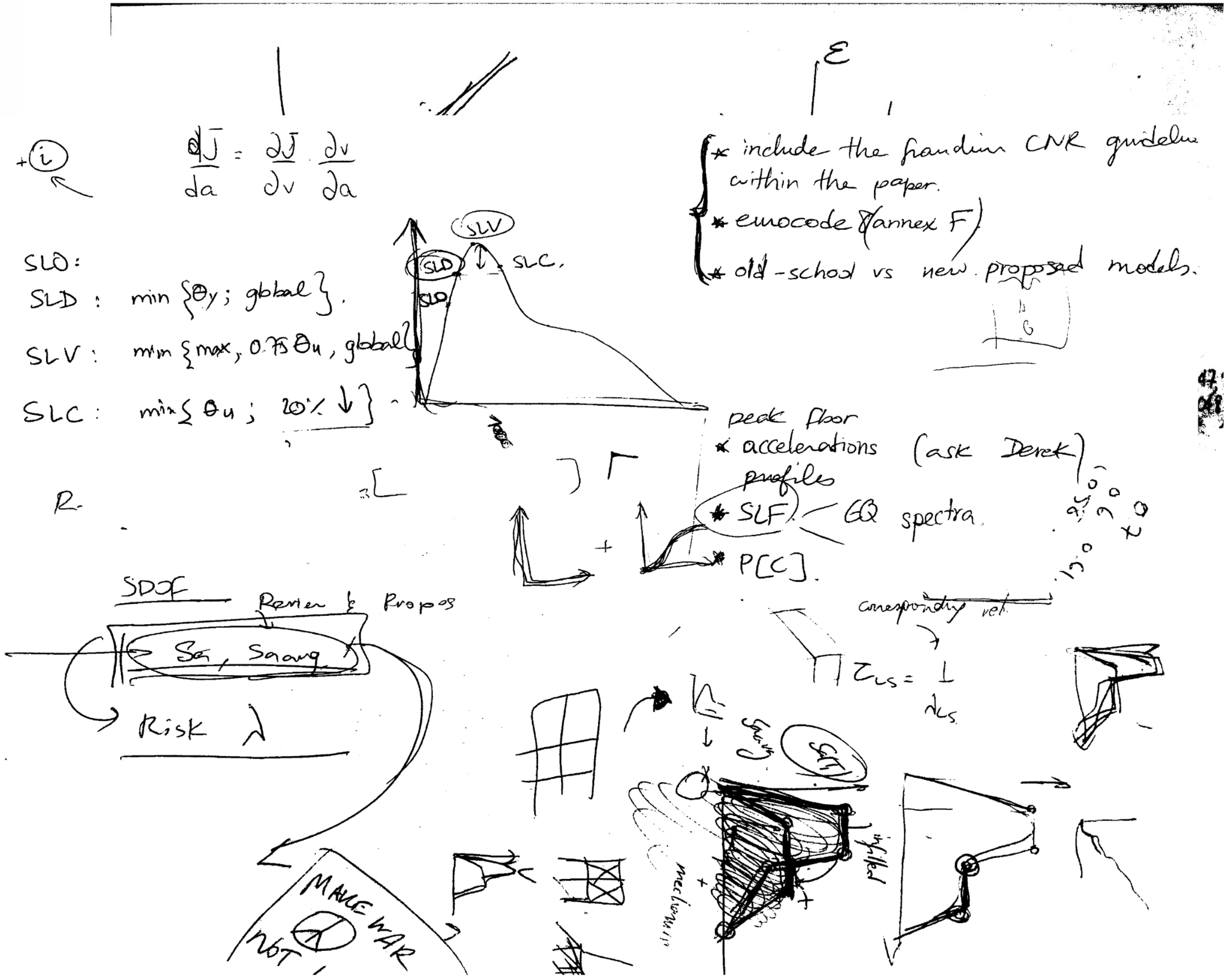
Nafeh, A.M.B. & O'Reilly, G.J.,

- *Unbiased simplified seismic fragility estimation of non-ductile infilled RC structures, Soil Dynamics and Earthquake Engineering, Volume 157, 2022, 107253, ISSN 0267-7261,* https://doi.org/10.1016/j.soildyn.2022.107253.
- *Simplified pushover-based seismic loss assessment for existing infilled frame structures. Bull Earthquake Eng* ***22****, 951–995 (2024).* https://doi.org/10.1007/s10518-023-01792-x
- *Simplified pushover-based seismic risk assessment methodology for existing infilled frame structures. Bull Earthquake Eng* ***21****, 2337–2368 (2023). https://doi.org/10.1007/s10518-022-01600-y*

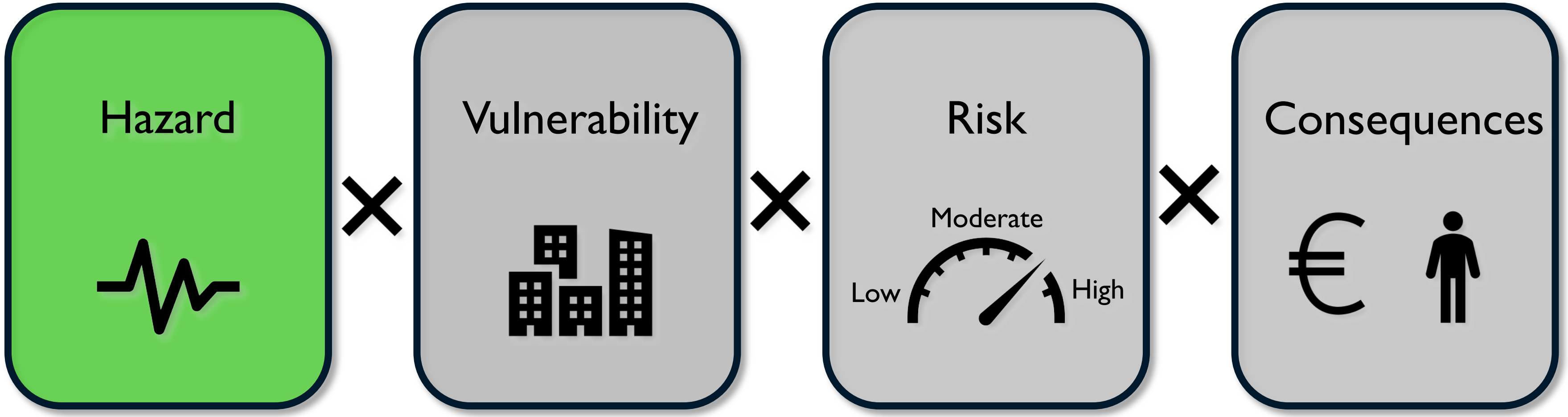


PB-Loss: Concept Doodles





PB-Loss: Hazard



Fundamental components of performance-based earthquake assessment

PB-Loss: Code-Based IMLs

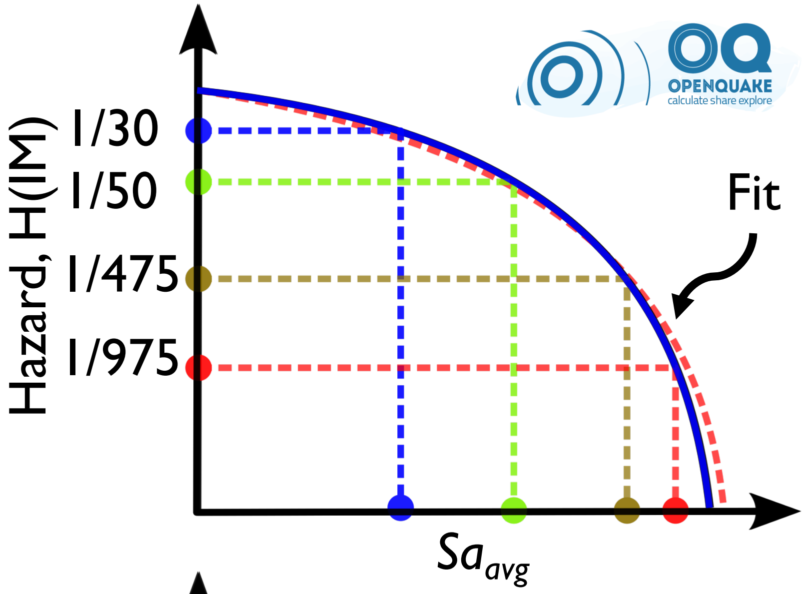
Hazard

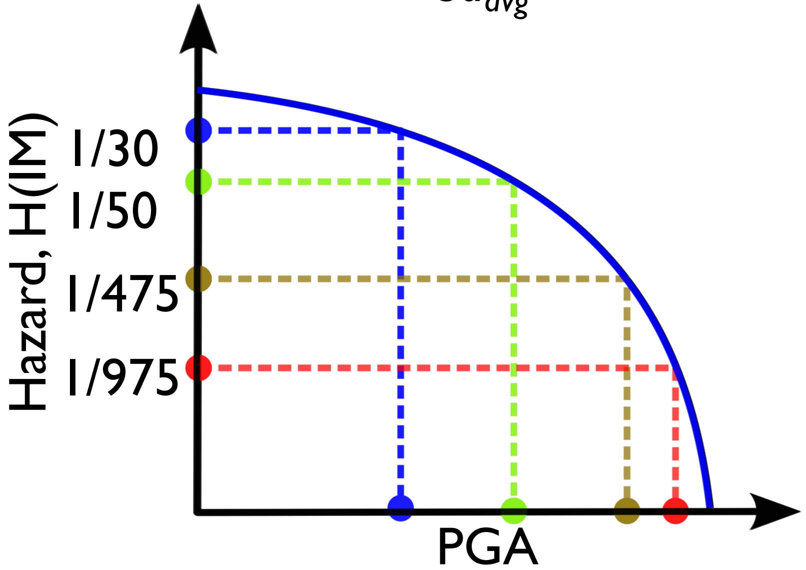
1. Mean average spectral acceleration (Sa_{avg}) hazard curve
2. Mean peak ground acceleration (PGA) hazard curve
3. Identify the intensity levels (*im*) corresponding to the code-based return periods, T_R

$$H(\mathrm{IM} = \mathrm{im}) = 1/T_R$$

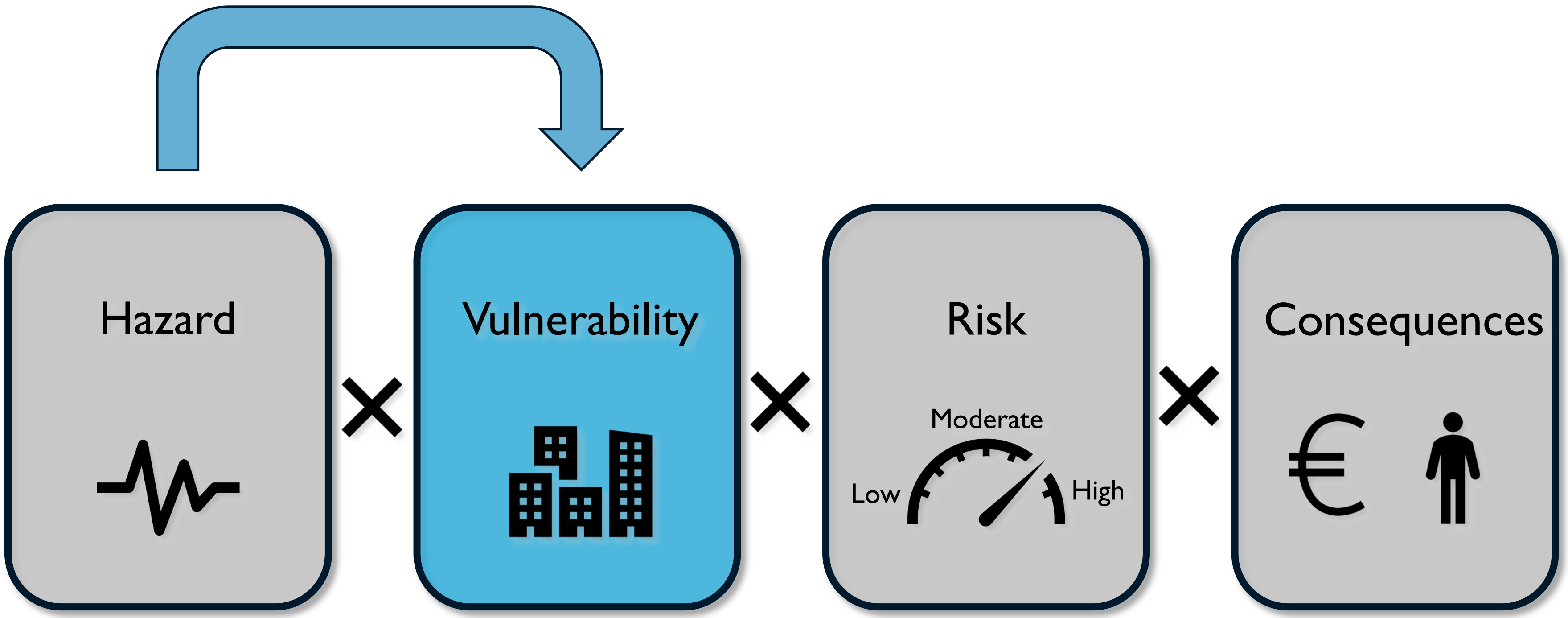
4. Second-order fitting to the Sa_{avg} hazard curve:

$$H(\mathrm{IM}) = k_0 \exp\left[-k_2 \ln^2(\mathrm{IM}) - k_1 \ln(\mathrm{IM})\right]$$





PB-Loss: Vulnerability

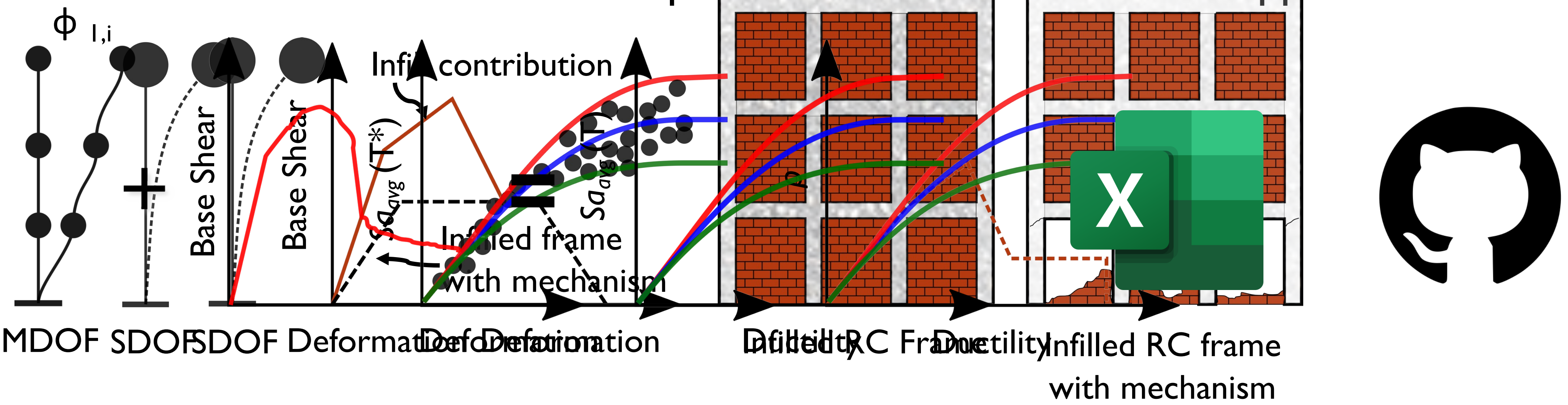


Fundamental components of performance-based earthquake assessment

PB-Loss: Estimation of Dynamic Capacity

Vulnerability

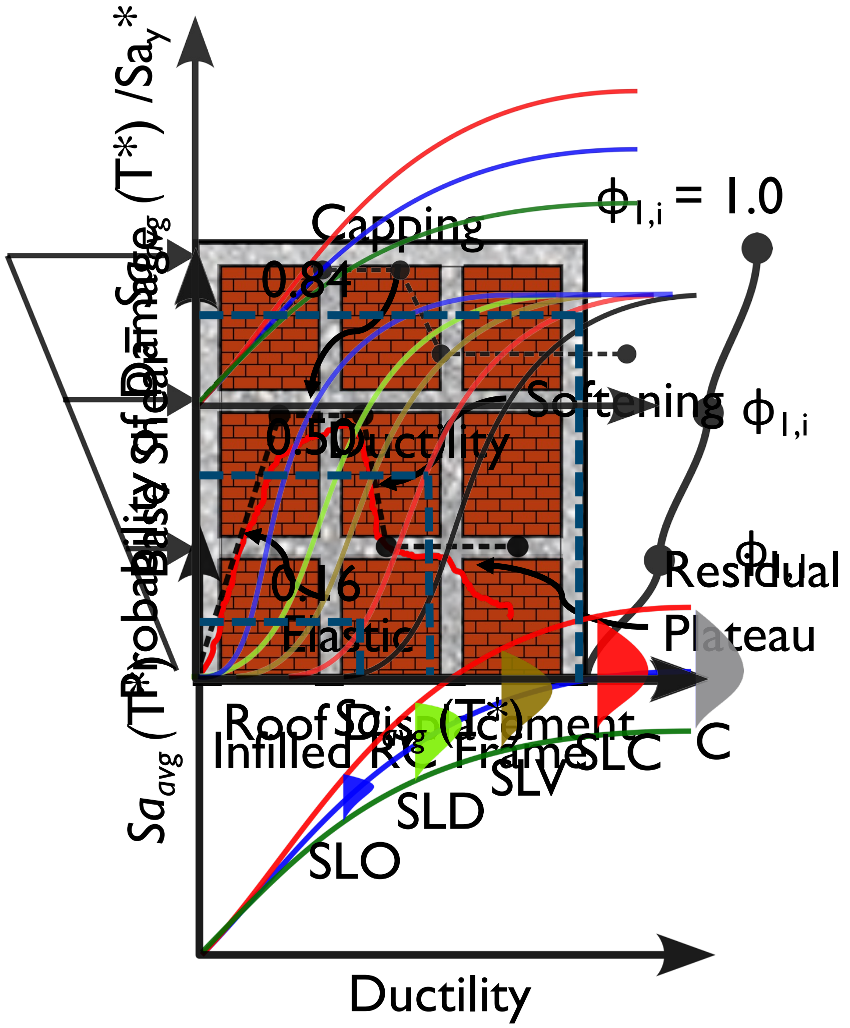
- Pushover-based tool for the direct estimation of the seismic demand and capacity of infilled RC structures with multi-linear response using Sa_{avg} as IM
- Integrates ***ρ-μ***-T relationships calibrated on a series of cloud analysis on a large dataset of sampled equivalent SDOF oscillators
- Requires low-level input (modal analysis and SPO results) to estimate probabilistically the dynamic capacity of an MDOF system
- Tool available on GitHub in Excel spreadsheet format for ease of application



PB-Loss: Estimation of Dynamic Capacity

Vulnerability

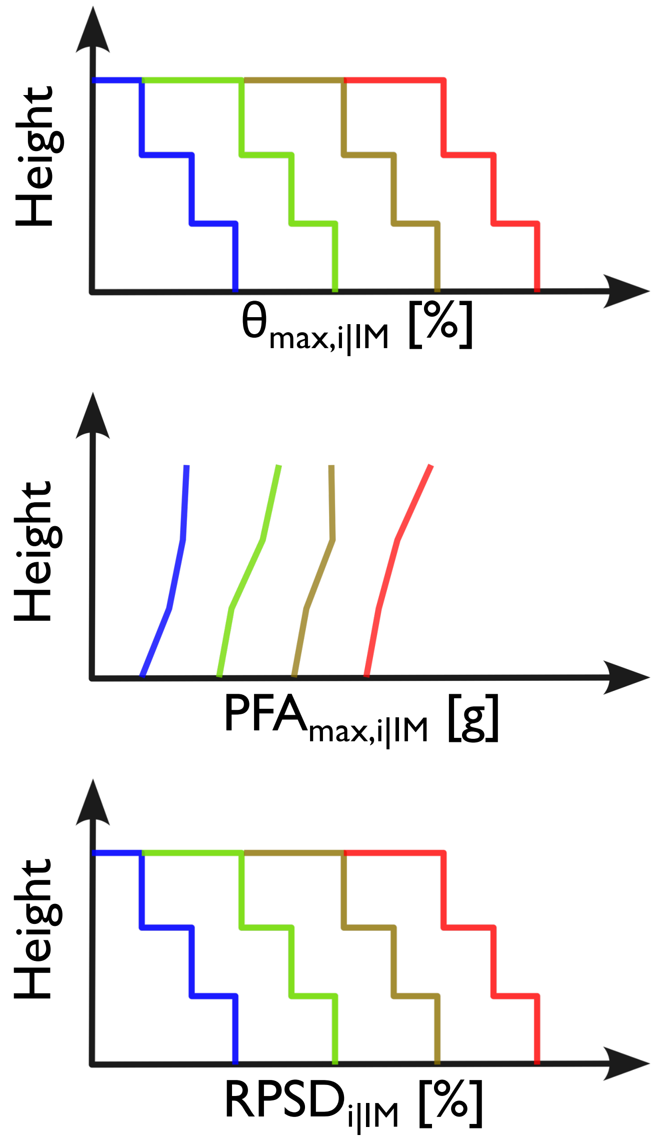
1. Build a sufficiently detailed numerical model
2. Perform a modal analysis to obtain the normalized first mode-shape ordinates, $\phi_{1,i}$
3. Perform static pushover analysis to characterize the lateral response of the case study building
4. Multi-linearise the SPO curve indicating the onset and end of each response branch
5. The dynamic capacity of the system is directly estimated via the integrated strength-deformation relationships



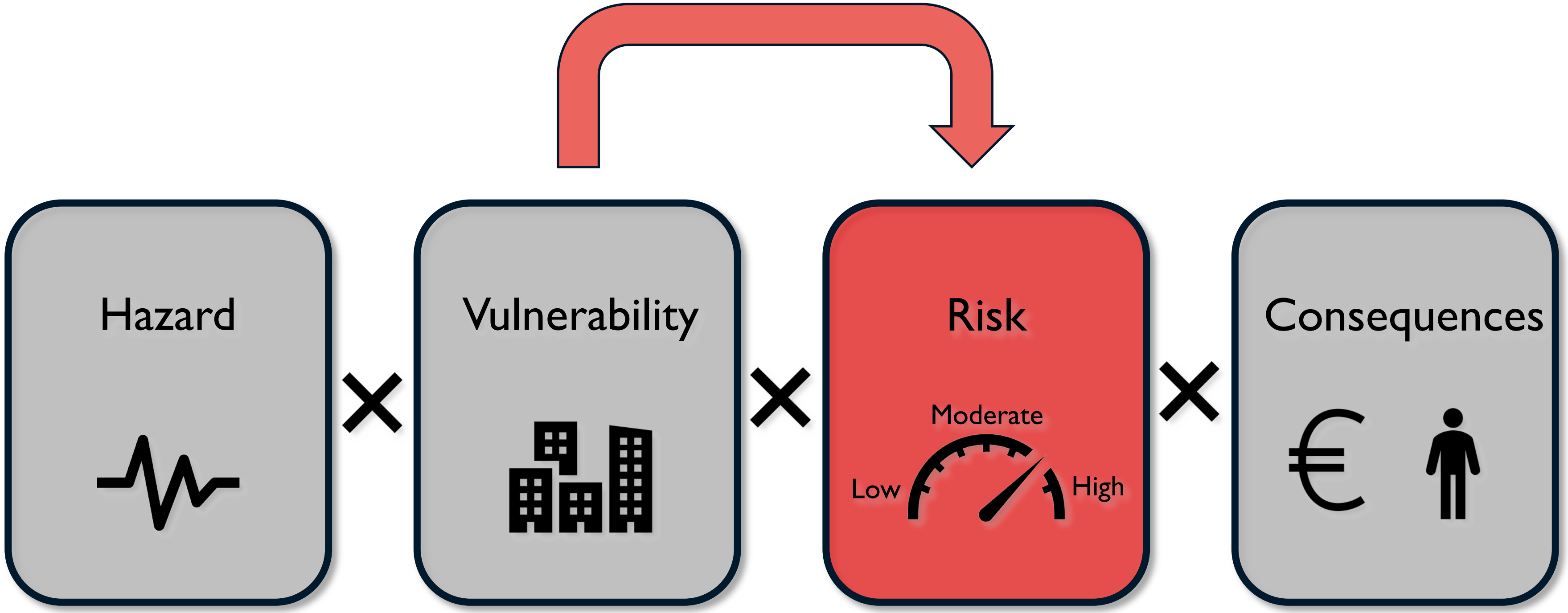
PB-Loss: Estimation of Seismic Demands

Vulnerability

6. Peak storey drifts ($\theta_{max,i|IM}$) using first-mode approximation
7. Peak floor accelerations ($PFA_{max,i|im}$) using deformation-dependent empirical functions (Muho *et al.* 2021)
8. Residual peak storey drifts ($RPSD_{i|IM}$) using FEMA P-58 approximation method



PB-Loss: Collapse Risk



Fundamental components of performance-based earthquake assessment

PB-Loss: Collapse Risk

1. IM-based SAC/FEMA approach (Vamvatsikos 2013) for the direct estimation of collapse risk or λ_C

$$\underbrace{\lambda_C}_{\text{MAFC}} = \sqrt{p}\,k_0^{1-p}\underbrace{\left[H\left(\overbrace{\widehat{Sa}_{avg,C}}^{\text{Median Collapse Intensity}}\right)\right]}_{\text{Annual Rate of Exceedance}}^{p} exp\left[\frac{1}{2}pk_1^2\overbrace{\beta_C^2}^{\text{Dispersion}}\right]$$

$$p = \frac{1}{1 + 2k_2\underbrace{\beta_C^2}_{\text{Dispersion}}}$$

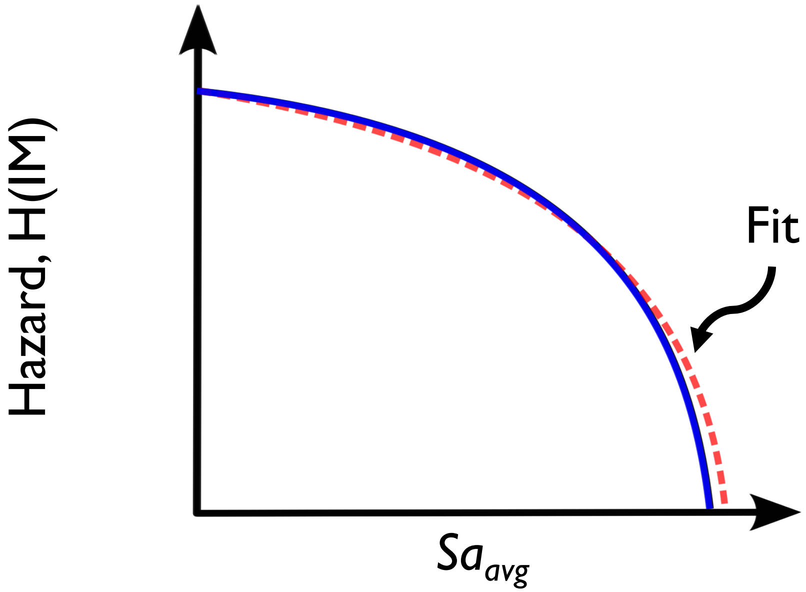
Seismic Risk

- *Vamvatsikos, D. (2013), Derivation of new SAC/FEMA performance evaluation solutions with second-order hazard approximation. Earthquake Engng Struct. Dyn., 42: 1171-1188.* https://doi.org/10.1002/eqe.2265

Recall

- Second-order approximation was fitted to the Sa_{avg} hazard curve and k_0, k_1 and k_2 are the fitting coefficients

$$H(IM) = k_0 \exp\left[-k_2 \ln^2(IM) - k_1 \ln(IM)\right]$$

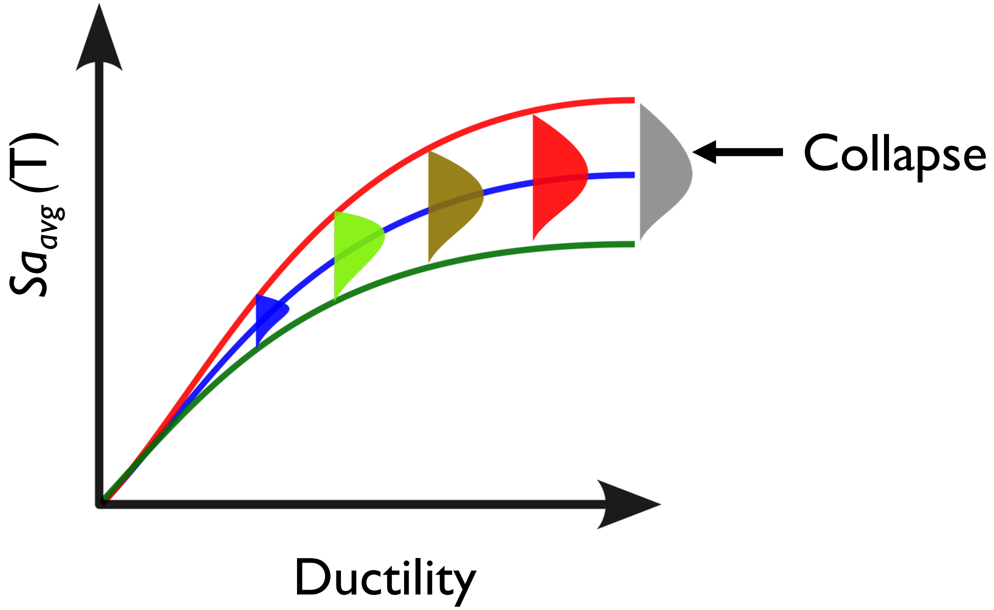


PB-Loss: Vulnerability

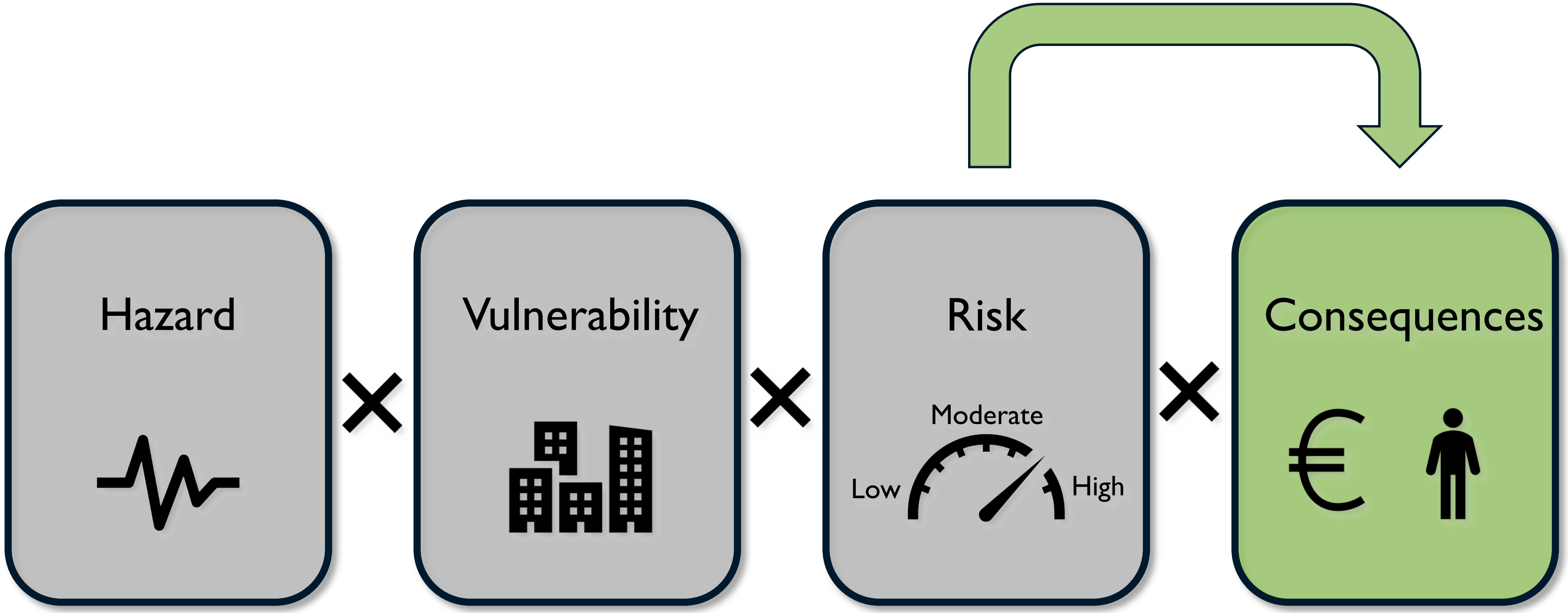
Recall

- Recall: the median collapse intensity and associated dispersion are directly estimated via the response estimation tool

$$\widehat{Sa}_{avg,C}, \beta_C$$



PB-Loss: Consequences



Fundamental components of performance-based earthquake assessment

PB-Loss: Estimation of Direct Economic Losses

Economic

Losses

€

- Building-specific direct economic losses are typically expressed in terms of the expected annual loss (EAL)
- The EAL is evaluated by integrating the vulnerability curves with the site hazard

$$EAL = \int \underbrace{E[L_T|IM = im]}_{\text{Expected loss @ limit state IM}} \left|\frac{dH(IM > im)}{dim}\right| dim$$

PB-Loss: Estimation of Direct Economic Losses

Economic

Losses

€

$$E[L_T|IM] =$$

Non-collapse requiring repair

$$E[L_T|NC \cap R, IM](1 - P[D|NC, IM])(1 - P[C|IM])$$

$$+$$

Non-collapse requiring demolition

$$E[L_T|NC \cap D]P[D|NC, IM](1 - P[C|IM])$$

$$+$$

Total replacement due to collapse

$$E[L_T|C]P[C|IM]$$

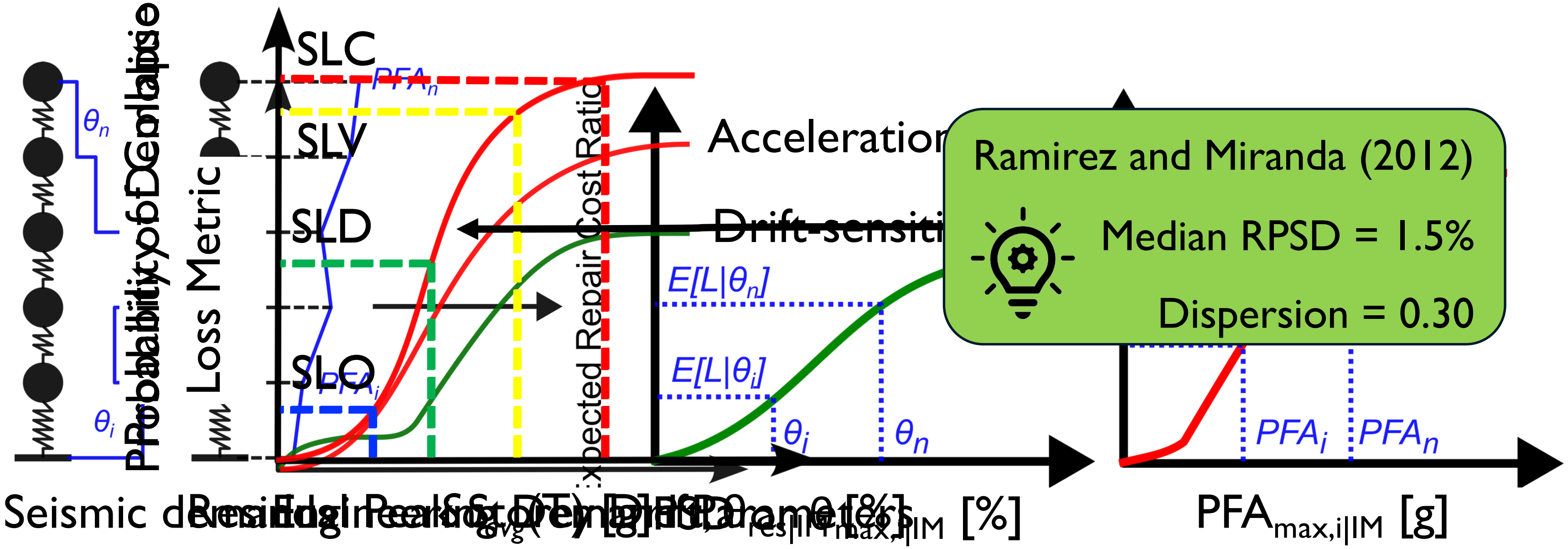
PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Non-collapse requiring repair

$$\underbrace{E[L_T|NC \cap R, IM]}_{\text{Repair Costs}}\underbrace{(1 - P[D|NC, IM])}_{\text{Probability of no-demolition}}\underbrace{(1 - P[C|IM])}_{\text{Probability of no-collapse}}$$



Ramirez and Miranda (2012)

Median RPSD = 1.5%

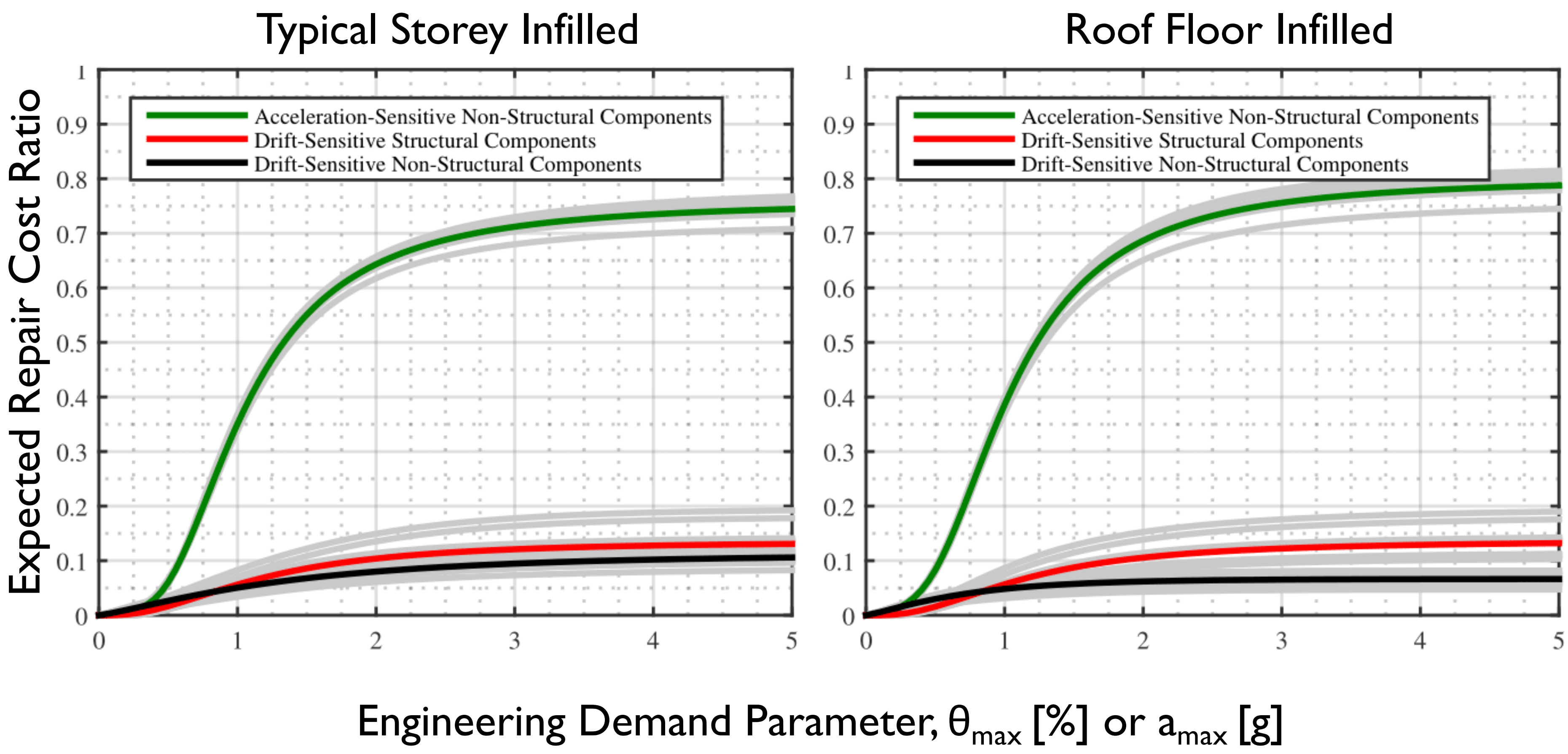
Dispersion = 0.30

PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Non-collapse requiring repair

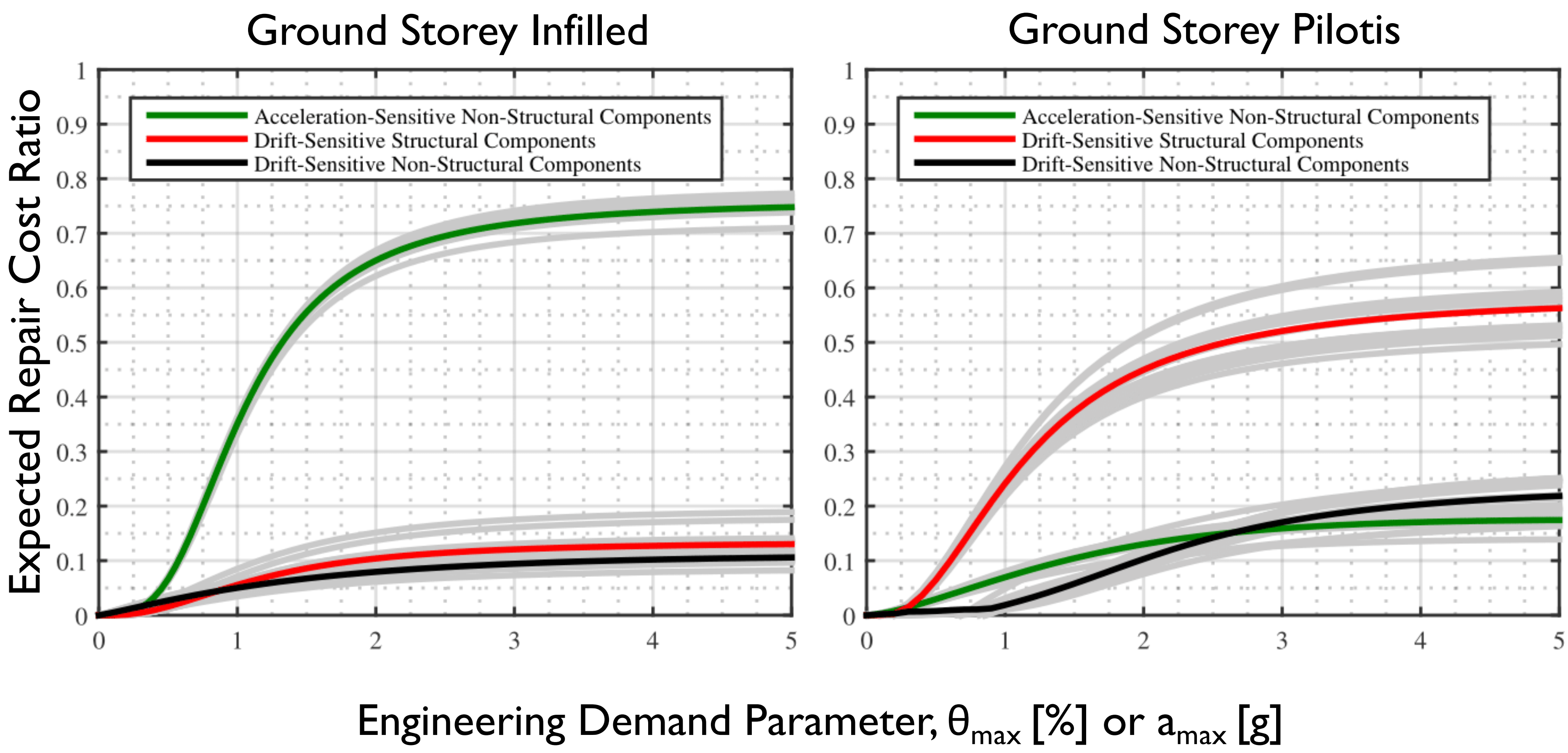


PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Non-collapse requiring repair



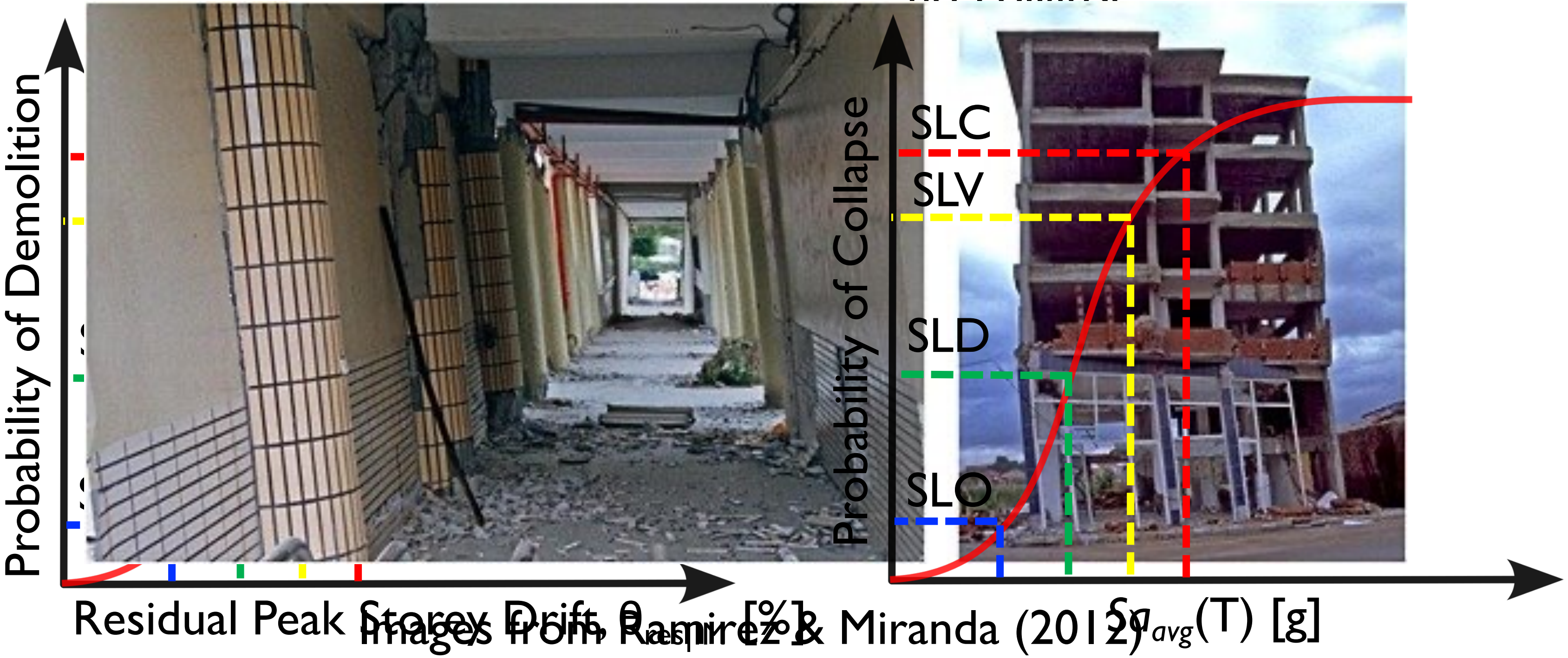
PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Non-collapse requiring demolition

$$\underbrace{E[L_T|NC \cap D]}_{\text{Demolition costs}}\underbrace{P[D|NC, IM]}_{\text{Probability of demolition}}\underbrace{(1 - P[C|IM])}_{\text{Probability of no-collapse}}$$



Images from Ramirez & Miranda (2012)

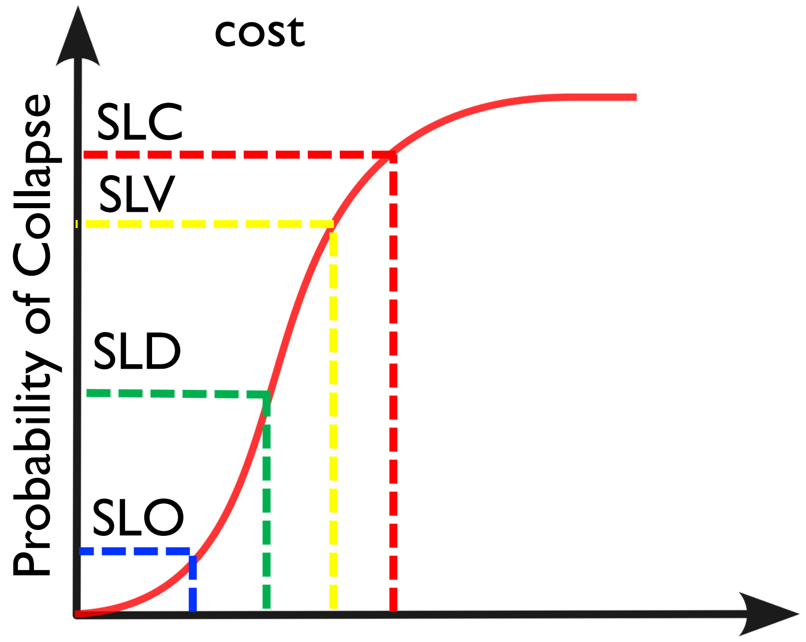
PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Collapse requiring total replacement

$$\underbrace{E[L_T|C]}_{\text{Total replacement cost}}\ \underbrace{P[C|IM]}_{\text{Probability of collapse}}$$

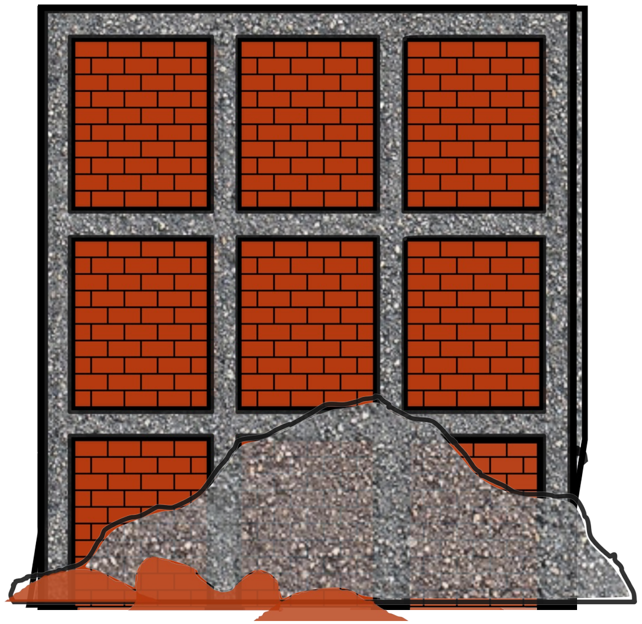


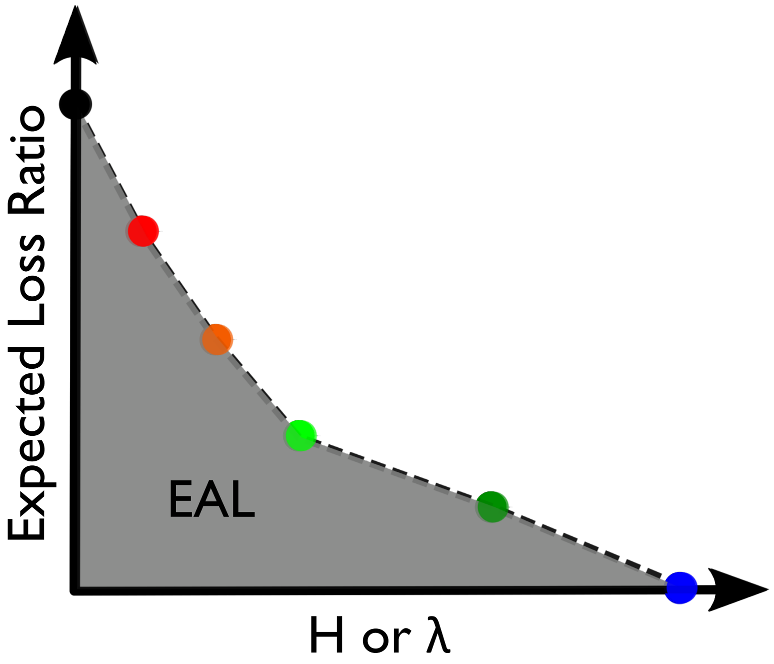
PB-Loss: Estimation of Direct Economic Losses

Economic Losses

€

- Building the Loss Curve and EAL





Zero-Loss (Undamaged)
- H = 0.01
- $E[L_T|ZL]$ = 0.0

SLO: Operational
- H = 0.033
- $E[L_T|SLO]$

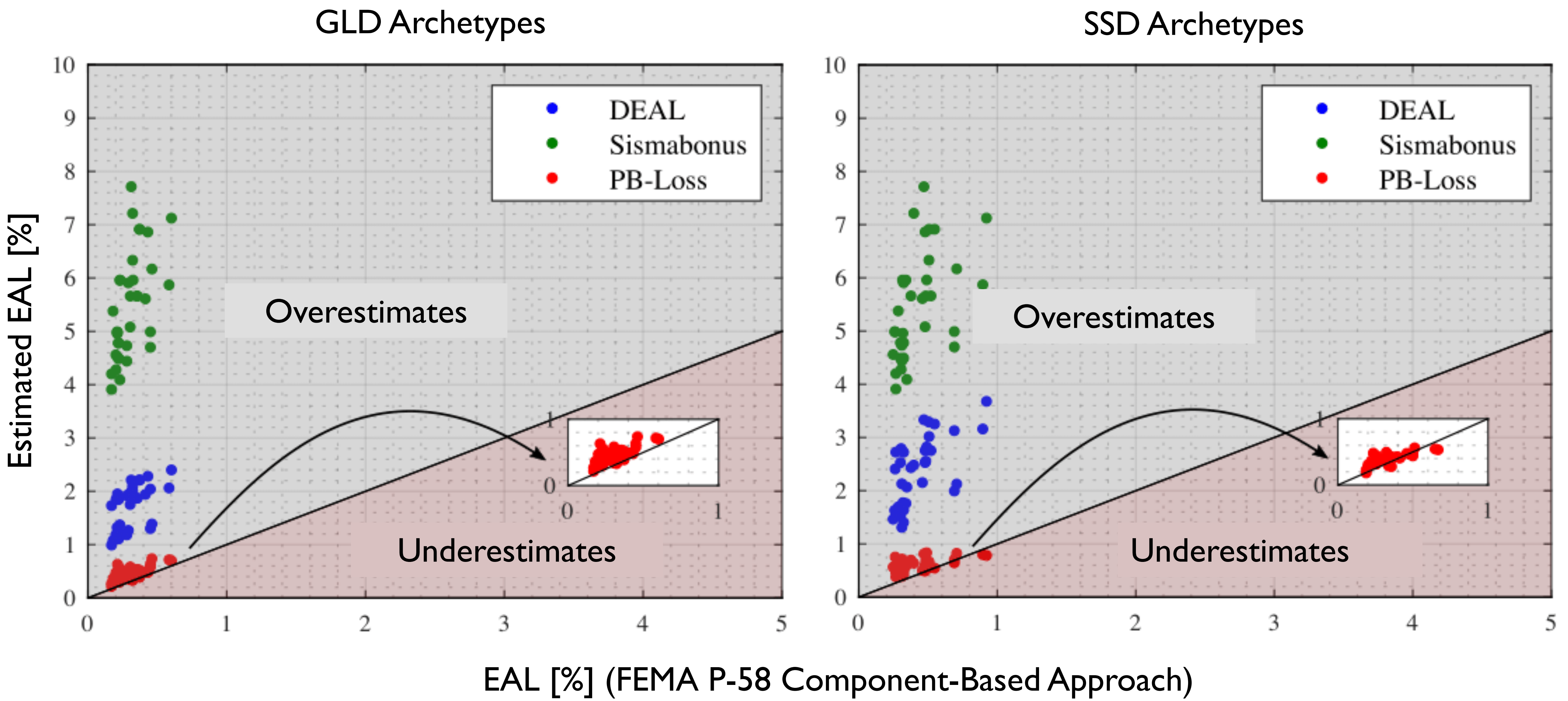
SLD: Damage Limitation
- H = 0.020
- $E[L_T|SLD]$

SLV: Life-Safety
- H = 0.0021
- $E[L_T|SLV]$

SLC: Collapse Prevention
- H=0.0010
- $E[L_T|SLC]$

Collapse
- λ_C
- $E[L_T|C]$ = 1.0

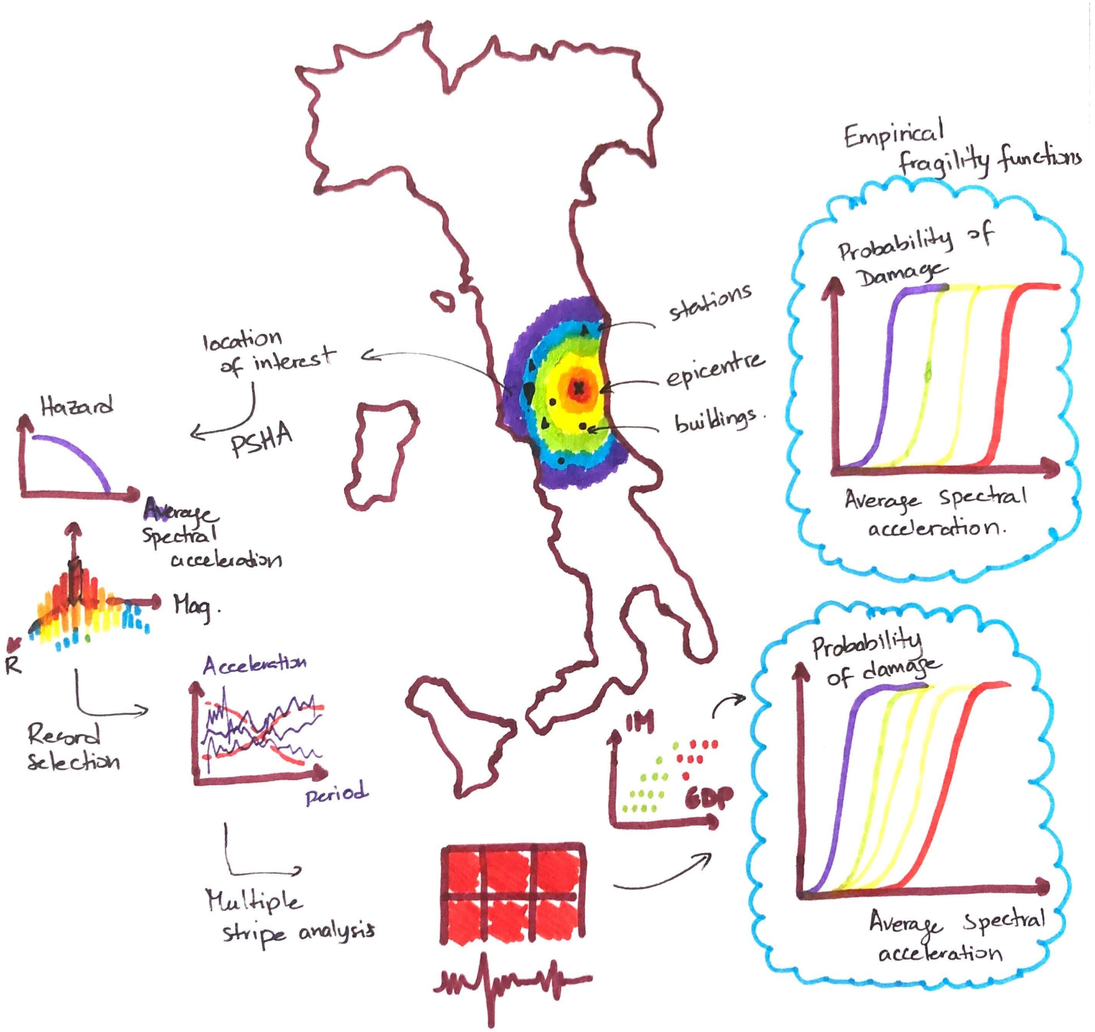
PB-Loss: Validation



Next-Generation-IM-based Fragility Functions for the Regional Assessment of Existing Infilled RC Buildings

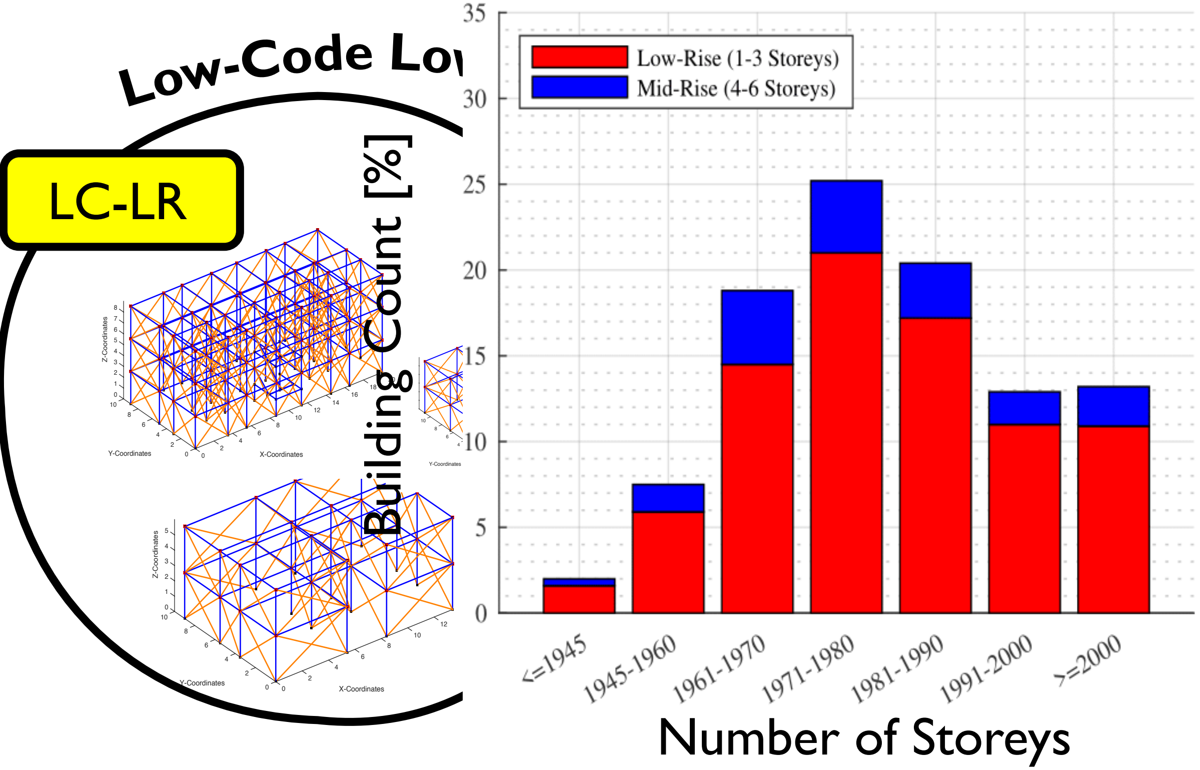
Nafeh, A.M.B. & O'Reilly, G.J.,

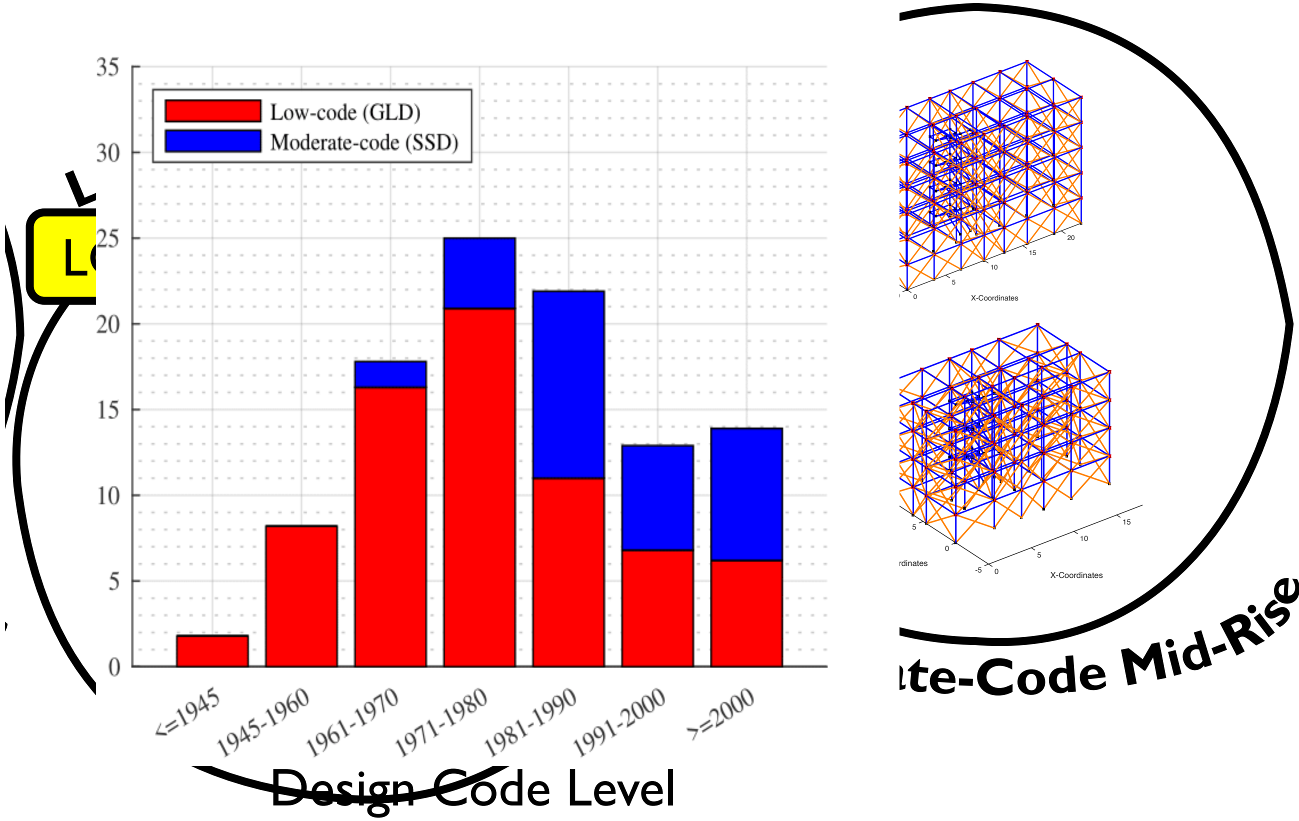
- *Fragility functions for non-ductile infilled reinforced concrete buildings using next-generation intensity measures based on analytical models and empirical data from past earthquakes (Under Review)*



Regional Assessment: Definition of Building Classes

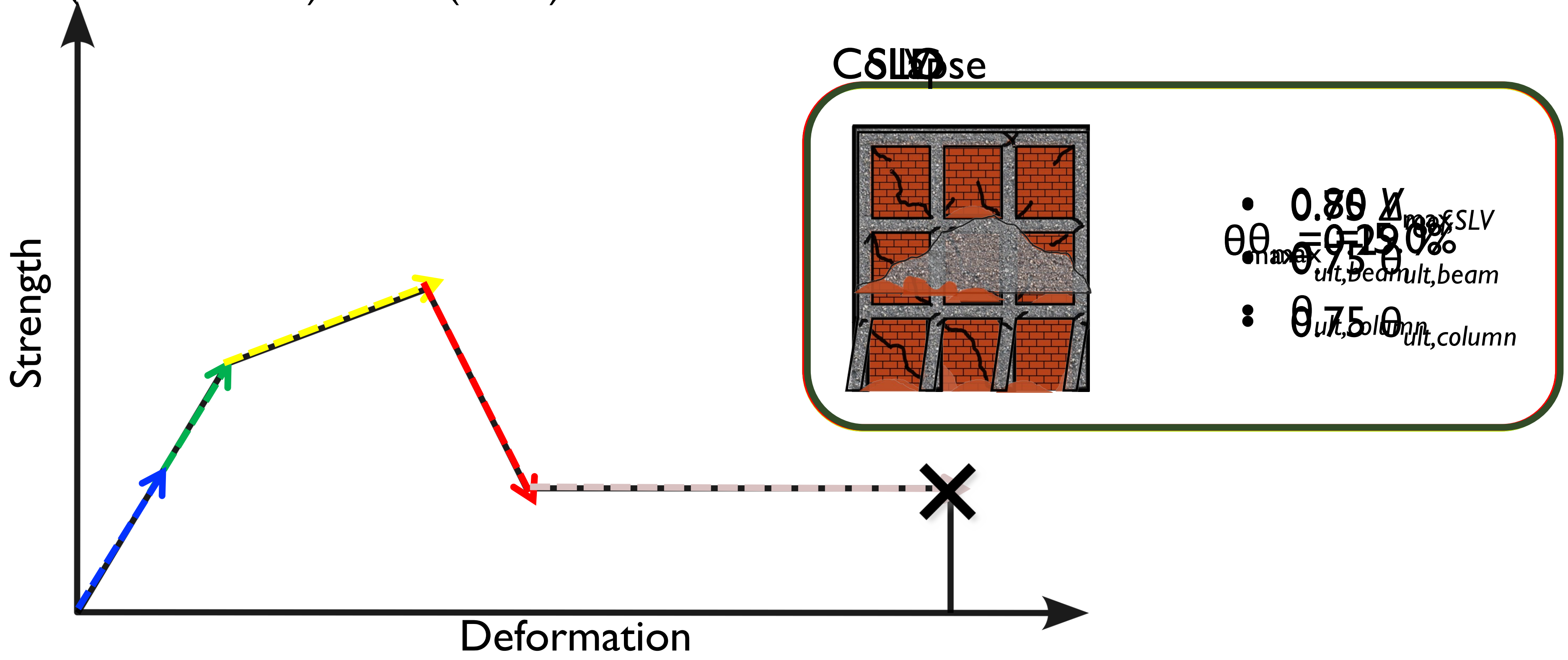
- The definition of a building class is a key step towards assessing seismic risk.
- Building classes must be defined using building attributes relevant to seismic vulnerability





Regional Assessment: Definition of DSs Thresholds

- A hybrid definition of the damage state thresholds was considered
  - Serviceability Limit States (SLO and SLD): Kurukulasuriya *et al.* (2022)
  - Ultimate Limit States (SLV and SLC): NTC (2018)



- *Kurukulasuriya et al. (2022) Investigation of seismic behaviour of existing masonry infills through combined cyclic in-plane and dynamic out-of-plane tests, 9th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering Methods in Structural Dynamics and Earthquake Engineering*

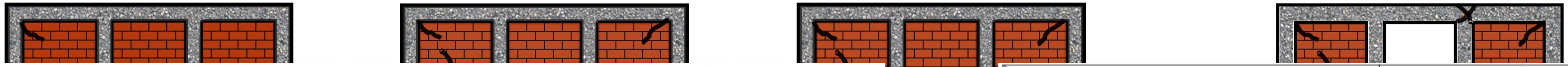
- An objective-based relationship between analytical and empirical DS was assumed to ensure a consistent verification of FFs

Quantitative Damage States

Norme Tecniche Per Le Costruzioni (2018)

Qualitative Damage States

Agibilità e Danno nell' Emergenza Sismica



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Spediz. abb. post. - art. 1, comma 1
Legge 27-02-2004, n. 46 - Filiale di Roma

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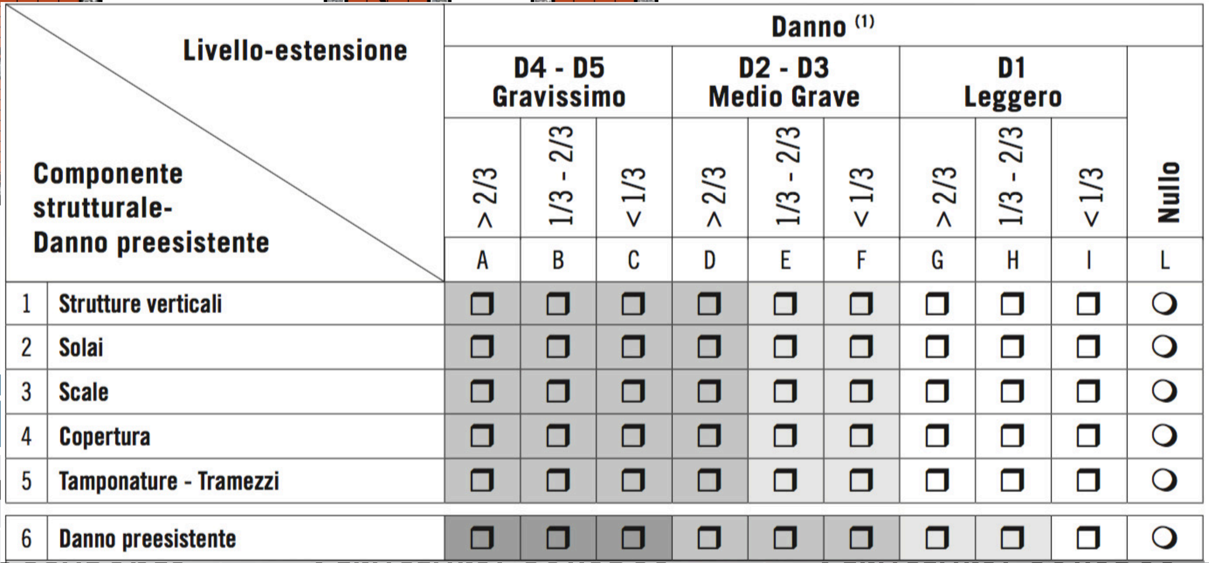
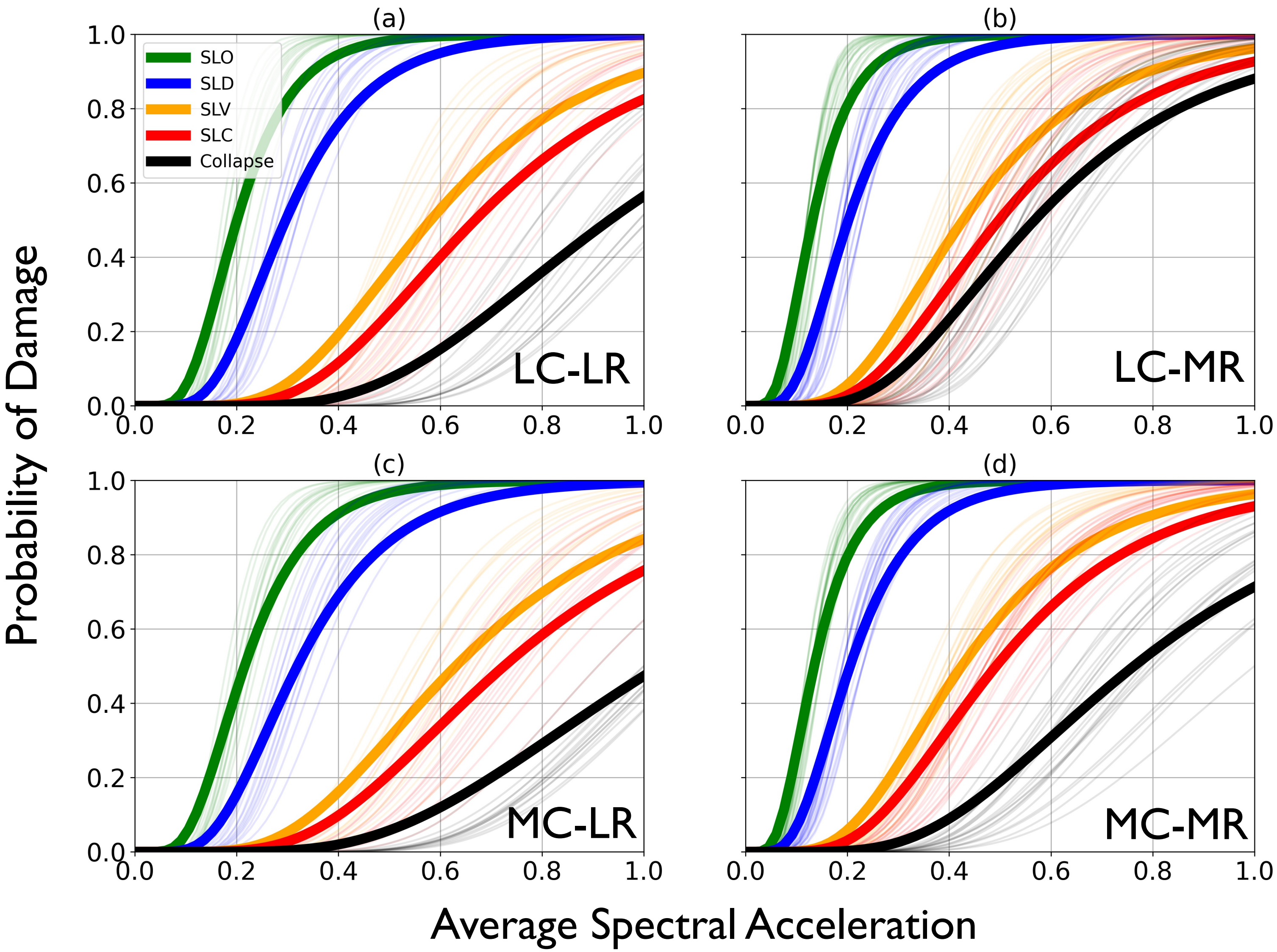


Livello-estensione / Componente strutturale-Danno preesistente		Danno (1)									
		D4 - D5 Gravissimo			D2 - D3 Medio Grave			D1 Leggero			Nullo
		> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	
		A	B	C	D	E	F	G	H	I	L
1	Strutture verticali	☐	☐	☐	☐	☐	☐	☐	☐	☐	○
2	Solai	☐	☐	☐	☐	☐	☐	☐	☐	☐	○
3	Scale	☐	☐	☐	☐	☐	☐	☐	☐	☐	○
4	Copertura	☐	☐	☐	☐	☐	☐	☐	☐	☐	○
5	Tamponature - Tramezzi	☐	☐	☐	☐	☐	☐	☐	☐	☐	○
6	Danno preesistente	☐	☐	☐	☐	☐	☐	☐	☐	☐	○

		SLV		
		D2-D		
Functionality and usability of the building	Safety and immediate occupancy	Protection of occupants lives and ensurance of safe evacuation	Structural collapse prevention	Structural collapse

Regional Assessment: Analytical Fragility Functions

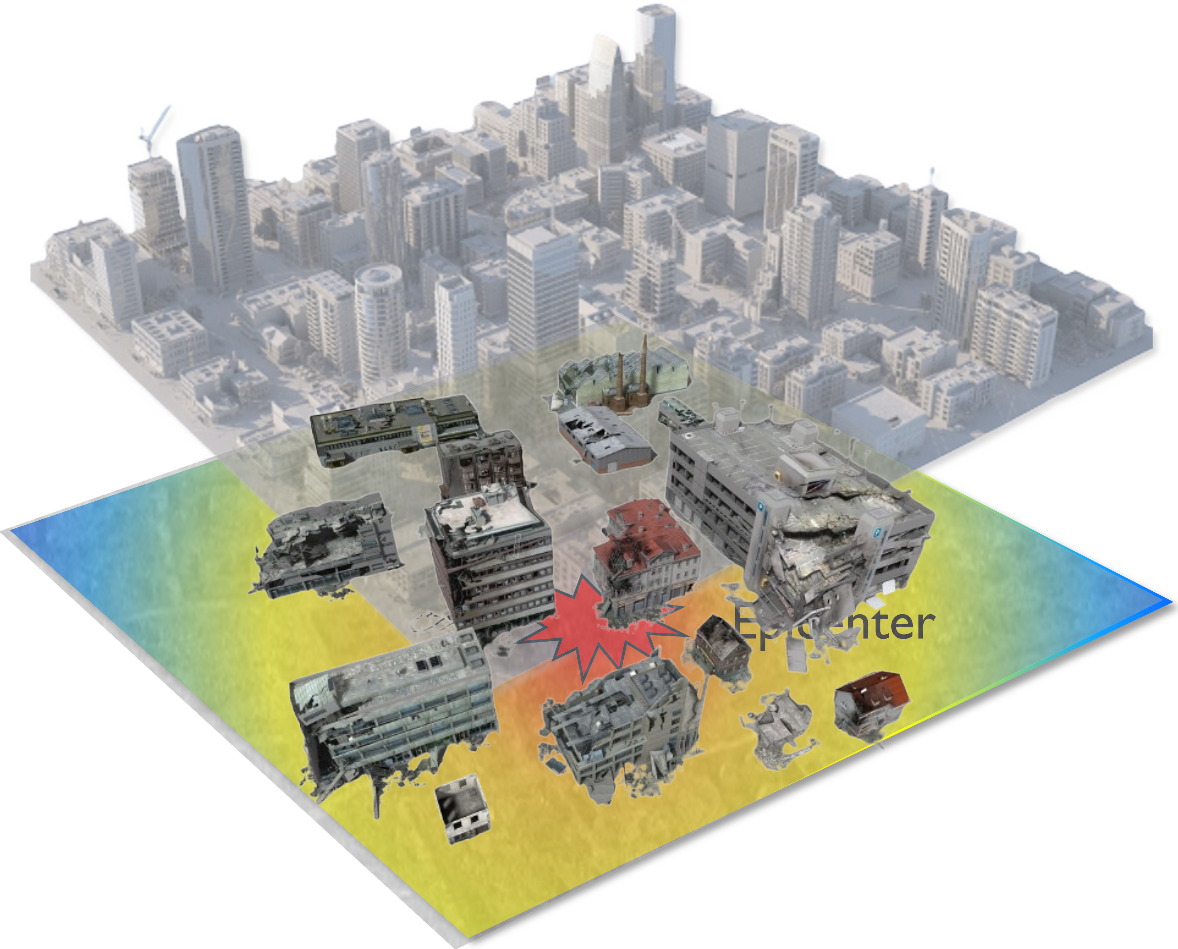


Regional Assessment: Empirical Fragility Functions

- Empirical fragility functions are the end result of convolving two layers of information in combination with robust statistical tools

  - ➢Observed damage to buildings

  - ➢Ground-motion fields (GMFs)



Regional Assessment: Observed Building Damage

- DaDO: Database of Observed Damage

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Regional Assessment: Case Study Events

- DaDO: Database of Observed Damage

- Friuli 1976
- Irpinia 1980
- Abruzzo 1984
- Umbria-Marche 1997
- Pollino 1998
- Molise-Puglia 2002
- Emilia 2003
- L'Aquila 2009
- Emilia 2012
- Garfagnana-Lunigiana 2013
- Central Italy 2016 - 2017
- Mugello 2019

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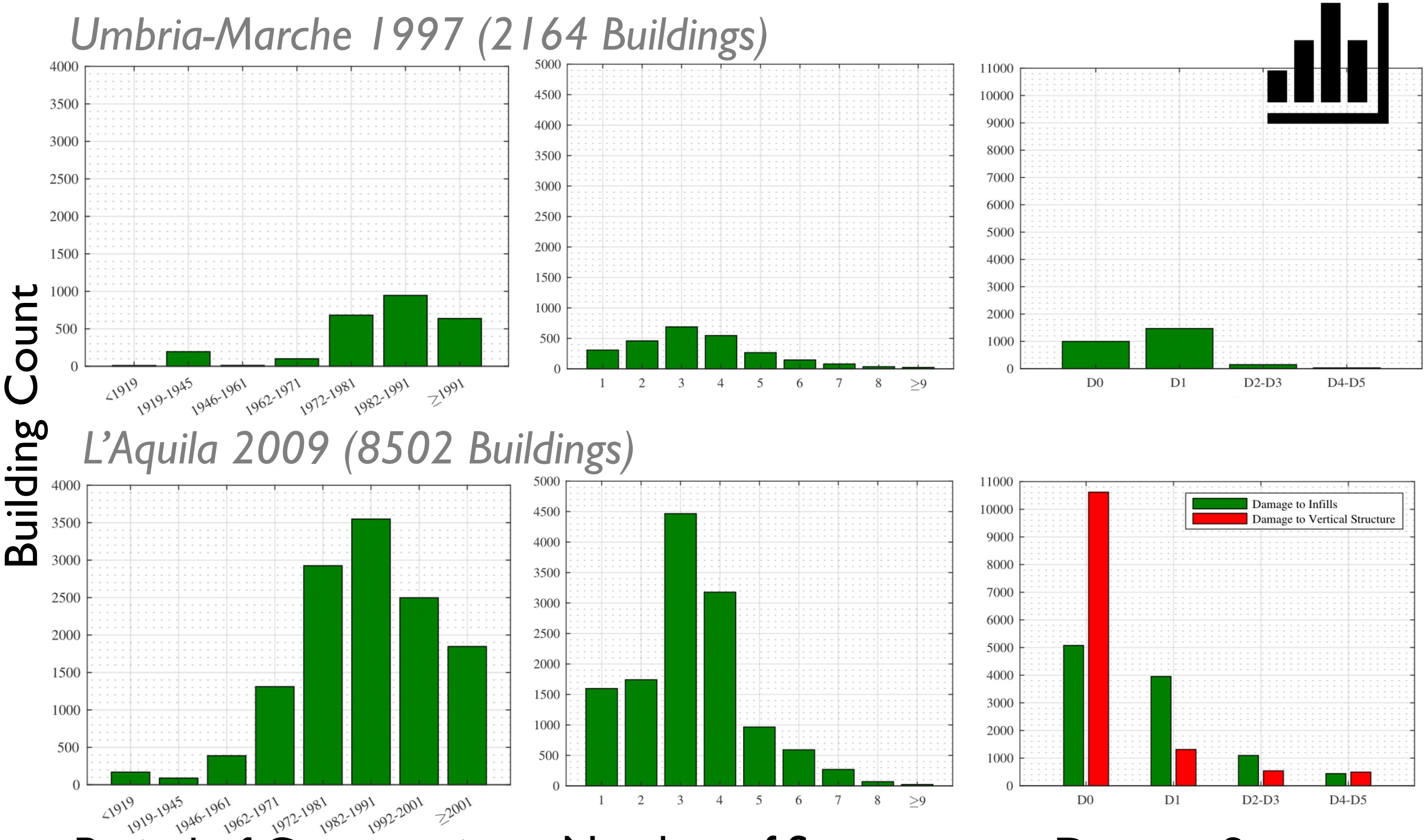
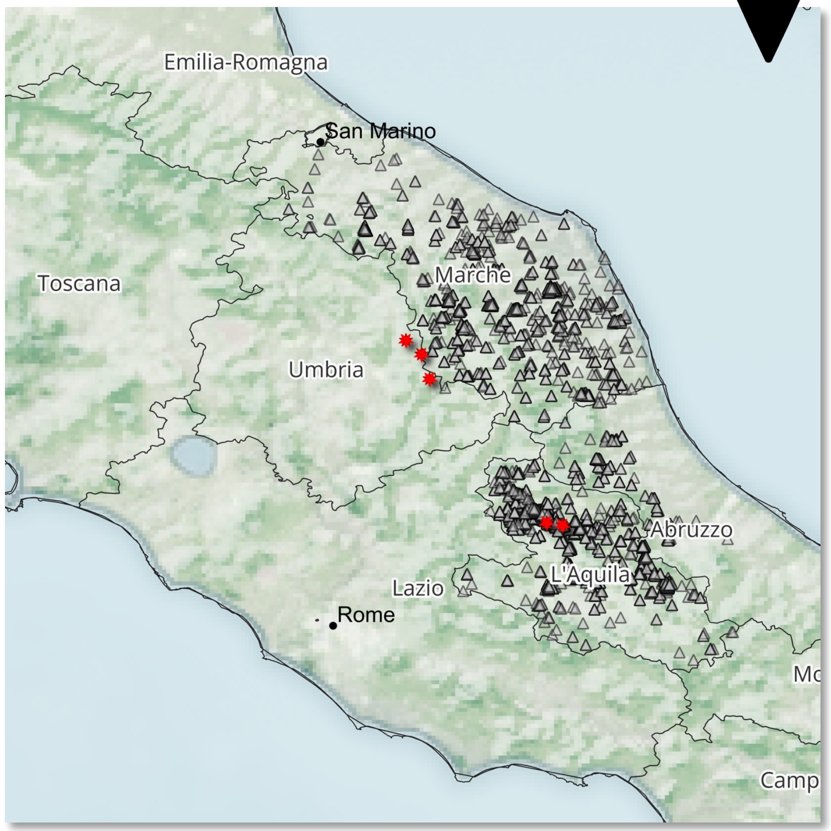
Regional Assessment: Observed Building Damage

- Building characteristics and spatial distributions (DaDO)



Period of Construction | Number of Storeys | Damage States



Inspected Building Locations

Regional Assessment: Ground-Motion Fields

- Physically realistic ground-motion fields are a combination of:
  - Handling of ground-motion models (GMMs) for the estimation of spectral intensities (Bindi *et al.* 2011) and indirect approach highlighted in Kohrangi *et al.* 2018 to estimate Sa_{avg} values and the total associated uncertainty
  - Conditioning of GMMs on seismic station data (ITACA) to account for "ground-truth" in the within-event uncertainty (Engler *et al.* 2022)
  - Spatial correlation to consider the spatial dependence in the joint probability distribution function of an intensity measure given a rupture scenario
  - Cross-correlation between IMs to consistently sample ground-shaking intensities from a GMM distribution over multiple IMTs and preserving the spectral shape properties

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

https://github.com/gem/oq-engine/tree/master/openquake/hazardlib/

- *[illegible] (2): 1060–1079. doi: https://doi.org/10.1785/0120210177*
- *Kohrangi, M., Kotha, S.R. & Bazzurro, P. Ground-motion models for average spectral acceleration in a period range: direct and indirect methods. Bull Earthquake Eng 16, 45–65 (2018). https://doi.org/10.1007/s10518-017-0216-5*

Regional Assessment: Ground-Motion Fields

- Physically realistic ground-motion fields are a combination of:
  - Simulations via multivariate distributions
    - ➢ To simulate the intensities at each site *j* for a given rupture event *i*, the distribution of $\ln \boldsymbol{IM}$

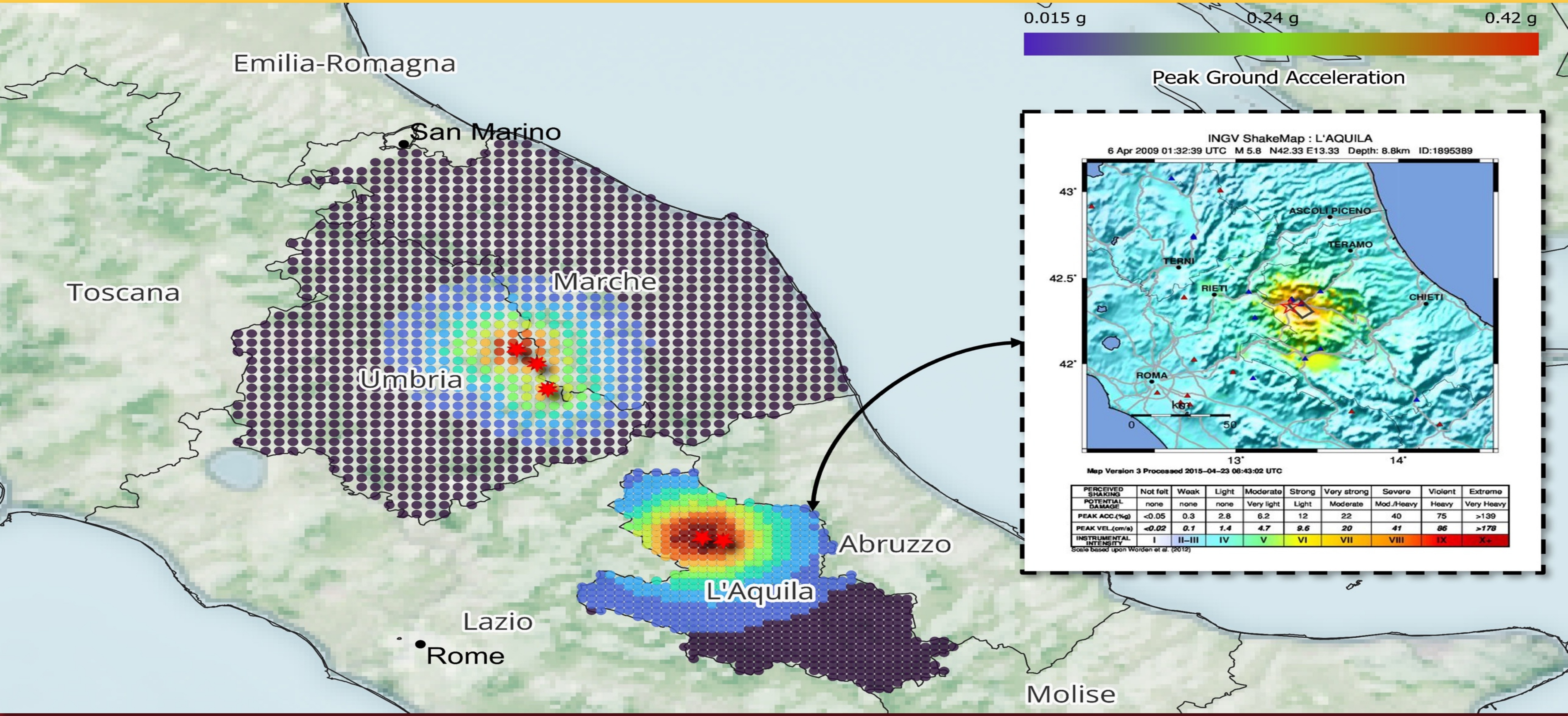
$$\ln \boldsymbol{IM} \sim \mathcal{N}(\boldsymbol{M}, \boldsymbol{\Sigma})$$

where $\sim\mathcal{N}(\,)$ denotes that $\ln \boldsymbol{IM}$ is multivariate normal distribution, parameterised by the mean vector $\boldsymbol{M}$ and covariance matrix $\boldsymbol{\Sigma}$ defined for *n* sites as follows:

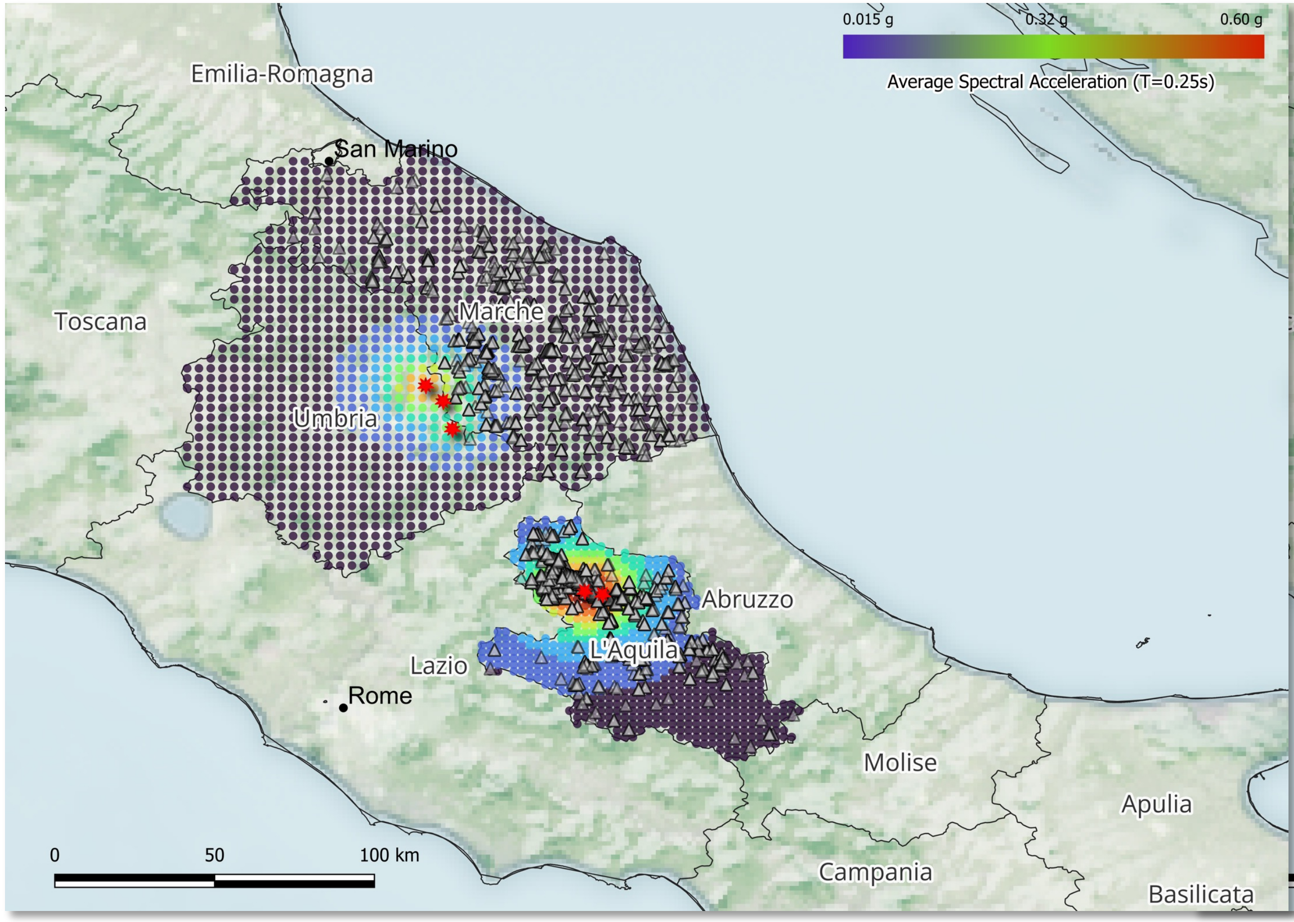
$$\boldsymbol{M} = \begin{bmatrix} \ln \mu_{IM}(rup_i, site_1) \\ \ln \mu_{IM}(rup_i, site_j) \\ \cdots \\ \ln \mu_{IM}(rup_i, site_n) \end{bmatrix} = \begin{bmatrix} \ln \mu_{Sa_{avg}}(rup_i, site_1) \\ \ln \mu_{Sa_{avg}}(rup_i, site_j) \\ \cdots \\ \ln \mu_{Sa_{avg}}(rup_i, site_n) \end{bmatrix}$$

$$\boldsymbol{\Sigma} = \sigma_{inter}^2 1 + \sigma_{intra}^2 \boldsymbol{R}$$

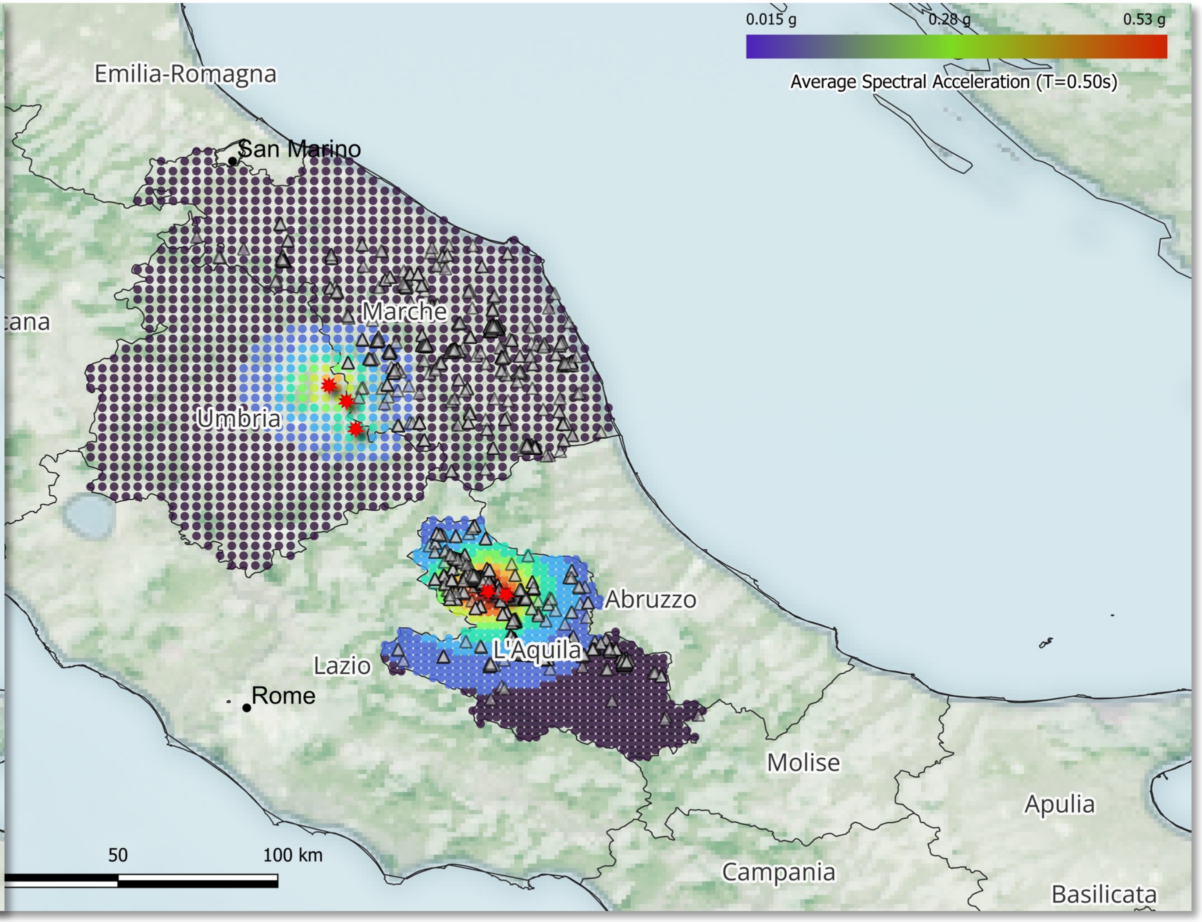
Regional Assessment: Ground-Motion Fields Validation



Regional Assessment: Sa_{avg}–based Ground-Motion Fields



Sa_{avg} (0.25s)-based GMFs for Low-Rise Buildings



Sa_{avg} (0.50s)-based GMFs for Mid-Rise Buildings

Regional Assessment: Empirical Fragility Functions

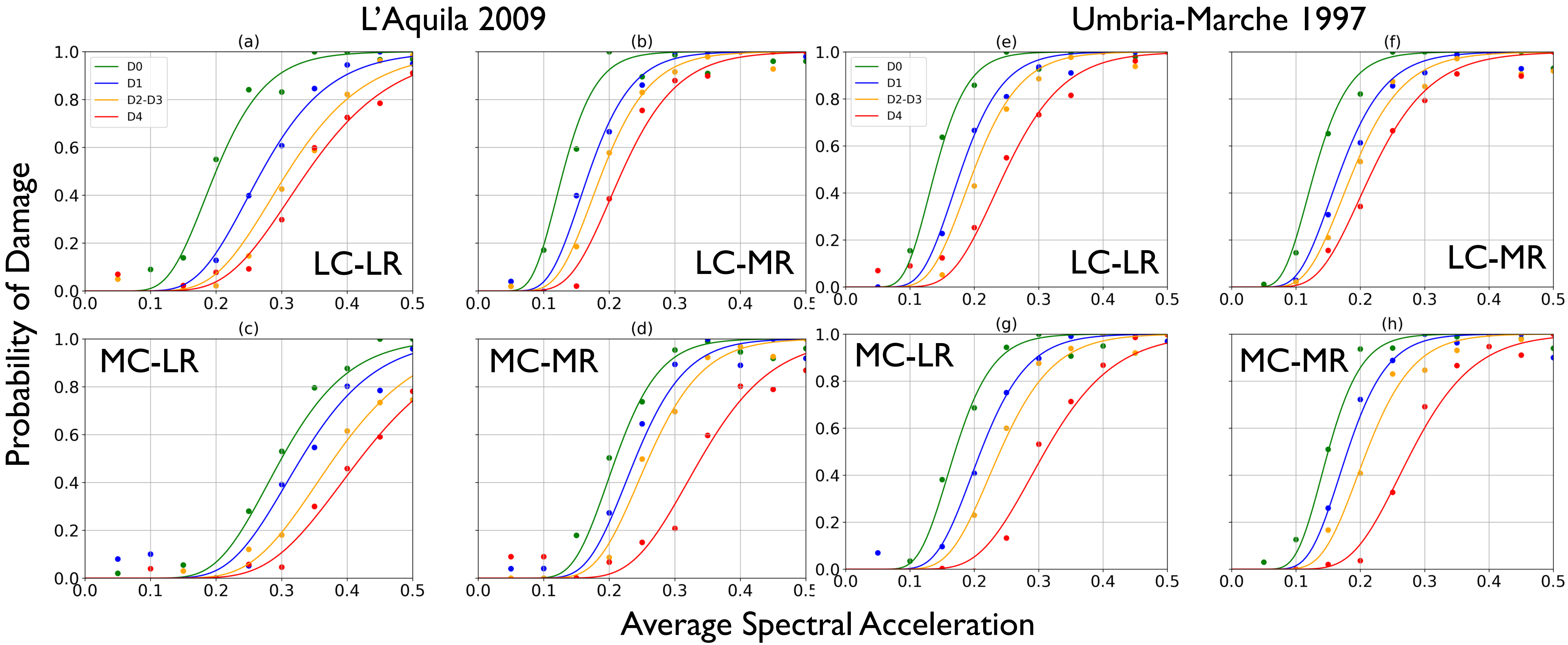
- Bernoulli distribution is selected to characterize the random component of the statistical model (probability of exceedance)

$$P\left(D \middle| S > ds_i, IM = im_j\right) = \binom{n_j}{y_{ij}} {p_{ij}}^{y_{ij}} \left[1 - p_{ij}\right]^{(n_j - y_{ij})}$$

- Maximum likelihood method and a unique constant dispersion value, β, is assumed for all damage states to prevent intersecting fragility curves

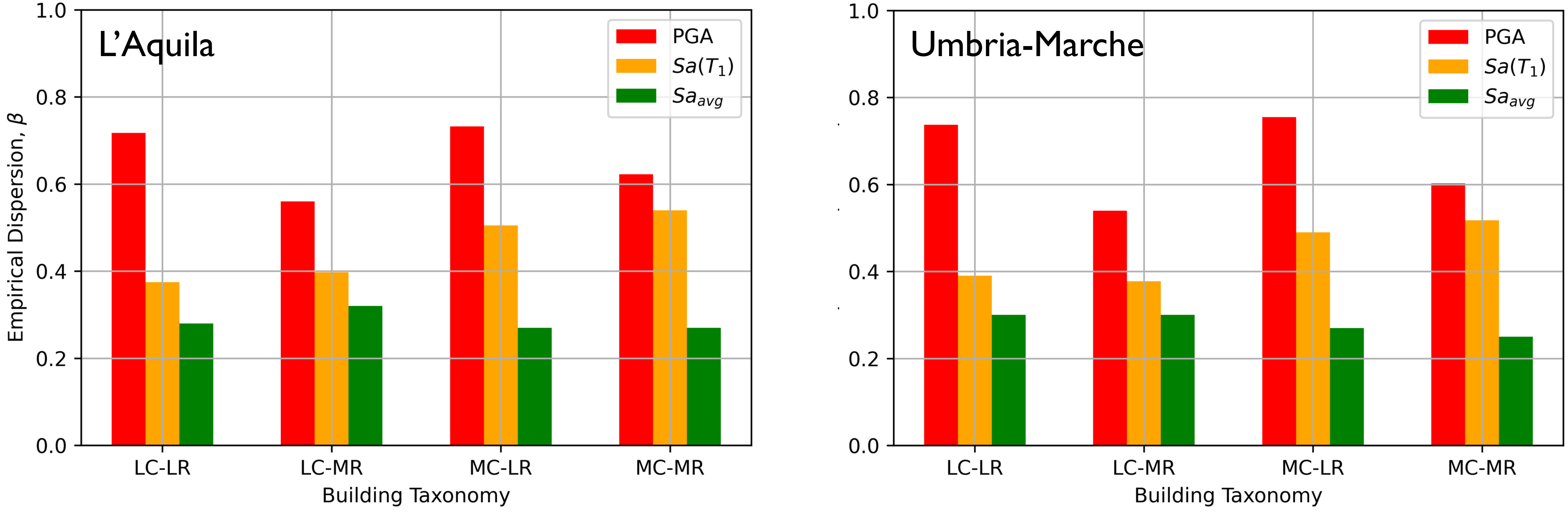
$$\eta_{DS_i}, \beta_{DS_i} = argmax \left[\log\left(\prod_{i=1}^{nDS} \prod_{j=1}^{N} \frac{n_j!}{y_{ij}!\left(n_j - y_{ij}\right)} {p_{ij}}^{y_{ij}} \left(1 - p_{ij}\right)^{(n_j - y_{ij})} \right) \right]$$

Regional Assessment: Empirical Fragility Functions



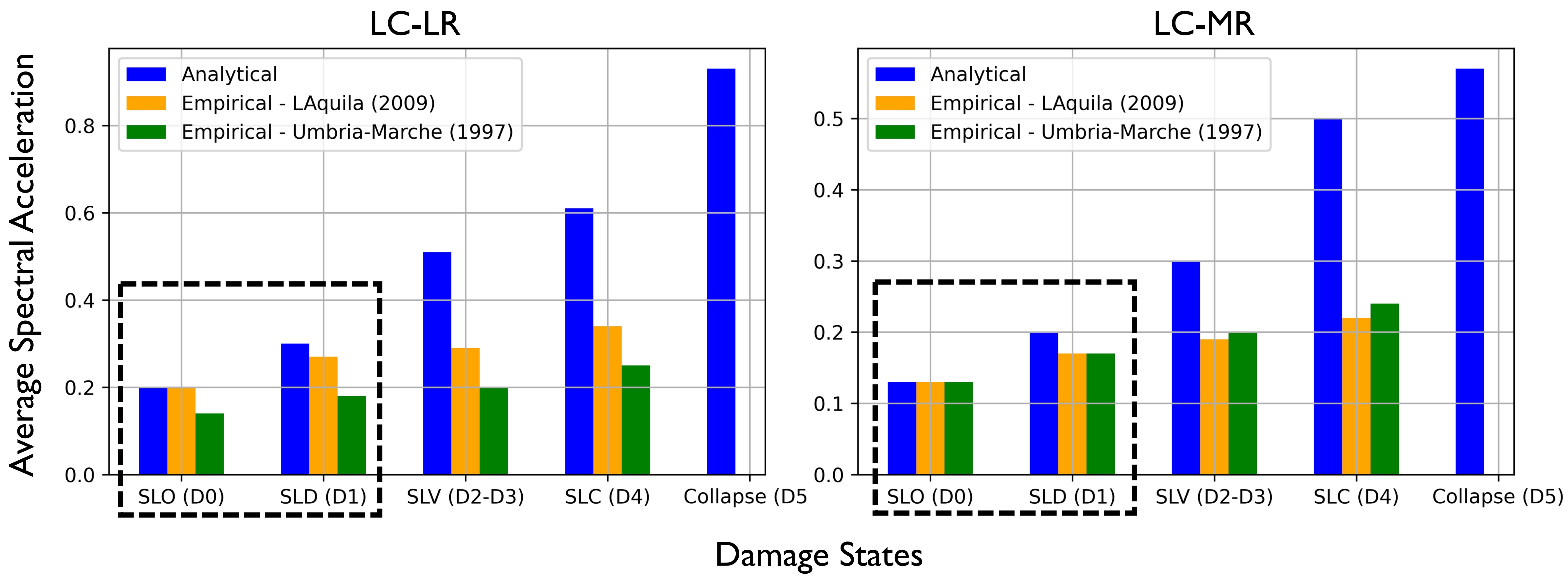
Regional Assessment: Discussion

- The dispersion values associated with the fitted empirical Sa_{avg}-based fragilities were compared to dispersions considering conventional IMs such as $Sa(T_1)$ and PGA



Regional Assessment: Discussion

- A good match between analytical and empirical FFs with regards to the serviceability DSs (i.e., operational and damage limitation) was observed, with reasonable errors varying between 0 and 16%.



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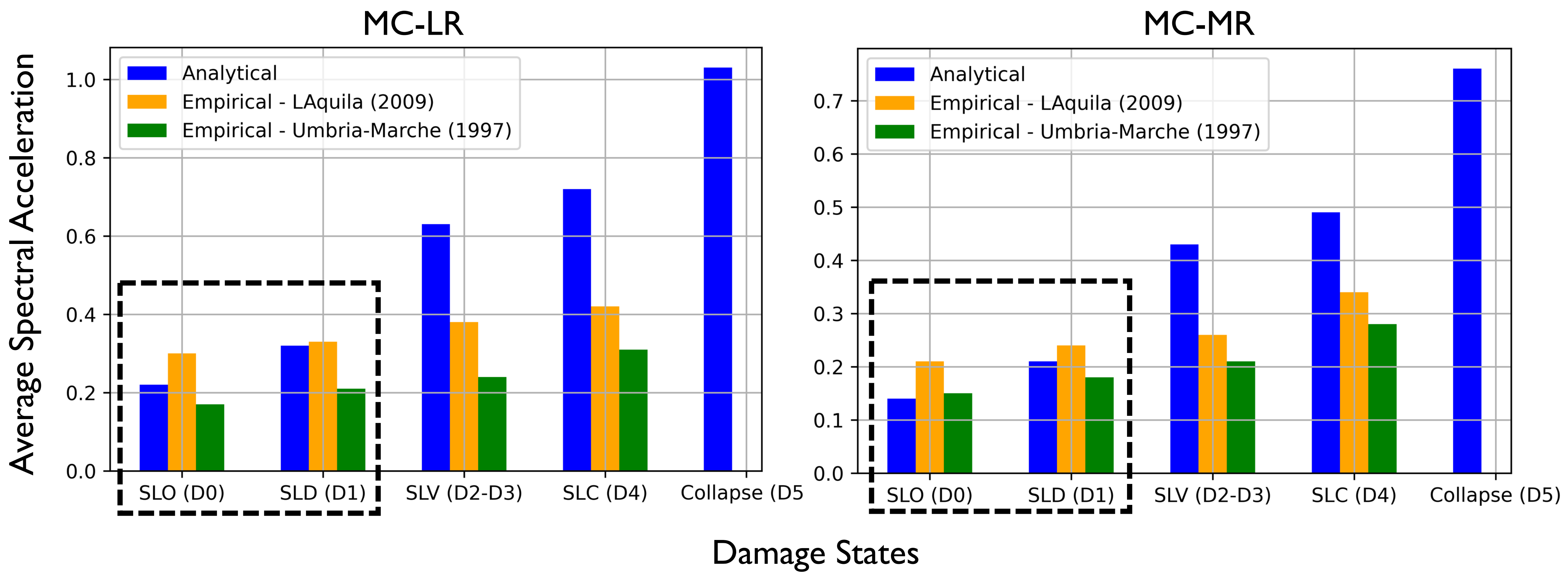
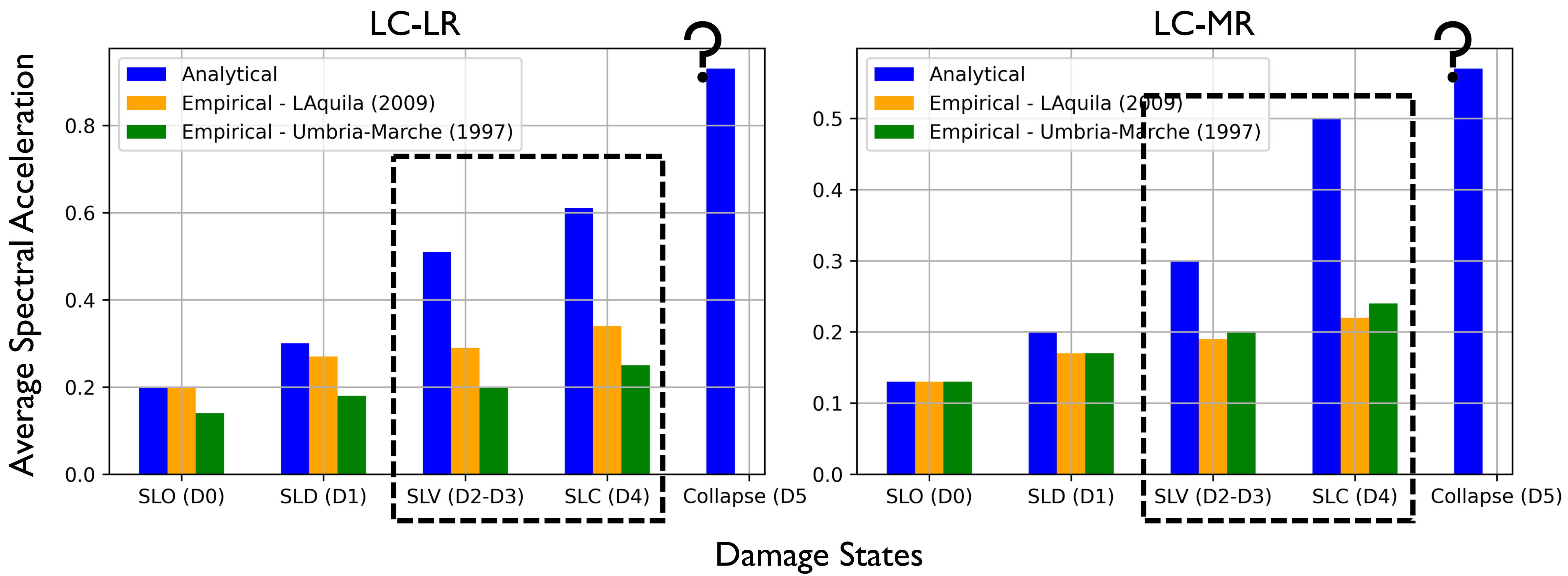


Regional Assessment: Discussion

- For the life-safety and near-collapse DSs, it can be seen that the analytical FFs tended to consistently overestimate the median intensities with respect to the empirical observations



Regional Assessment: Discussion

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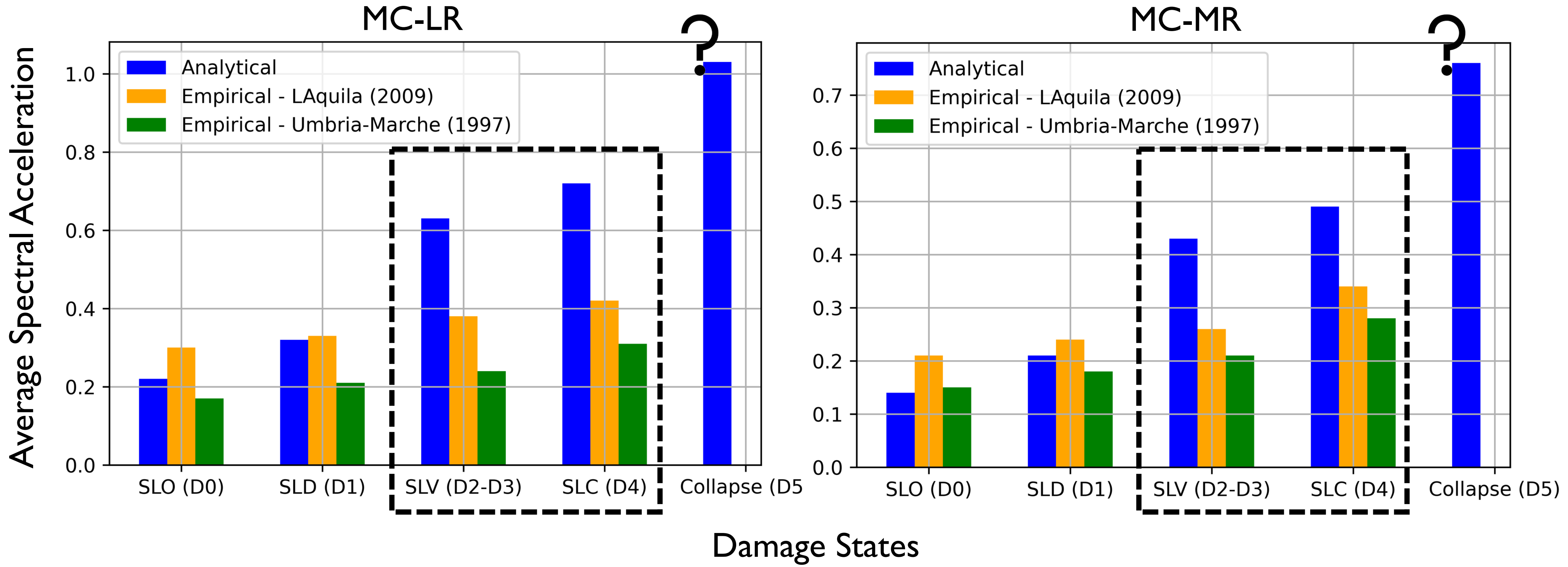

Regional Assessment: Discussion

- Similarities and discrepancies may be due to:
  - Quality of data particularly for the 1997 Umbria-Marche earthquake sequences, and the AeDES form before 2002:
    - ➢ Inability to encompass all potential structural component types;
    - ➢ Equal classification of the seismic behaviour among typologies that appeared similar aesthetically
  - Damage accumulation in buildings following earthquake sequences
    - ➢ Data was collected following the conclusion of EQ sequences
    - ➢ Highlights the importance of input energy, hysteretic energy dissipation and proper ground motion record selection to characterise response to mainshock-aftershock sequences
  - Uncertainty in the ground-shaking prediction and site conditions (e.g., Vs30)
  - Harmonization in the DS definition between Italian code and macro-seismic scales
  - Bias in data collection due to the differences in DS perception from one evaluator to another

Conclusions: On PB-Loss

- Simplified pushover-based procedure (PB-Loss) was derived and proposed for the risk- and loss-based assessment and classification of existing non-ductile infilled RC buildings
- The procedure:
  - Integrates state-of-the-art closed-form solutions
  - Probabilistic (due consideration of uncertainty)
  - Reduces significantly the computational demand
  - Offers acceptable levels of accuracy and reliability
  - Reproducible to other building classes
  - Ready for integration with the current Italian guidelines for risk classification of existing buildings

Conclusions: On PB-Loss

- The proposed approach and its components are available for consultation as published works:
  - Nafeh *et al.* (2020): Equivalent SDOF modelling
  - Nafeh *et al.* (2021): Derivation of empirical ρ-μ-T relationships and archetype database
  - Nafeh *et al.* (2022): Integration of the SAC/FEMA approach with empirical ρ-μ-T relationships for simplified risk estimation
  - Nafeh *et al.* (2023): Derivation of SLFs and PB-Loss procedure

Bulletin of Earthquake Engineering (2020) 18:1579–1611
https://doi.org/10.1007/s10518-019-00758-2

ORIGINAL RESEARCH

Simplified seismic assessme

Al Mouayed Bellah Nafeh[1] · Gerard

Contents lists available at ScienceDirect

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Soil Dynamics and Ear

journal homepage: www.el

Unbiased simplified seismic fragility estimat
RC structures

Al Mouayed Bellah Nafeh, Gerard J. O'Reilly *

Bulletin of Earthquake Engineering
https://doi.org/10.1007/s10518-022-01600-y

ORIGINAL ARTICLE

Simplified pushover-based seismic methodology for existing infilled fr

Al Mouayed Bellah Nafeh[1] · Gerard J. O'Rei

Bulletin of Earthquake Engineering
https://doi.org/10.1007/s10518-023-01792-x

ORIGINAL ARTICLE

Simplified pushover-based seismic loss assessment for existing infilled frame structures

Al Mouayed Bellah Nafeh[1] · Gerard J. O'Reilly[1]

Conclusions: On Sa_{avg}–based Regional Applications

- Analytical and empirical fragility curves were derived for large-scale applications on building portfolios considering:
  - ➢Distinct sub-classes of the infilled RC building class
  - ➢Average spectral acceleration as intensity measures
- Analytical functions were derived considering:
  - ➢Comprehensive database of archetype numerical models
  - ➢Hybrid quantitative damage state definitions based on experimental findings and code-based prescriptions
- Empirical functions were derived considering:
  - ➢Database of observed damage (DaDO) for damage characterization
  - ➢Simulated Sa_{avg}-based ground-motion fields conditioned on station recordings

In case you missed it..

- Video Presentations on ROSE Centre YouTube Channel

  - ➢ROSE Seminar on the Simplified Risk- and Loss-Based Methodology for Building-Specific Assessment: https://www.youtube.com/watch?v=mjh_JaIeZgw

  - ➢ROSE Seminar on the Fragility Functions of Infilled RC Buildings for Regional Applications: https://www.youtube.com/watch?v=nAomrS9QdA4

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Link to Academic Profile

Link to GEM Profile

Questions