ECEE2026
18th European Conference on Earthquake Engineering

A COMPREHENSIVE GLOBAL SEISMIC VULNERABILITY MODEL FOR IMPROVED EARTHQUAKE LOSS MODELLING

Al Mouayed Bellah Nafeh*, Karim Aljawhari, Vitor Silva

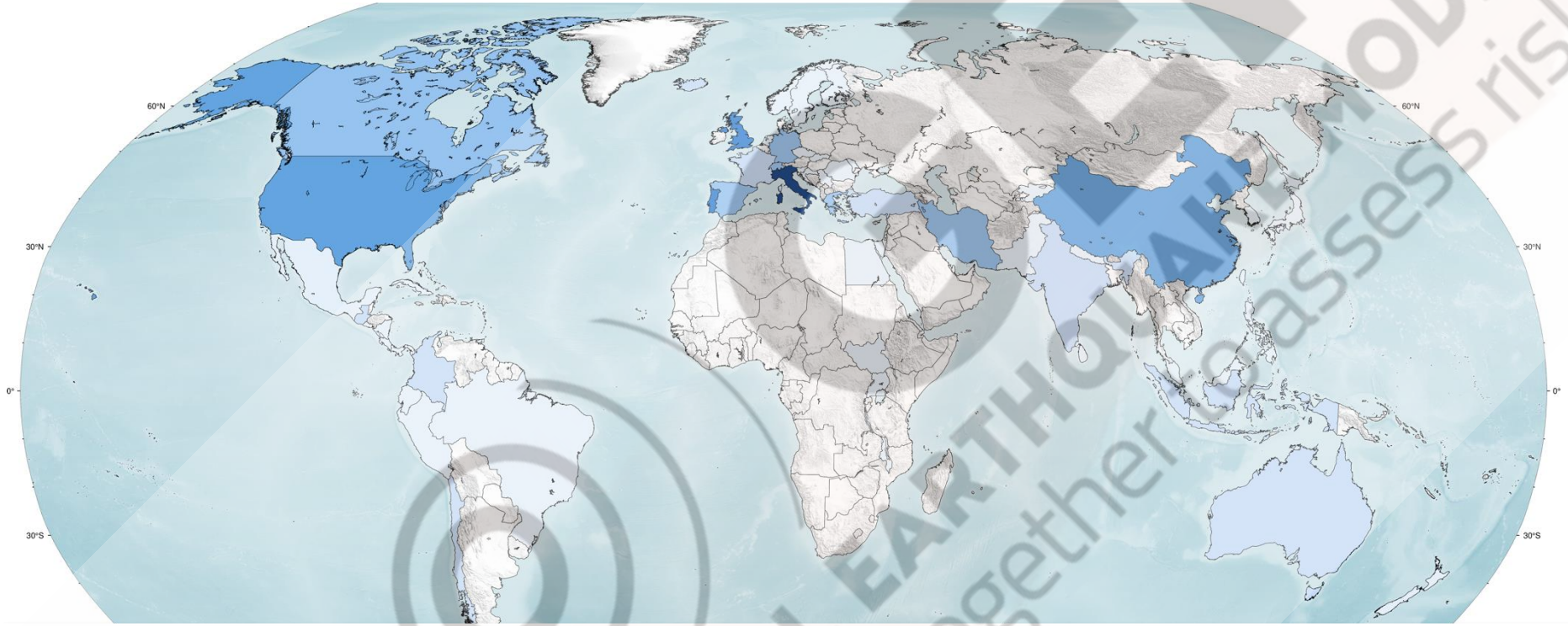
Global Earthquake Model (GEM) Foundation



RPTU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau

TECHNISCHE UNIVERSITÄT BERLIN

Sunsetting the 2023 Global Seismic Vulnerability Model



Global Distribution of Published Works Citing the 2023 Global Seismic Vulnerability Model (Martins and Silva, 2021)

Introducing the 2026 Global Seismic Vulnerability Model

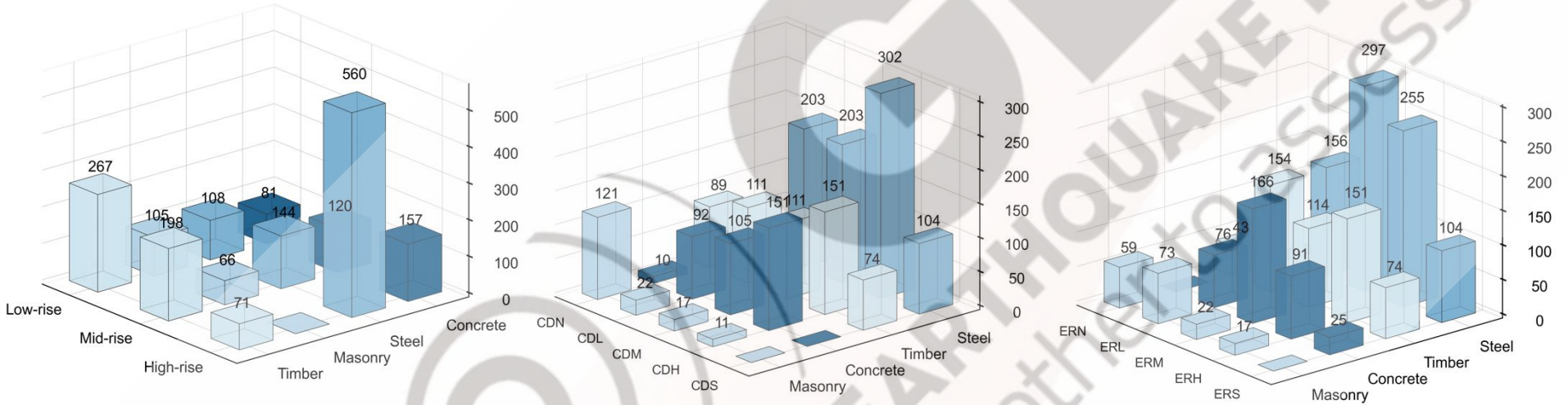
Extended Building Class Coverage



Supported Building Classes in the Global Seismic Vulnerability Model for Engineered and Non-Engineered Classes

Introducing the 2026 Global Seismic Vulnerability Model

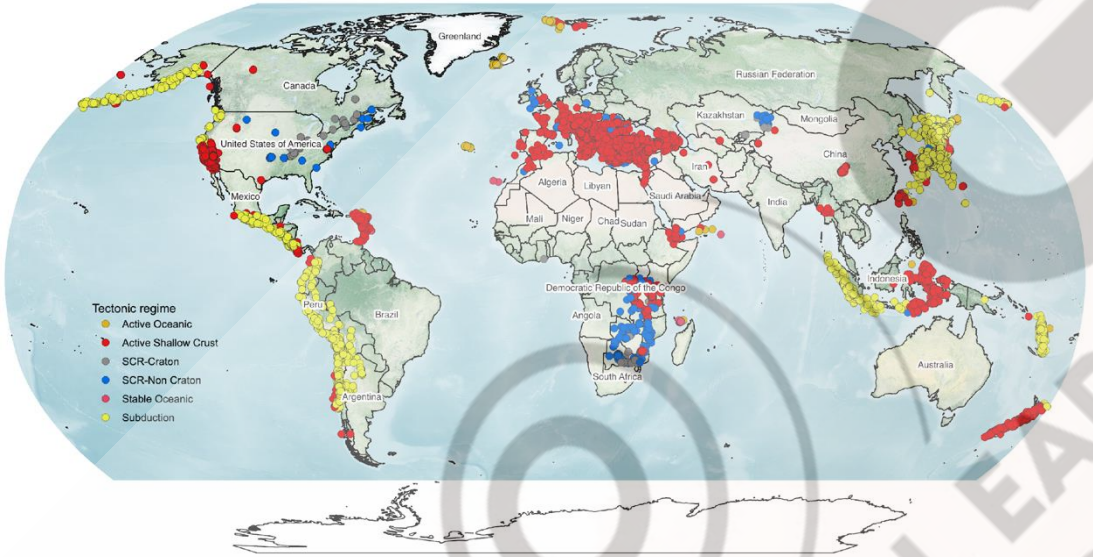
Extended Building Class Coverage

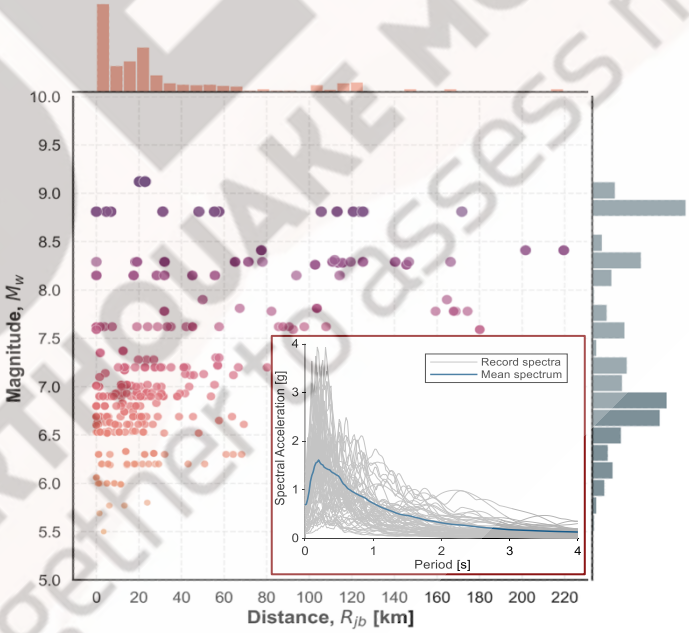


Distribution of GEM Vulnerability Classes by Primary Construction Material, Height Categories, Seismic Design Code Level

Introducing the 2026 Global Seismic Vulnerability Model

Sufficient Ground Motion Suite

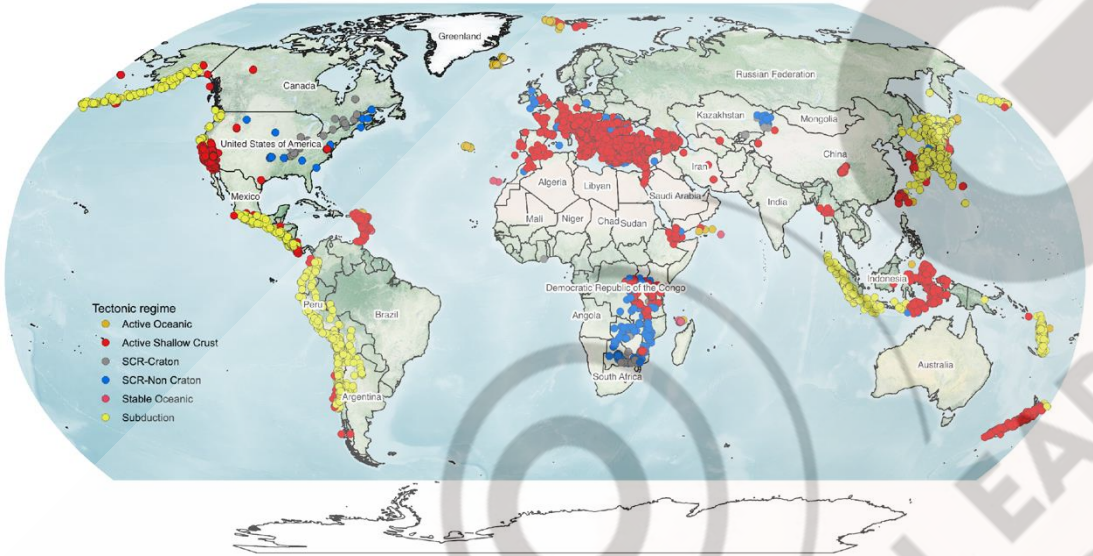


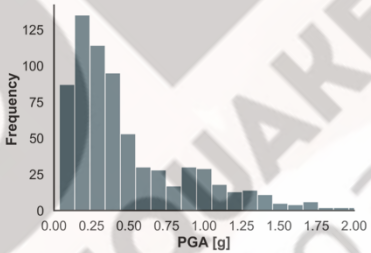


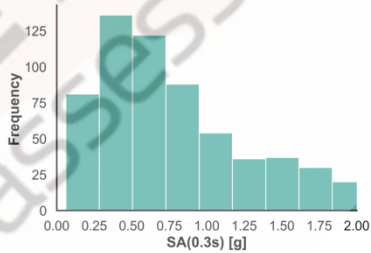
Distribution of Selected GMRs for NLTHA Representing Global Tectonic Region Types sourced from International Databases

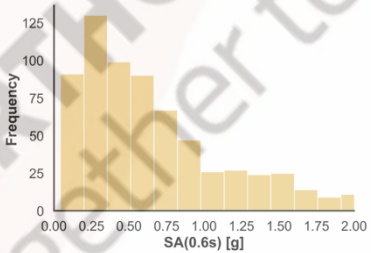
Introducing the 2026 Global Seismic Vulnerability Model

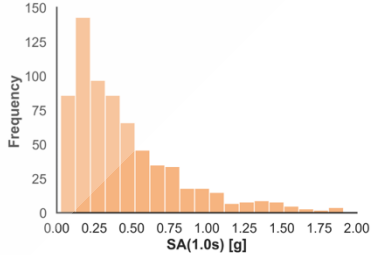
Sufficient Ground Motion Suite







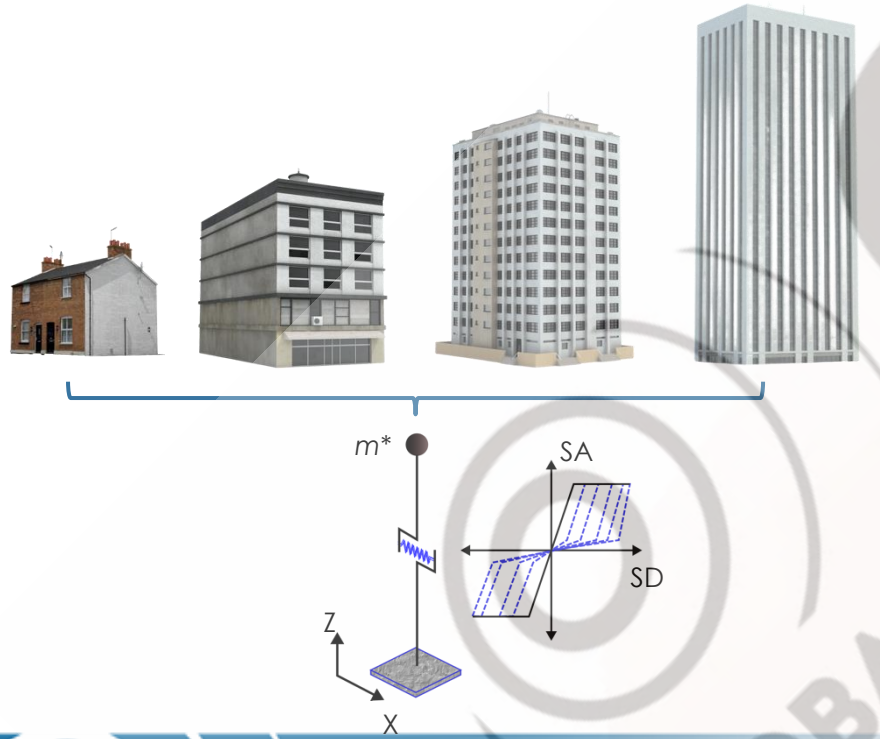




Distribution of Intensity Measures from Selected GMRs for NLTHA

Introducing the 2026 Global Seismic Vulnerability Model

Efficient Numerical Modelling



Single-Degree-of-Freedom Oscillators (v2023)

Pros

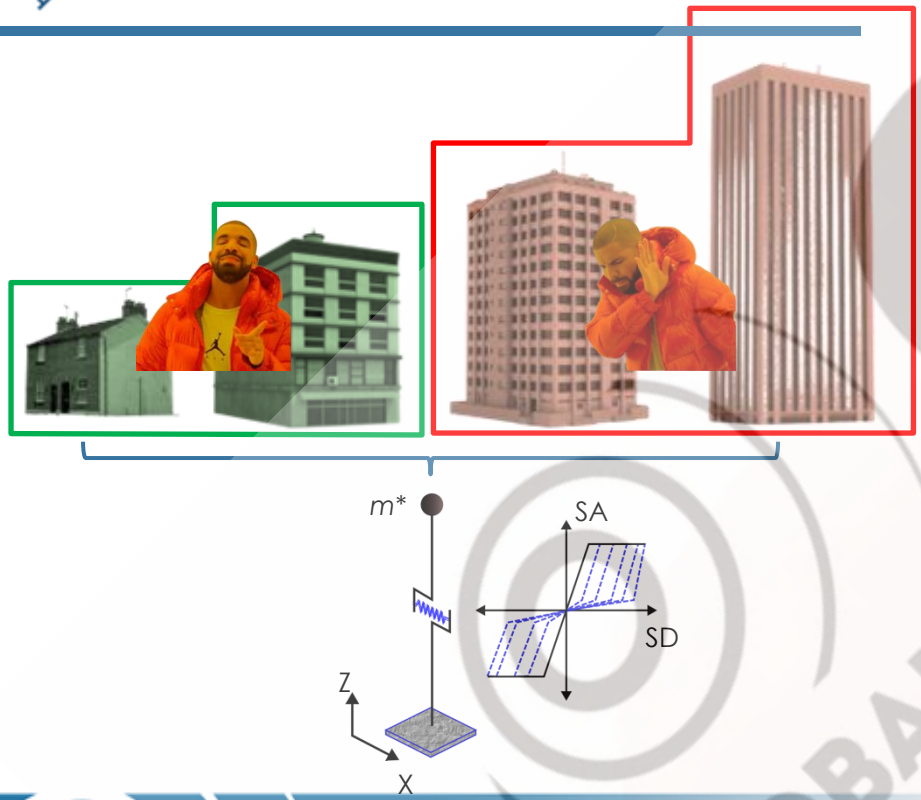
- **Simplicity: Easy to model and analyze**
- **Speed: Requires minimal computational resources**
- **Intuitive Understanding: Provides clear insight into the building's fundamental behaviour**

Cons

- **Over-simplification: Ignores complex mechanisms and higher modes of vibration**
- **Limited accuracy: Not suitable for applications requiring distribution of demands**

Introducing the 2026 Global Seismic Vulnerability Model

Efficient Numerical Modelling



Single-Degree-of-Freedom Oscillators (v2023)

Pros

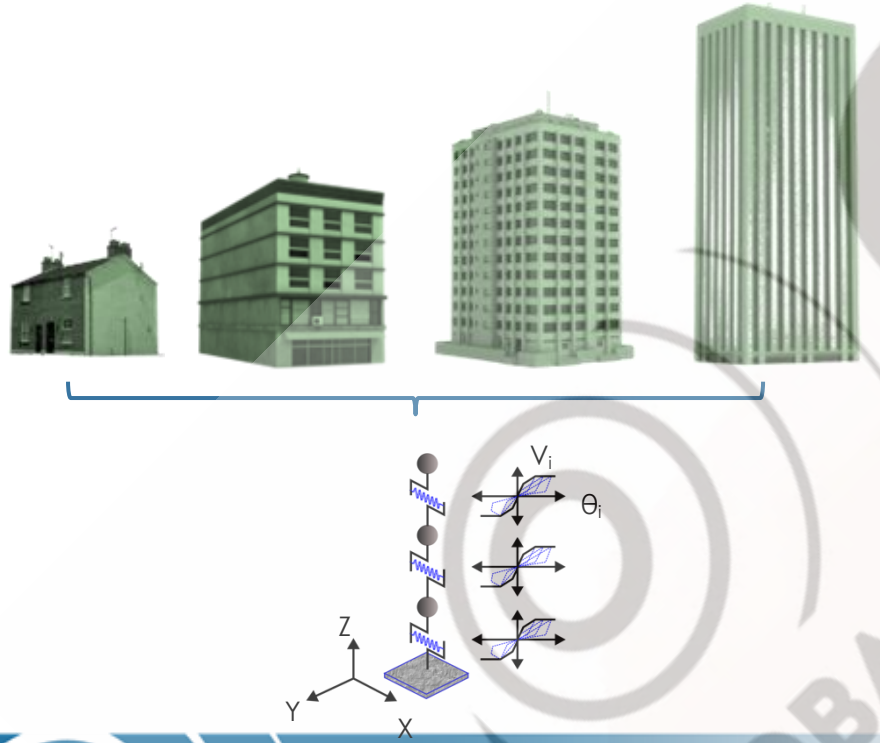
- **Simplicity: Easy to model and analyze**
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Cons

- **Over-simplification: Ignores complex mechanisms and higher modes of vibration**
- **Limited accuracy: Not suitable for applications requiring distribution of demands**

Introducing the 2026 Global Seismic Vulnerability Model

Efficient Numerical Modelling



Multi-Degree-of-Freedom Stick Models (v2026)

Pros

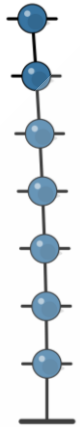
- **Simplicity: Easy to model and analyze**
- **Speed: Requires minimal computational resources**
- **Intuitive Understanding: Provides clear insight into the building's fundamental behaviour**
- **Explicit modeling of vertical irregularities (soft-storey mechanisms, catastrophic collapse modes)**

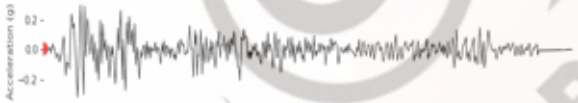
Introducing the 2026 Global Seismic Vulnerability Model

Efficient Numerical Modelling

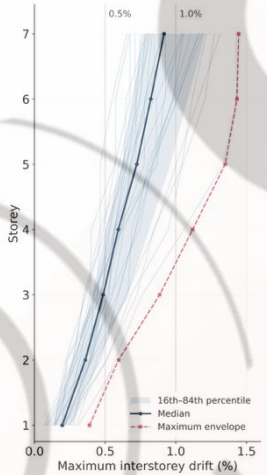
Structural Response







Deformations



Drift-Sensitive Components



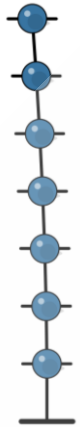


Introducing the 2026 Global Seismic Vulnerability Model

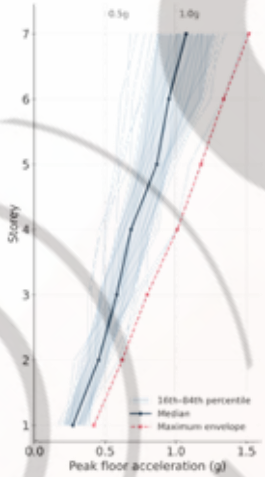
Efficient Numerical Modelling

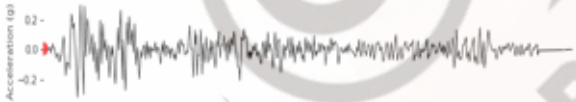
Structural Response





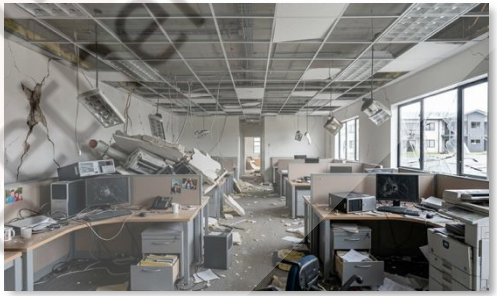
Accelerations





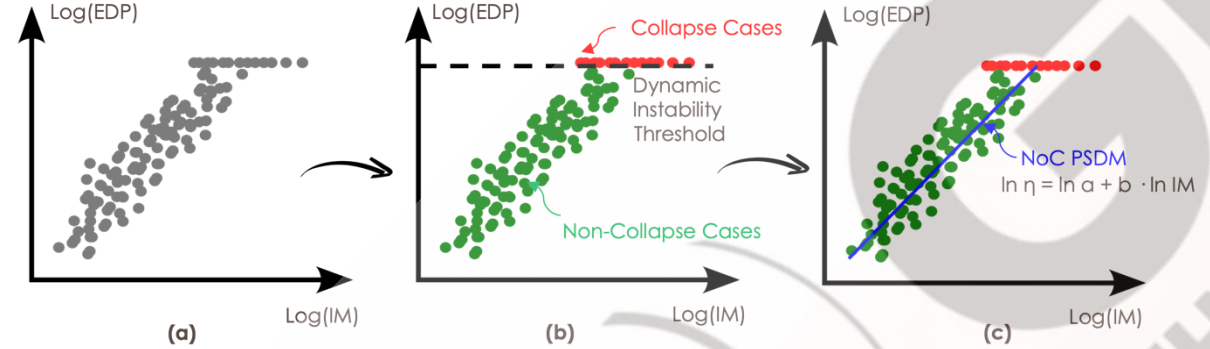
Acceleration-Sensitive Components

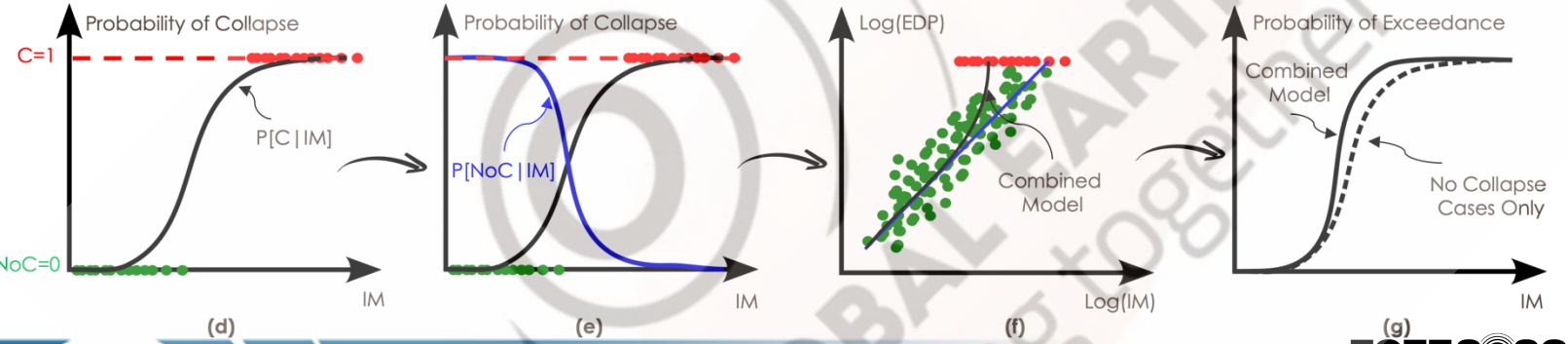




Introducing the 2026 Global Seismic Vulnerability Model

Efficient Probabilistic Seismic Demand Modelling





Modified Cloud Analysis Approach

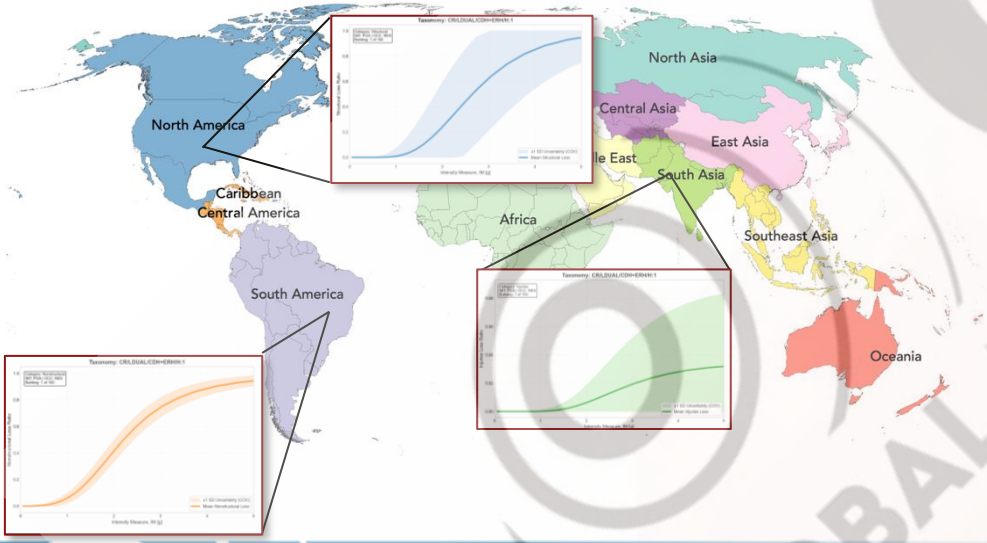
Accounting for collapse/dynamic instability cases in fragility models

Introducing the 2026 Global Seismic Vulnerability Model

Higher Definition, Finer Resolution

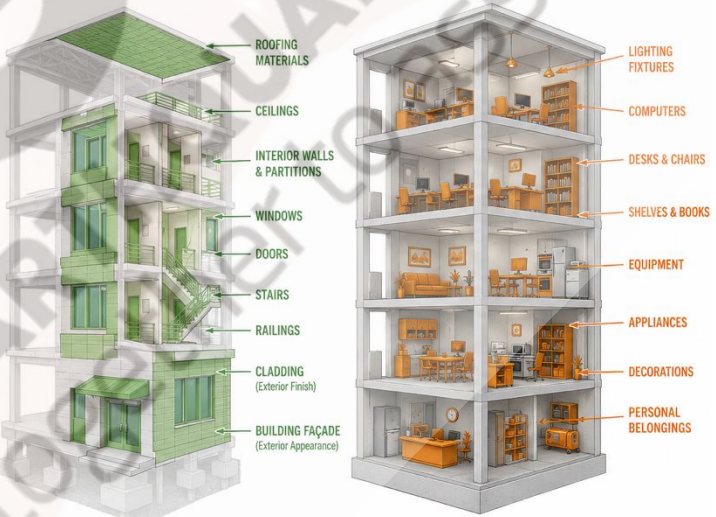
Region-Specific Models

Capturing regional differences in construction practice.



Component Storey- / Floor-Based Modelling

Combining storey-level demands with component modelling



Product Coverage



Economic-Based

- Structural Loss
- Nonstructural Loss
- Contents Loss



Damage-Based

- Structural fragility models
- Area damaged
- Number of buildings completely damaged



Population-Based

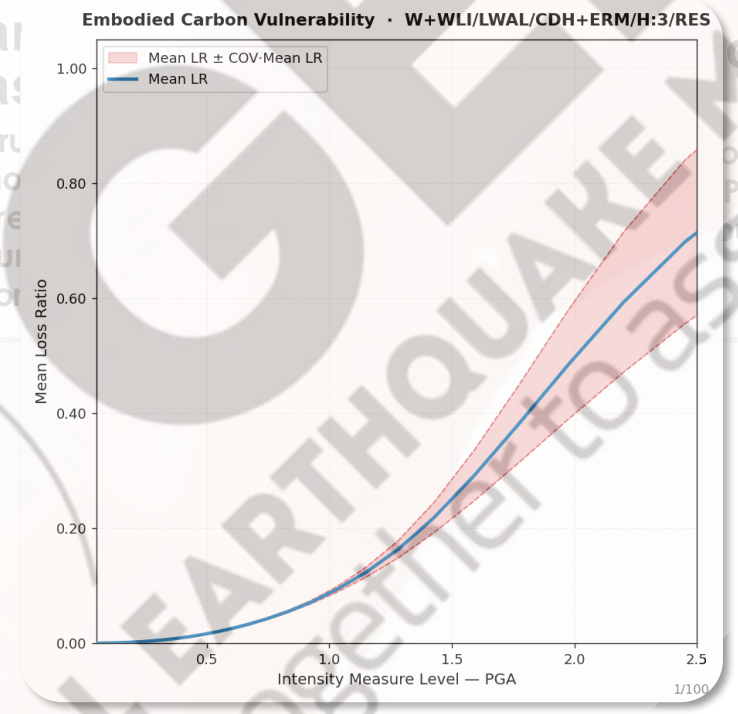
- Affected Population
- Displaced Population
- Injured Population
- Casualties

GLOBAL EARTHQUAKE MODEL
working together to assess risk

Product Coverage

Embodied Carbon

- Ground Shaking
- Building Damage
- Material Supply
- Carbon Emissions



The 2026 Global Embodied Carbon Vulnerability Model

A New Global Embodied-Carbon Seismic Risk Model

M. Caruso, K. Aljawhari, AMB. Nafeh, V. Silva, C. Galasso

Session S03-16-SRAMH on Seismic Risk Assessment and Multi-Hazard Risk (incl. Tsunami and NaTech)

Time: Monday 14/09/2026 (4:35 PM – 6:00 PM)

Location: S03



A New Database of Seismic Vulnerability Functions for Carbon Emissions in Europe

K. Aljawhari, M. Caruso, AMB. Nafeh, V. Silva

Session S01-18-RCI on Resilience of Communities and Infrastructure, Seismic Risk Management and Social/Economic Aspects

Time: Wednesday 16/09/2026 (11:30 AM – 12:55 PM)

Location: S03



Model Testing and Validation





Internal Model Consistency

Model Testing and Validation

Test Product



Internal Model Consistency



Risk Metrics Sanity Checks

Model Testing and Validation



Model Testing and Validation



Full Event-Based Risk



Internal Model Consistency

Test Product



Historical Scenarios



Risk Metrics Sanity Checks

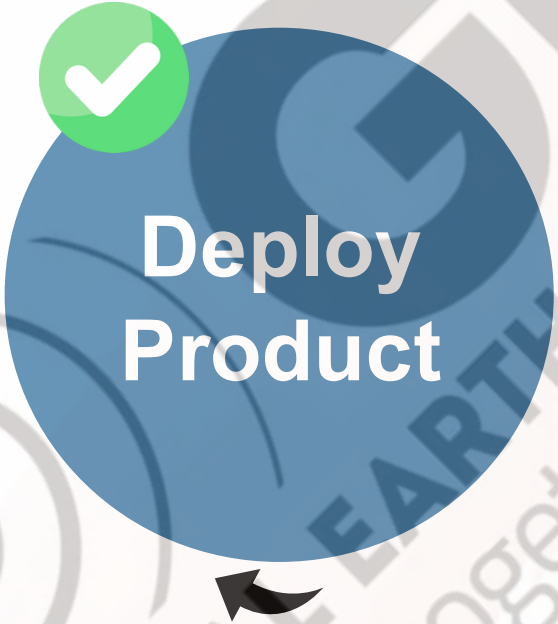
Model Testing and Validation



Full Event-Based Risk



Internal Model Consistency





Historical Scenarios

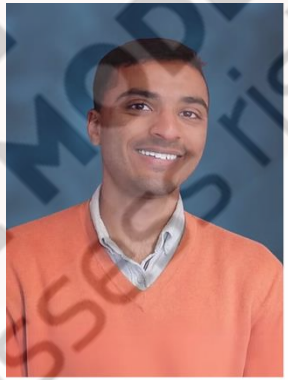


Risk Metrics Sanity Checks

Model Testing and Validation

Benchmarking GEM's Global Seismic Risk Model through Historical Scenarios

A. Rao, J. Borozan, AMB. Nafeh, C. Yepes-Estrada, V. Silva



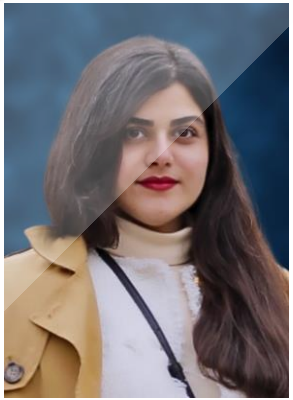
Session S08-16-SRAMH Seismic Risk Assessment and Multi-Hazard Risk (incl. Tsunami, NaTech)

Time: Wednesday 16/09/2026 (11:30 AM – 12:55 PM)

Location: S09

Advancing Earthquake Loss Normalization: Adjusting Fatalities and Building Losses

Z. Karim Zadeh, V. Silva



Session S03-16-SRAMH Seismic Risk Assessment and Multi-Hazard Risk (incl. Tsunami, NaTech)

Time: Monday 14/09/2026 (16:35 AM – 18:00 PM)

Location: S03

Model Accessibility

Link to Open-Access Country-Specific Models

Request Access/License for Supplementary Models

GEM Vulnerability Models Documentation

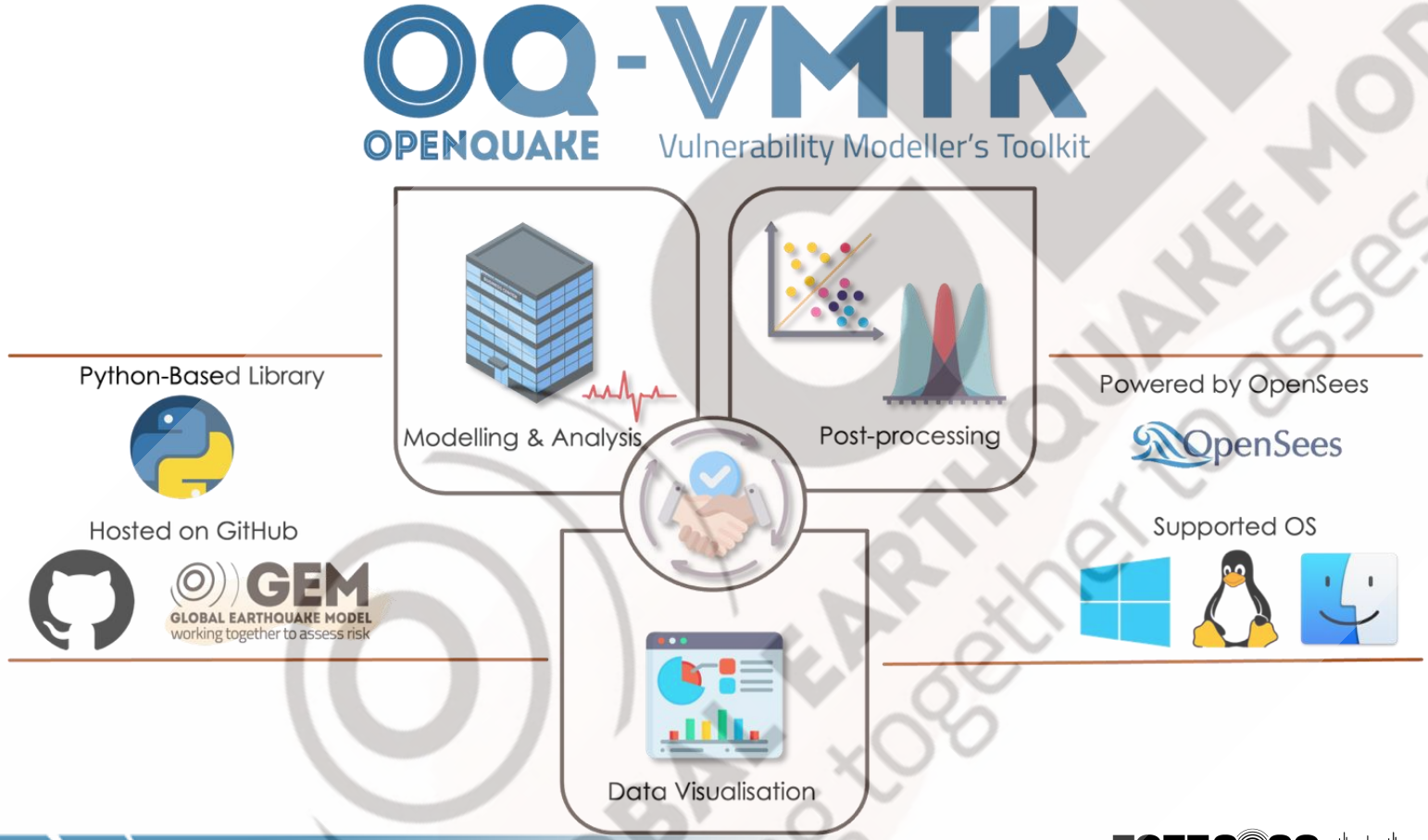
Welcome to the documentation for the GEM Global Vulnerability Models. This documentation provides comprehensive information about the building vulnerability models developed by the GEM Foundation for seismic risk assessment.

Contents:

- Overview
  - Introduction
  - Building Classification
  - Methodology Overview
  - How Were the Models Developed?
  - Data Access and Recommended Use
  - References
- Capacity Models
  - Introduction
  - Idealised Capacity Curve Shapes
  - SDOF to MDOF Calibration
  - Capacity Model References
  - Interactive Viewer
  - References
- Ground-Motion Records
  - Introduction
  - Database Sources
  - Tectonic Environments
  - Record Selection Criteria
  - Intensity Measures
  - Ground-Motion Record Summary
  - Record Visualization
  - References
- Structural Analysis
  - Introduction
  - Modified Cloud Analysis Methodology
  - Interactive Viewer
  - Engineering Demand Parameters
  - Intensity Measures
  - References

Link to Model Documentation

The OpenQuake Vulnerability Modeller's Toolkit

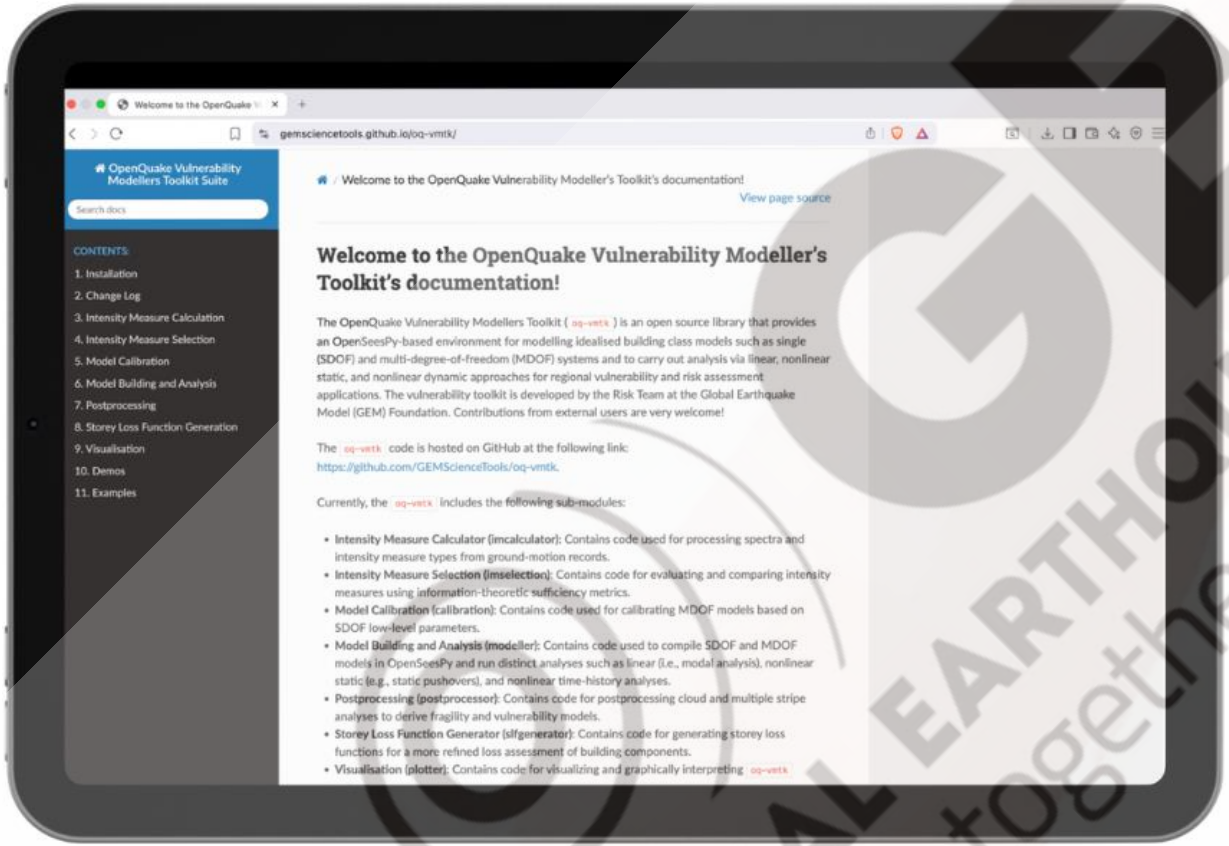


The OpenQuake Vulnerability Modeller's Toolkit



Link to OQ-VMTK Repository

The OpenQuake Vulnerability Modeller's Toolkit

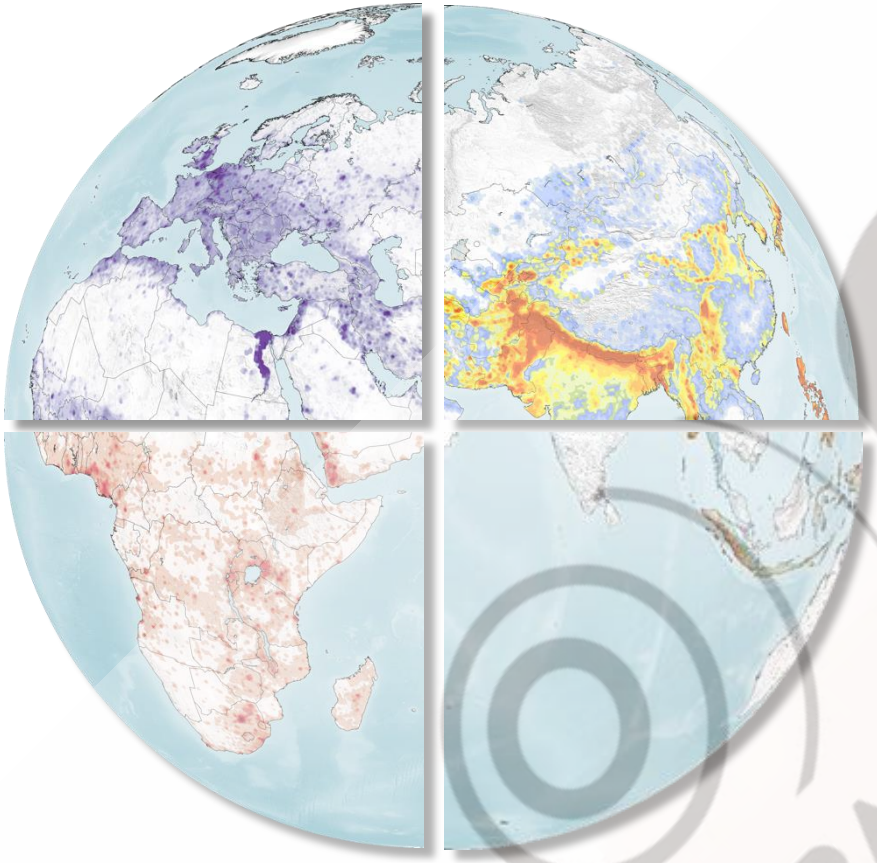


Link to OQ-VMTK Documentation

The Global Product Release

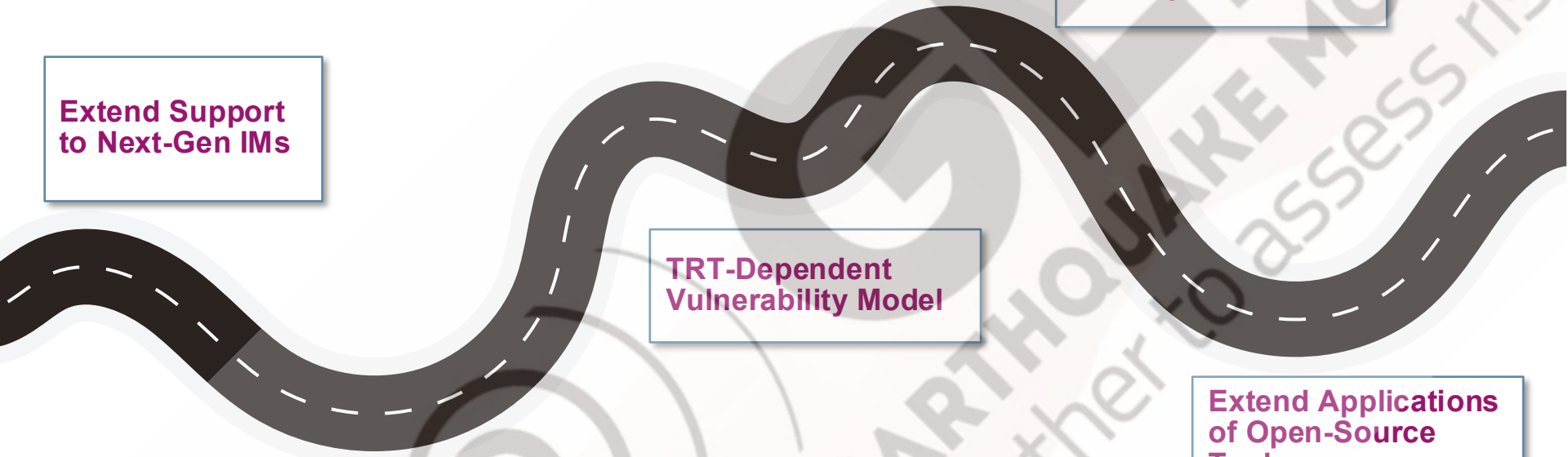


The Global Product Release



- The Global Seismic Vulnerability Model
- The Global Exposure Model
- The Global Seismic Risk Model
- The Global Liquefaction Model
- The Global Seismic Hazard Model
- Country Risk Profiles
- The Global Embodied Carbon Model

Beyond 2026



Extend Support to Next-Gen IMs

Extend Support for EQ Sequence Risk Application via Damage Dependent Functions

TRT-Dependent Vulnerability Model

Business Interruption Models

Extend Applications of Open-Source Tools

Beyond 2026

Business Interruption Models

Extend Support for EQ Sequence Risk Application via Damage Dependent Functions

Tools

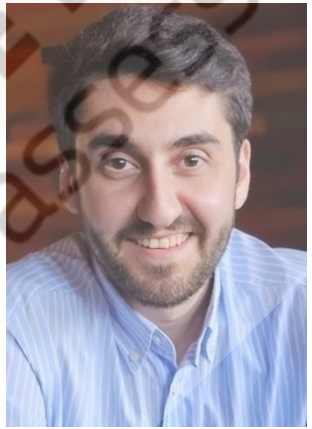
Towards a State-Dependent Fragility and Vulnerability Model Database for Earthquake Sequence Risk Assessment Applications

F. Narlitepe, AMB. Nafeh, K. Aljawhari, V. Silva

Special Session S01-SS04-AVMR on Advancing Vulnerability Modelling for Regional Risk Assessment and Resilient Communities

Time: Wednesday 16/09/2026 (11:30 AM – 12:55 PM)

Location: S10



Thank you!

Please attribute to the GEM Foundation with a link to:
https://www.globalquakemodel.org



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