MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

Call: UCPM-2022-PP: Prevention and Preparedness Projects on Civil Protection and Marine Pollution

Priority 1: Cross-border risk assessment for identified cross-border risks

BENEFICIARIES

eCampus University – Italy
Francesco Focacci

University of Pisa – Italy
Francesco Pistolesi

Gasilska Zveza Slovenije - Slovenija
Neža Strmole

Medjimurje County – Croatia
Alan Resman

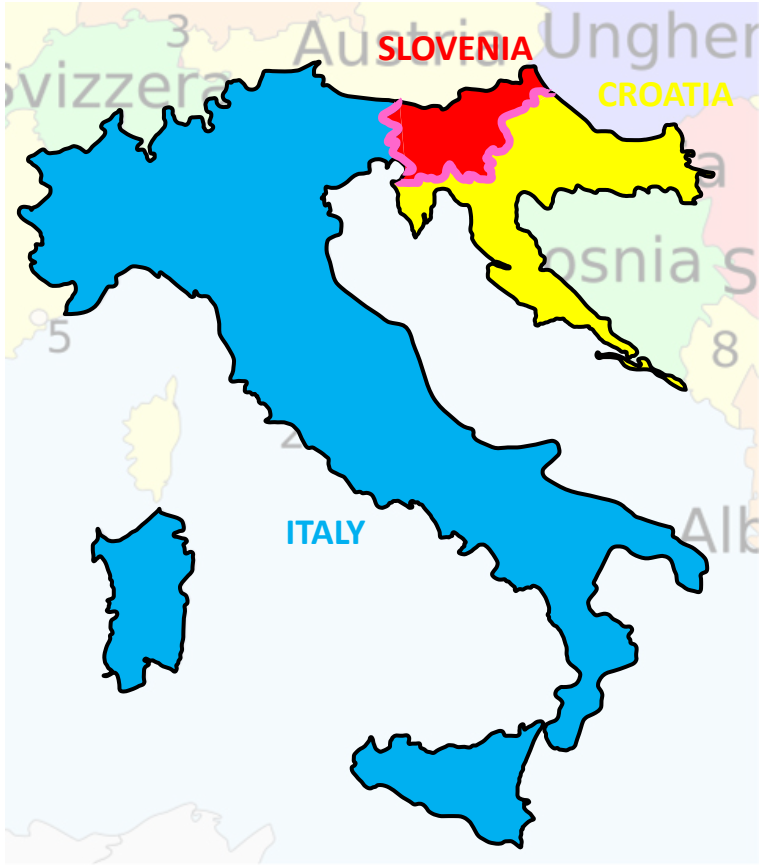
eCAMPUS UNIVERSITÀ

UNIVERSITÀ DI PISA

GASILSKA ZVEZA SLOVENIJE

MEĐIMURSKA ŽUPANIJA

➡ TWO SHARED BORDERS



MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

Call: UCPM-2022-PP: Prevention and Preparedness Projects on Civil Protection and Marine Pollution

Priority 1: Cross-border risk assessment for identified cross-border risks

PROJECT OVERVIEW

- Starting date: December 1, 2022
- End date: November 30, 2024
- Total Eligible costs: € 1076463
- EU contribution: € 911500

- € 353500 (39%) eCampus (Italy)
- € 254000 (28%) UNIPI (Italy)
- € 146500 (16%) Gasilska Zveza Slovenije (Slovenija)
- € 157500 (17%) Medjimurje County (Croatia)

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

SEISMIC RISK ASSESSMENT → **Prediction the probability of damages and economic losses produced by a potential seismic event**

IMPORTANCE OF SEISMIC RISK ASSESSMENT

POTENTIAL END USERS

PUBLIC ADMINISTRATIONS

PLANNING MITIGATION STRATEGIES

- Detect critical situations (poor/old structure) and plan strengthening strategies
- Rational use of economic resources

CIVIL PROTECTION AUTHORITIES

MANAGEMENT OF THE CIVIL PROTECTION EMERGENCY

- Define optimal emergency management procedures based on the expected damage scenarios
- Include planning of psychological support

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

SEISMIC RISK ASSESSMENT → **Evaluation of the probability of damages and losses produced by a potential seismic event**

TWO DIMENSIONS OF DAMAGE →
- **STRUCTURAL DAMAGES**
- **PSYCHOLOGICAL CONSEQUENCES**

} **PRODUCED BY A SEISMIC EVENT**

Depression
Anxiety
Post-traumatic stress disorder

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

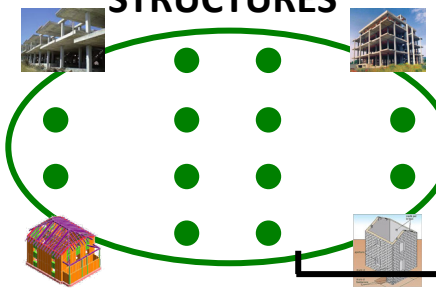
Co-funded by the European Union

eCAMPUS UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

CLASSES OF STRUCTURES

REPRESENTATIVE (BENCHMARK) STRUCTURES



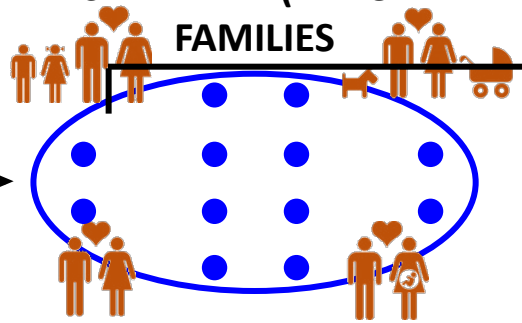
REPRESENTATIVE SEISMIC ACTIONS

STRUCTURAL ANALYSIS

STRUCTURAL DAMAGES

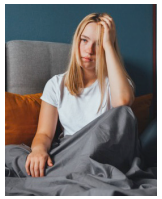
CLASSES OF FAMILIES

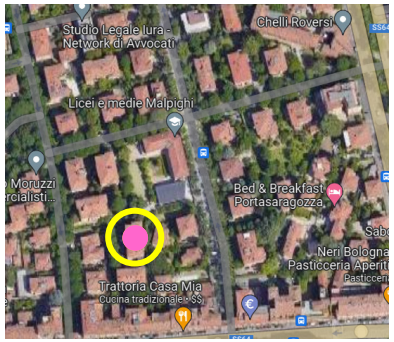
REPRESENTATIVE (BENCHMARK) FAMILIES



PSYCHOLOGICAL ANALYSIS

PSYCHOLOGICAL CONSEQUENCES





REAL STRUCTURES AND FAMILIES

EXPECTED SEISMIC ACTION

XAI TO ESTABLISH SIMILARITY CRITERIA

RISK ASSESSMENT INCLUDING STRUCTURAL DAMAGES AND LOSSES AND PSYCHOLOGICAL CONSEQUENCES

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

Work packages (WPs)	Objectives	WP leader
WP1: Project management and coordination	Optimizing the allocation of resources by creating a management framework that links together all the parts of the project Systematic monitoring of the activities planned Optimizing the technical work within the project and among partners Ensuring fulfillment of all the requirements by EC regarding communication and reporting	Francesco Focacci (eCampus)
WP2: Communication	Disseminate awareness of the project outputs and disseminate deliverables to interested authorities and stakeholders	Elisabetta Cattoni (eCampus)
WP3: Benchmark structures, EDPs, and representative families	Identification of benchmark structures Selection and calculation of the best EDPs to quantify the effect of seismic actions on structures Identification of the representative families of a set of representative seismic actions	Fabrizio Comodini – Elena Camisasca (eCampus)
WP4: XAI to estimate EDP values, structural/psychological damages, and losses	Design of XAI techniques to determine the level of similarity between benchmark and real structures Using XAI and analytical/numeric methods to estimate the EDP values of real structures Design and development of XAI methods to estimate structural/psychological damages and losses Design of data fusion techniques to obtain the multidimensional seismic risk assessment	Francesco Pistolesi (UNIPI)
WP5: Implementation of the website and web application	Design and development of the website Design and development of the web application	Francesco Pistolesi (UNIPI)
WP6: Application to pilot studies in cross-border areas	Multidimensional risk assessment in cross-border pilot areas	Alan Resman - Neža Strmole (MED - GZS)

Each WP is organized in tasks

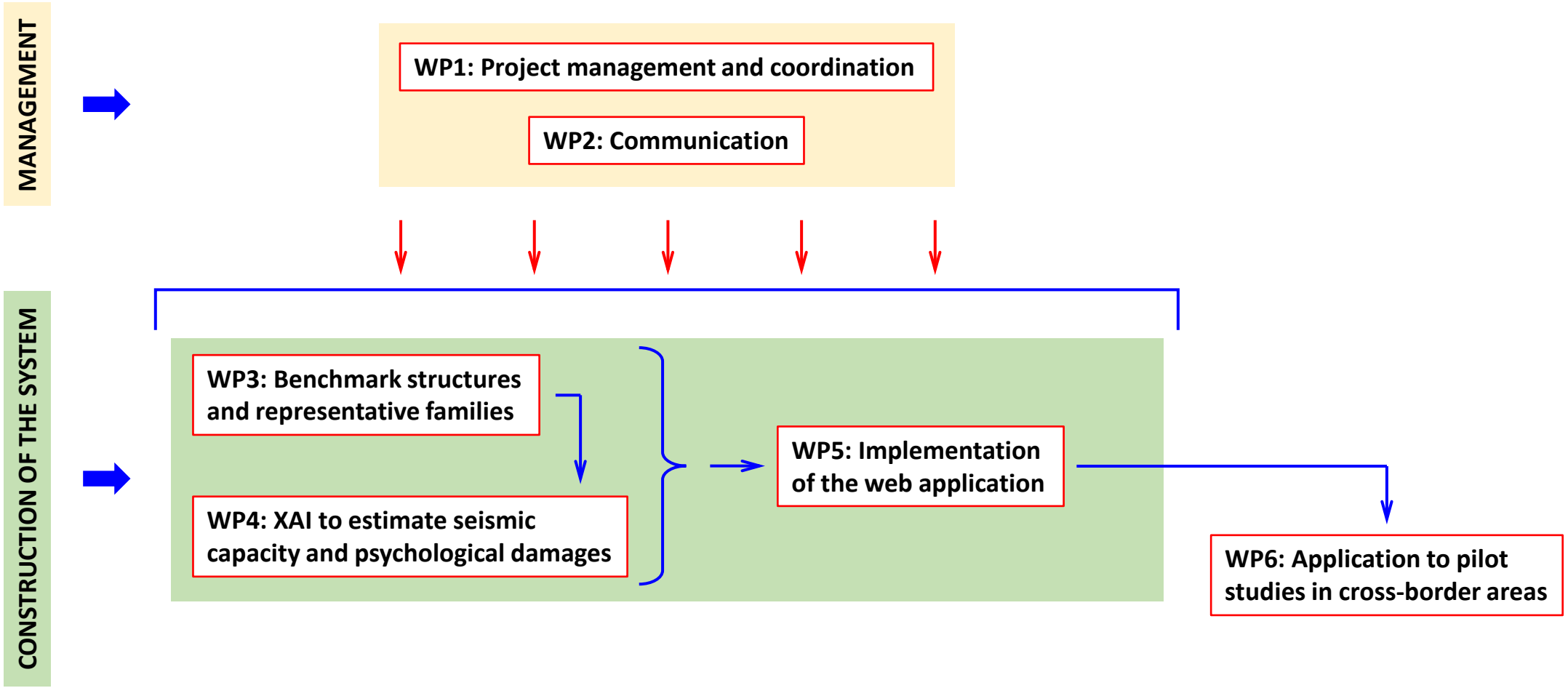
MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

Interaction among WPs



MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

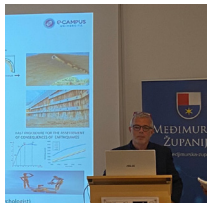
eCAMPUS UNIVERSITÀ

WP1: PROJECT MANAGEMENT AND COORDINATION

Smooth project running
Effective communication among partners and towards EC

Rome (IT)
Jan. 18, 2024

- **Technical activities**
  - Technical meetings and SC meetings
  - Defining procedures for collecting data and sharing them with all the partners
  - Submission of deliverables
  - Risk identification and mitigation planning



Cacovec (Croatia)
Oct. 03, 2024

Bovec (Slovenija)
Jan. 18, 2024

- Rome (Kick-off), Jan. 23, 2024 (Italy)
- Bovec , Jan. 18, 2024 (Slovenija)
- Sveti Martin na Muri , Jul. 04, 2024 (Croatia)
- Cacovec, Oct. 03, 2024 (Croatia)
- Moraro, Aug. 20, 2024 (Italy)
- Moraro, Oct. 03, 2024 (Italy)
- Online meetings (15)
- SC meetings (8)
- Novedrate (final meeting), Nov. 24, 2024 (Italy)

- **Administrative activities**
  - Recruitment procedures
  - Purchase of equipment
  - Agreement with the municipalities for collecting data
  - Contracts with consultants
  - Reallocation of economic resources

- Salvatore Verre (from 01/03/23 to 31/03/24)
- Riccardo Panico (from 17/07/23 to 30/11/2024)
- Cristal Sirotich (from 15/03/2023 to 30/11/2024)
- Evelina Volpe (from 14/08/2023 to 30/11/2024)
- Michele Baldassini (from 01/03/2023 to 30/11/2024)

Cristal

Riccardo

Evelina

Salvatore

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

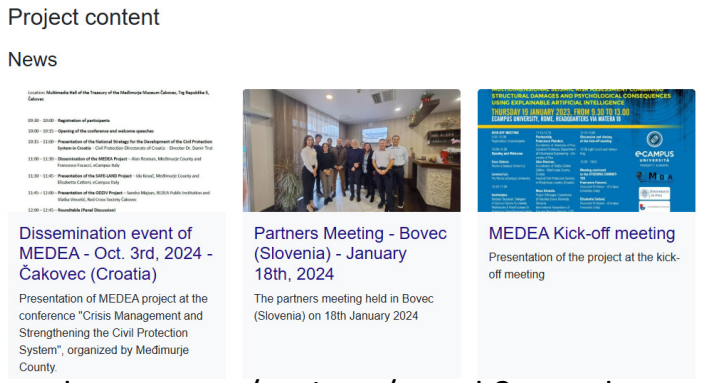
WP2: COMMUNICATION

- **Logo**

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

- **Web page**

European Union
Union Civil Protection Knowledge Network



https://civil-protection-knowledge-network.europa.eu/projects/search?s=medea

- **Dissemination events:**
  - Cacovec, Oct. 03, 2024 (Croatia)
  - Bovec, Nov. 22-23, 2024 (Slovenija)
  - Moraro, Sept. 11, 2024 (Italy)
  - Bruxelles, Oct. 22, 2024 (Belgium)
  - Novedrate, Nov. 27, 2024 (Italy)

- **Social networks**

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

WP3: BENCHMARK STRUCTURES AND REPRESENTATIVE FAMILIES

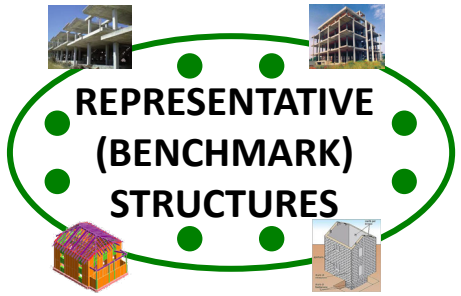
- **Structures**
  - → Definition classes of structures
    - → Simple (regular) masonry buildings
    - → Irregular masonry buildings
    - → Regular and irregular reinforced concrete buildings
  - → Definition of the structural and technical parameters
  - → Construction of sets of benchmark structures
    - → ≈ 1500 Simple masonry buildings
    - → ≈ 1200 Irregular masonry buildings
    - → ≈ 1400 Reinforced concrete buildings
  - → Structural analysis of benchmark structures to determine the seismic actions producing predefined levels of damage
    - D1: Negligible to slight
    - D2: Moderate
    - D3: Substantial to heavy
    - D4: Very heavy
- **Families**
  - → Definition of the psychological parameters
  - → Definition of questionnaires
  - → Definition of levels of psychological risk

MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

CONSTRUCTION OF DATASETS OF STRUCTURES (benchmark structures)

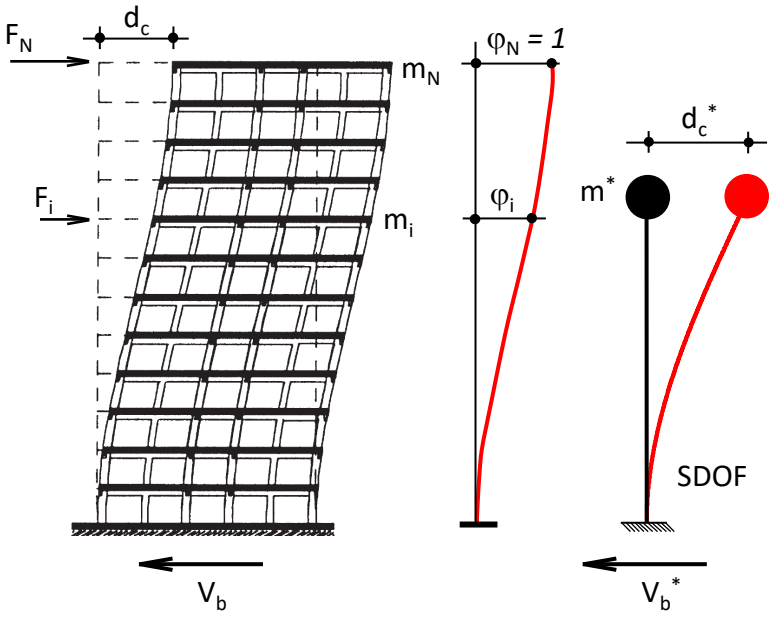


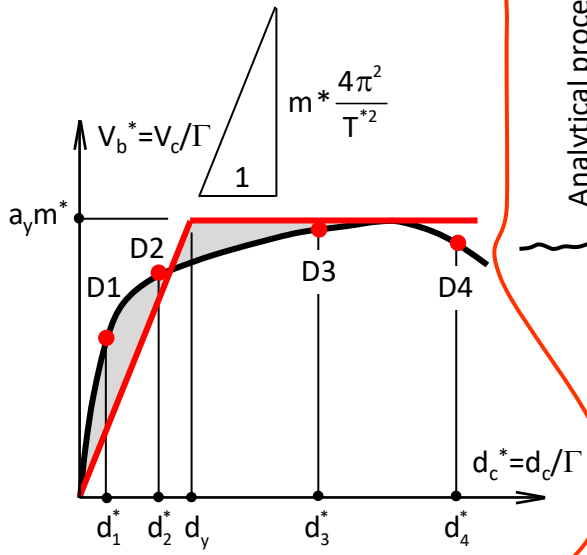
FOR ANY BENCHMARK STRUCTURE (of any class of structures)

Definition of a set of technical parameters

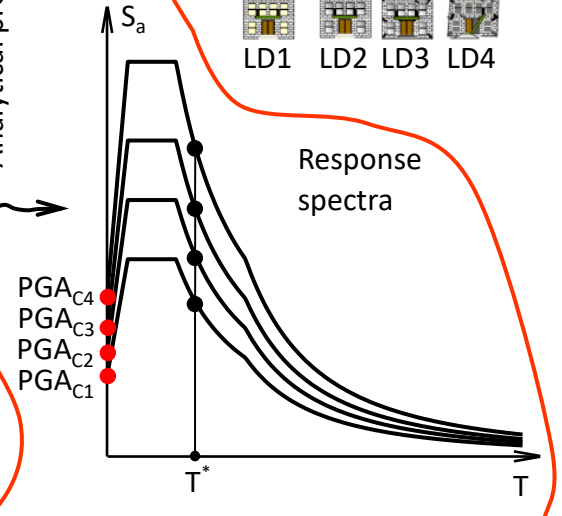
Analysis	Number	504 s
Analysis	Unit	Analysis 504
Number of Level	[-]	3.00
Average floor height	[m]	3.40
Sides ratio (x-length/ y-length)	[-]	1.28
Average floor area	[m²]	120.28
Number of internal alignments of masonry wall in	[-]	0.00
Number of internal alignments of masonry wall in Y	[-]	2.00
Area of the openings of the external masonry walls	[m²]	28.08
Area of the openings of the external masonry walls	[m²]	21.60
Area of the openings of the external masonry walls	[m²]	21.60
Area of the openings of the internal masonry walls	[m²]	6.60
Area of the openings of the internal masonry walls	[m²]	13.20
Area of the openings of the internal masonry walls	[m²]	13.20
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average shear strength of masonry (GF)	[MPa]	0.04
Average shear strength of masonry (EF 1)	[MPa]	0.04
Average shear strength of masonry (EF 2)	[MPa]	0.04
Average compressive strength of masonry (GF)	[MPa]	1.93
Average compressive strength of masonry (EF 1)	[MPa]	1.93
Average compressive strength of masonry (EF 2)	[MPa]	1.93
Masonry gross density (GF)	[kN/m³]	18.00
Masonry gross density (EF 1)	[kN/m³]	18.00
Masonry gross density (EF 2)	[kN/m³]	18.00
Elastic Modulus (GF)	[MPa]	750.00
Elastic Modulus (EF 1)	[MPa]	750.00
Elastic Modulus (EF 2)	[MPa]	750.00
Shear Modulus (GF)	[MPa]	250.00
Shear Modulus (EF 1)	[MPa]	250.00
Shear Modulus (EF 2)	[MPa]	250.00
Average area of shear strength (GF)	[m²]	9.48
Average area of shear strength (EF 1)	[m²]	7.14
Average area of shear strength (EF 2)	[m²]	7.14
Seismic floor mass (EF 1)	[ton]	74.79
Seismic floor mass (EF 2)	[ton]	74.79
Seismic floor mass – roofing plan (RP)	[ton]	110.35
Ratio of Seismic floor mass/ Average area of shear	[ton/m²]	7.89
Ratio of Seismic floor mass/ Average area of shear	[ton/m²]	10.48
Ratio of Seismic floor mass/ Average area of shear	[ton/m²]	15.45

Structural (pushover) analysis

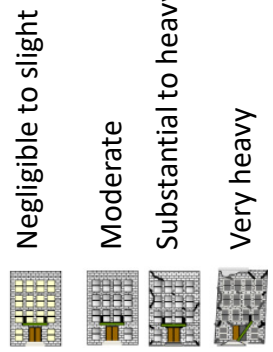




Analytical procedure



Response spectra



d_1^* d_2^* d_3^* d_4^*
a_y T^*

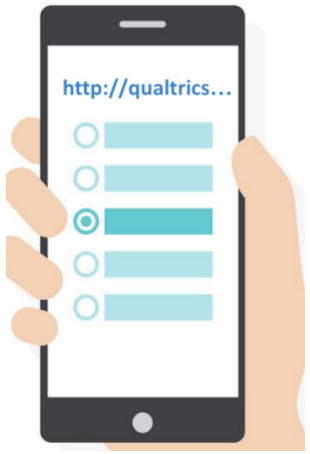
XAI learns the relation between the TP and parameters

PGA_{C4}
PGA_{C3}
PGA_{C2}
PGA_{C1}

LOSSES

PSYCOLOGICAL ASSESSSMENTS

→ **PEOPLE ARE PROVIDED WITH A QR CODE TO SEE A QUESTIONAIRE** → English, Slovenian, Croatian, Italian



Level 0 NO RISK	Individuals not at risk of developing vulnerability to PTSD thanks to the presence of only resources or proximal protective factors, and eventually 1 distal risk factor
Level 1 LOW RISK	Individuals with a low risk of developing vulnerability to PTSD thanks to the prevalence of resources or proximal protective facto
Level 2 RISK	Individuals with a moderate risk of developing vulnerability to PTSD caused by the compresence of proximal protective factors and distal or proximal risk factors
Level 3 HIGH RISK	Individuals with a high risk of developing vulnerability to PTSD caused by the prevalence of distal or proximal risk factors

ADULTS

1	Inventory Socio-demografico e peri-post terremoto
2	Brief Cope
3	Multidimensional Scale of Perceived Social Support (MSPSS)
4	Brief Assessment of Family Functioning Scale (BAFFS)
5	Cognitive Emotion Regulation Questionnaire (CERQ)
6	World Health Organisation-Five Well-Being (WHO-5)
7	Posttraumatic Stress Disorder Checklist (PC-PTSD-5)

ADULTS/PARENTS

8	Coparenting Relationship Scale (CRS)
9	Parenting Stress Index – Short Form (PSI-SF)
10	Child Behavior Checklist – only PTSD items (CBCL 1 ½ /5)

CHILDREN (7-18), with parents consent

1	Questionario socio-demografico
2	World Health Organisation-Five Well-Being (WHO-5)
3	Lum Emotional Availability of Parents (LEAP)
4	Cognitive Emotion Regulation Questionnaire (CERQ)
5	Coparenting Relationship Scale for children/adolescents (CRS-C; CRS-A)
6	Children's coping strategies checklist-revision 1 (CCSC-R1)
7	Child Revised Impact of Event Scale (CRIES-8)

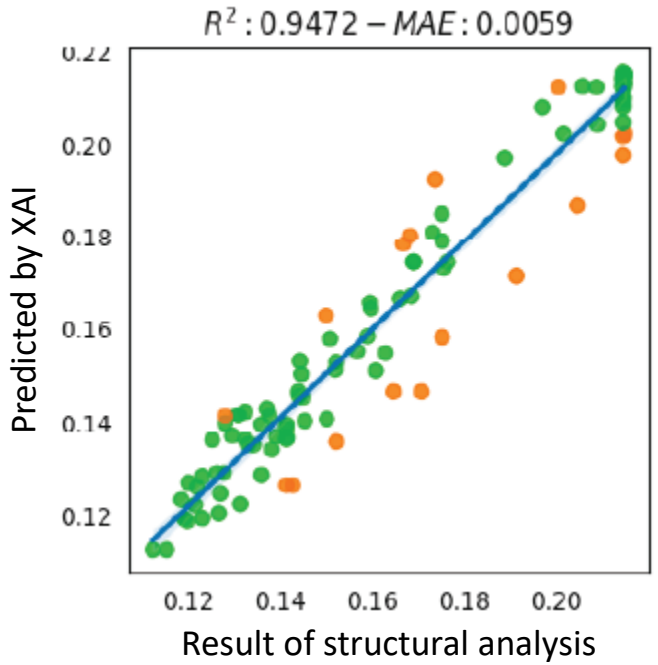
MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

WP4: XAI TO ESTIMATE EDP VALUES, STRUCTURAL/PSYCHOLOGICAL DAMAGES, AND LOSSES

- Application of different XAI models to datasets of benchmark structures
- Use of regression plots, beeswarm plot, and bar plot to asses the influence of different parameters on the seismic capacity
- Check of the reliability of the XAI models



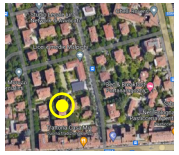
MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

WP5: IMPLEMENTATION OF THE WEB APPLICATION

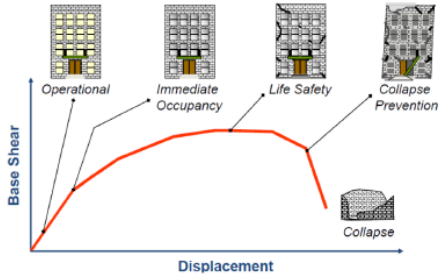
INPUT PARAMETERS FOR EACH STRUCTURE



Class
- Regular masonry structure
- Irregular masonry structure
- Reinforced concrete frames
- .....

Geometrical and mechanical data

→ Structural capacity : capacity PGAs (using XAI)



From Heintz J.A., Hamburger R.O., Mahoney M. (2014). FEMA P-58 Phase 2 – Development of performance-based seismic design criteria. 10th US National Conference on Earthquake, Anchorage Alaska.

Location (geographic coordinates)

Ground type
- A
- B
- ...
- E

OUTPUT PARAMETERS FOR EACH STRUCTURE

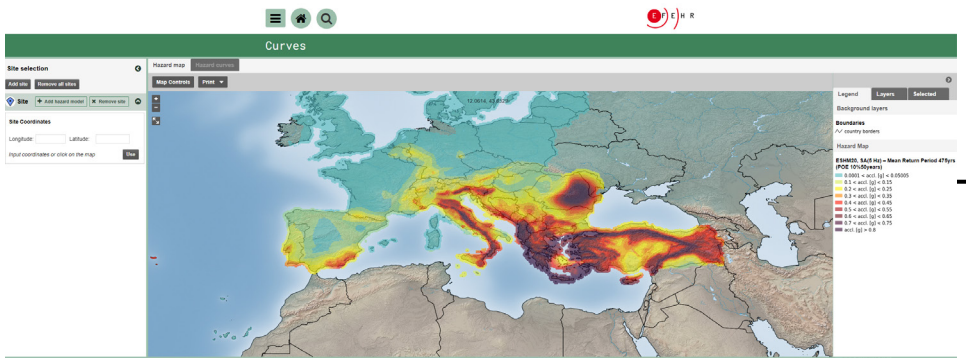
EAL
(Expected annual losses)

Average annual cost needed to repair the damages and cover losses induced by seismic events (depends on site hazard and the structural vulnerability).

Expressed as a **percentage of the construction cost**

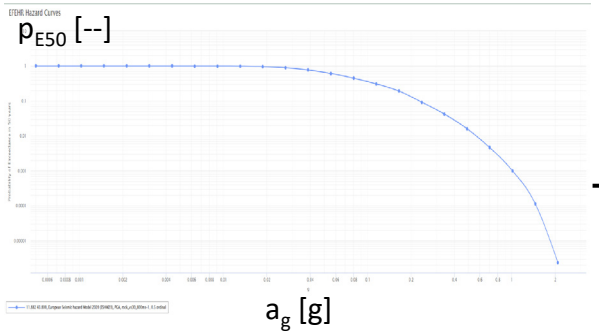
OUTPUT PARAMETERS FOR THE ENTIRE AREA

→ **Map of EAL**

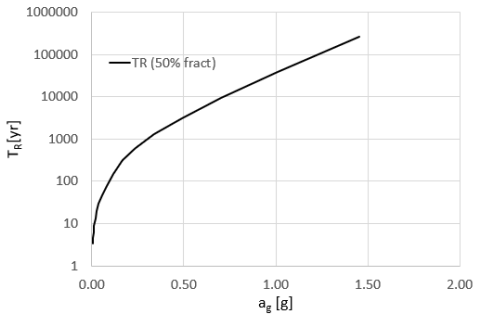


http://hazard.efehr.org/en/home/

→



→



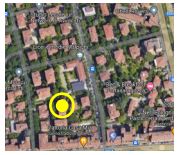
MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

WP5: IMPLEMENTATION OF THE WEB APPLICATION

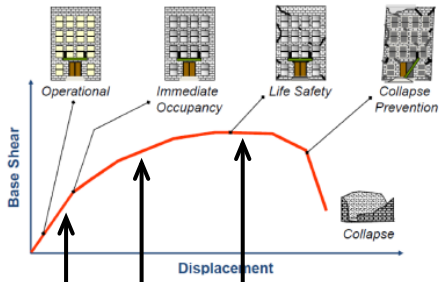
INPUT PARAMETERS FOR EACH STRUCTURE



Class
- Regular masonry structure
- Irregular masonry structure
- Reinforced concrete frames
- .....

Geometrical and mechanical data

→ Structural capacity : capacity PGAs (using XAI)



From Heintz J.A., Hamburger R.O., Mahoney M. (2014). FEMA P-58 Phase 2 – Development of performance-based seismic design criteria. 10th US National Conference on Earthquake, Anchorage Alaska.

Location (geographic coordinates)

Ground type
- A
- B
- ...
- E

Occurred or assumed seismic action (PGA_E)

Number of inhabitants (O)

Area of the building (A)

OUTPUT PARAMETERS FOR EACH STRUCTURE

EAL
(Expected annual losses)

Average annual cost needed to repair the damages and cover losses induced by seismic events (depends on site hazard and the structural vulnerability).
Expressed as a **percentage of the construction cost**

LD
(Level of damage)

Management of Civil Protection emergency

OUTPUT PARAMETERS FOR THE ENTIRE AREA

→ Map of EAL

→ Map of LD

- Number of short term unusable buildings
- Number of long term unusable buildings
- Number of homeless
- Number of deaths
- Number of injured
- Direct economic loss [€]

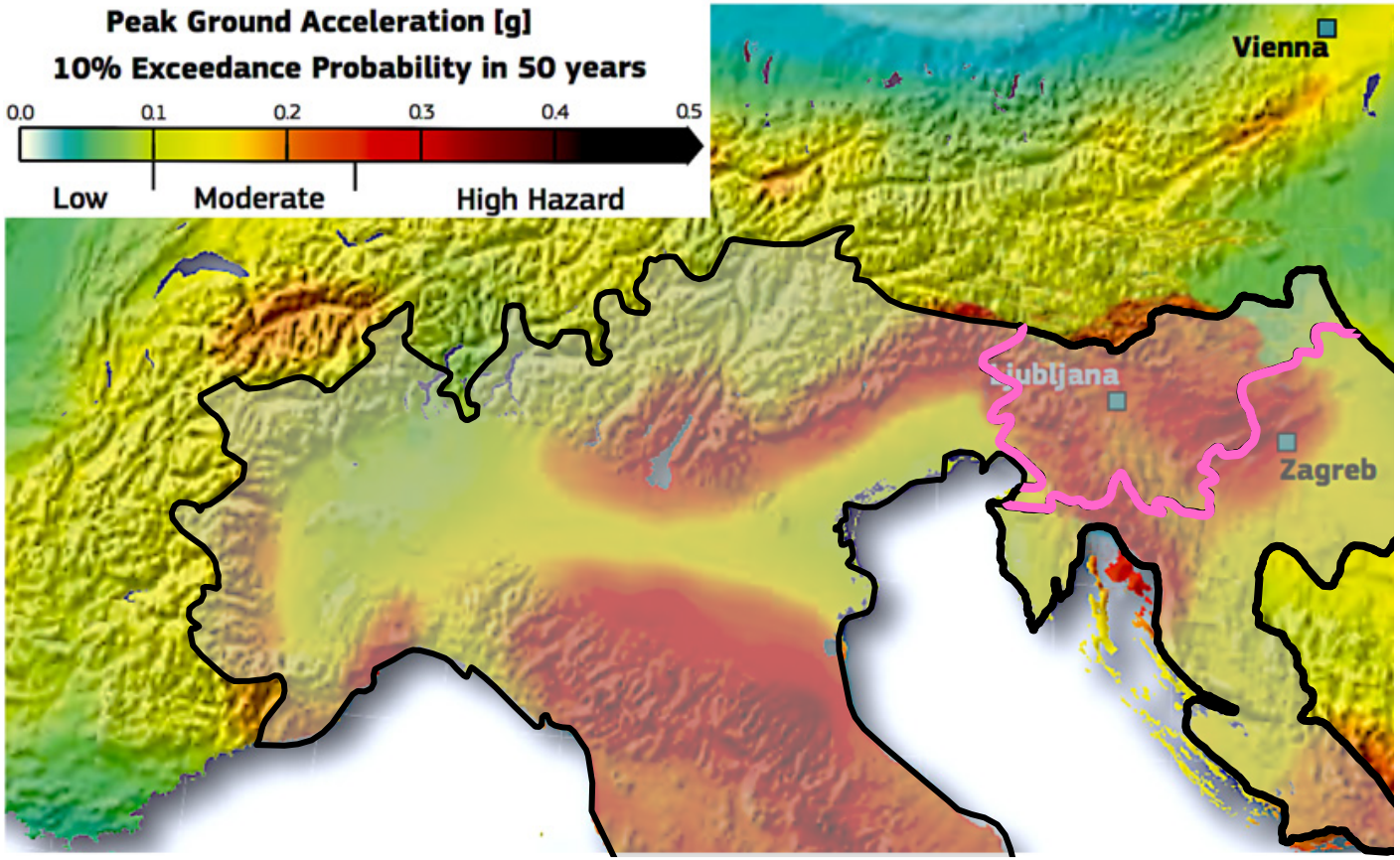
MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

WP6: APPLICATION TO PILOT STUDIES IN CROSS-BORDER AREAS

- **Use of the web application to perform risk assessment in cross-border areas**
  - → at the border between Italy and Slovenia
  - → at the border between Slovenia and Croatia



MEDEA
Multidimensional seismic risk assessment through explainable artificial intelligence

Co-funded by the European Union

eCAMPUS UNIVERSITÀ

SUMMARY OF TECHNICAL ACHIEVEMENTS

- **Two years of intense work successfully completed**
  - → Developed procedure for seismic risk assessment including **psychological consequences**
    - evaluation of **Expected annual losses** for a rational use of economical resources
    - evaluation of the **consequences** of an occurred or assumed seismic event for an effective emergency management
  - → Guideline for the identification of the most vulnerable families to seismic events
  - → Procedure implemented in a web application
  - → Web application applied in two cross-border areas
  - → Scientific publications

CONTINUATION

- **Maintenance and update of the web application**
  - → Introduction of further classes of structures for a wide spread of the system
  - → Increase of the datasets of benchmark structure to increase the reliability of the results
  - → Improvement of the algorithms to increase the reliability of the results