Construction of a scientific network among the partners and other competent research centres to devise a common strategy to early warning systems to tackle flood, meteo-tsunami and seismic hazards in IT and HR test sites;

Final Version

Deliverable Number D.5.1.4.

Project Acronym	PMO-GATE
Project ID Number	10046122
Project Title	Preventing, Managing and Overcoming natural-hazards risk to mitiGATE economic and social impact
Priority Axis	2: Safety and Resilience
Specific objective	2.2: Increase the safety of the Programme area from natural and man-made disaster
Work Package Number	5
Work Package Title	Measures for risk mitigation
Activity Number	5.1
Activity Title	Improved early warning systems for single risks
Partner in Charge	UNIST-FGAG
Partners involved	UNIFE, UNIST-FGAG, RERA SD, OGS, INGV, MUNKA, MUNFE
Status	Final
Distribution	Public

Table of content

Organization of Mini-symposium in ECCOMAS-MSF 2021 conference and presentation of the project results

UNIST and UNIFE organized a mini-symposium "Risk assessment and resilience estimation of civil engineering structures and systems", focusing on the PMO-GATE topics in the framework of an international conference ECCOMAS-MSF 2021 held in Split in the period June 30th – July 02nd 2021.

Researchers of eight international universities and research institutes with 43 participants (20 at the site and 23 on-line) have participated and presented their investigations.

Methodologies developed in PMO-GATE project and achieved results have been presented by UNIFE and UNIST-FGAG researchers in four papers:

1. Seismic assessment of historical stone masonry buildings [1] - keynote lecture (Fig. 1);
2. Coastal flood exposure assessment due to sea level rise and extreme wave events (Fig. 2);
3. A Promethee multiple-criteria methodology for combined seismic and hydraulic risk assessment: the case study of Ferrara (Italy)
4. A machine learning approach to the seismic fragility assessment of buildings

All papers have been published in the conference proceedings "5th International Conference on Multi-scale Computational Methods for Solids and Fluids" which is available at the web-site http://gf.unsa.ba/eccomas-msf-2021/Eccomas_MSF_2021.pdf.

ECCOMAS MSF 2021 THEMATIC CONFERENCE
30 June – 2 July 2021, Split, Croatia

SEISMIC ASSESSMENT OF HISTORICAL STONE MASONRY BUILDINGS

Željana Nikolić[1], Luka Runjić[2], Nives Ostojić Škomrlj[1], Vedrana Kozulić[1], Gabrijela Grozdanić[1], Elena Benvenuti[2]

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Many countries of moderate to high seismic risk, including Croatia, have old city cores with buildings built of stone or brick long before any regulations on construction in earthquake areas came into force. Some of them are categorized as cultural heritage and should be preserved for future generations. Strong earthquakes cause significant damage and demolition of such buildings and numerous casualties. Rehabilitation requires significant financial resources that cannot be secured at once. Therefore, systematic care and planning is necessary in order to detect the vulnerability of buildings to earthquakes, to determine priorities in rehabilitation and continuously provide funds for the reconstruction of such buildings. Between different approaches for the evaluation of structural vulnerability, static non-linear (pushover) method is recognized as reliable tool for analysis of capacity of structure and failure mechanism.

In this work, seismic vulnerability index method and static non-linear (pushover) analysis are used for seismic vulnerability assessment of stone masonry buildings in the historic city center of Kaštel Kambelovac (Fig.1). The investigation represents one of the activities of the PMO-GATE project, focusing on the preventing, managing and overcoming natural-hazards risks like seismic, floods and extreme sea wave risks.

Fig. 1. Historical center of Kaštel Kambelovac with analysed buildings

The evaluation of the global structural capacity is performed according to Eurocode 8 [1] and corresponding Croatian standard [2, 3]. It is shown for 5 masonry buildings, built between the 15th and 19th centuries. The buildings are made of stone blocks with mortar joints with a thickness of the walls between 45 and 75 cm and flexible wooden floors.

The response of the structure is investigated along the two geometrical orthogonal axes, in both the positive and negative directions. Non-regular distribution of the masses inside the structure is considered by the assumption of an eccentricity of the lateral loads equal to ±5% of the maximum floor dimension at each level. Three lateral load distributions (uniform, linear and modal distribution) with the presence of eccentricity in positive and negative direction give in total 24 analyses.

Each pushover analysis results with the MDOF capacity curve. After the tranformation of the MDOF curve in the SDOF one, bilinear curve is obtained. Then, capacity of the structure expressed in peak ground acceleration corresponding to the end of bilinear curve is calculated.

Seismic vulnerability assessment is performed by TREMURI software [4]. Complete 3D models of masonry structures can be obtained assembling 2-nodes macro-elements, representing the non-linear behaviour of masonry panels and piers. The macro-element considers both the shear-sliding damage failure mode and its evolution, controlling the strength deterioration and the stiffness degradation, and rocking mechanisms, with toe crushing effect, modelled by means of phenomenological non-linear constitutive law with stiffness deterioration in compression.

The seismic demand is defined by elastic acceleration response spectrum. Type 1 response spectrum [2] and soil class A [5] are used for HR test site Kastel Kambelovac. The design ground acceleration defined by seismic hazard map for the return period of 475 years is equal to a_g=0.22g. The seismic capacity of the buildings will be defined by checking if the seismic demand represents with 475 years is satisfied.

Numerical predictions of the collapse acceleration by non-linear static analyses show that no building meets the seismic requirement equal to a_g=0.22g in either directions. Namely, the peak ground acceleration corresponding to the collapse of the buildings are in the range of 0.07g and 0.10g. The failure occurs due to different collapse modes such as shear, bending, tension and compression failures. The analyses shows that pushover analysis of stone masonry buildings can provide an insight into both global seismic resistance and the mechanisms that lead to the structural failure. The seismic resistance capacity and obtained vulnerability indexes for chosen buildings are discussed.

Acknowledgements
This work has been supported through the project "Preventing, managing and overcoming natural-hazards risks to mitigate economic and social impact" (PMO-GATE), funded by the European Union through the programme Interreg Italy-Croatia, and the project KK.01.1.1.02.0027, co-financed by the Croatian Government and the European Union through the European Regional Development Fund - the Competitiveness and Cohesion Operational Programme.

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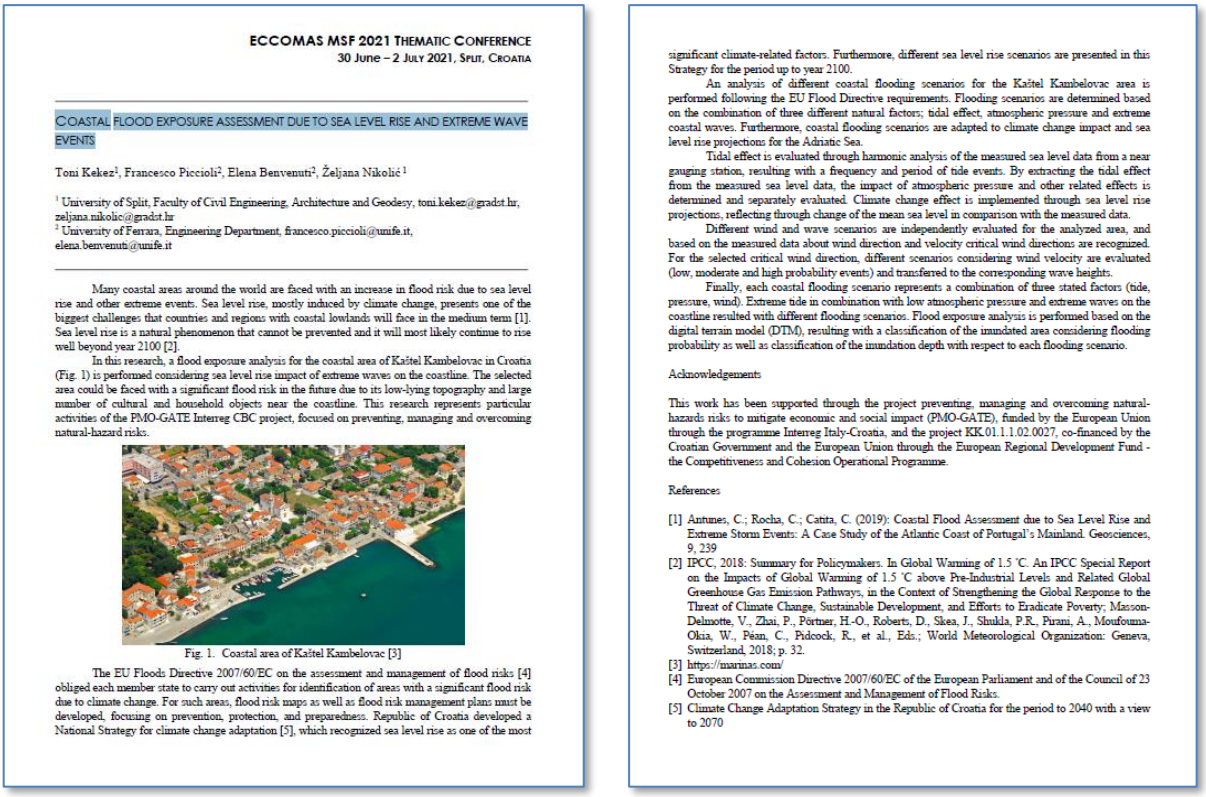
Fig. 1. The paper "Seismic assessment of historical stone masonry buildings"



ECCOMAS MSF 2021 THEMATIC CONFERENCE
30 June – 2 JULY 2021, SPLIT, CROATIA

COASTAL FLOOD EXPOSURE ASSESSMENT DUE TO SEA LEVEL RISE AND EXTREME WAVE EVENTS

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Many coastal areas around the world are faced with an increase in flood risk due to sea level rise and other extreme events. Sea level rise, mostly induced by climate change, presents one of the biggest challenges that countries and regions with coastal lowlands will face in the medium term [1]. Sea level rise is a natural phenomenon that cannot be prevented and it will most likely continue to rise well beyond year 2100 [2].

In this research, a flood exposure analysis for the coastal area of Kaštel Kambelovac in Croatia (Fig. 1) is performed considering sea level rise impact of extreme waves on the coastline. The selected area could be faced with a significant flood risk in the future due to its low-lying topography and large number of cultural and household objects near the coastline. This research represents particular activities of the PMO-GATE Interreg CBC project, focused on preventing, managing and overcoming natural-hazard risks.

Fig. 1. Coastal area of Kaštel Kambelovac [3]

The EU Floods Directive 2007/60/EC on the assessment and management of flood risks [4] obliged each member state to carry out activities for identification of areas with a significant flood risk due to climate change. For such areas, flood risk maps as well as flood risk management plans must be developed, focusing on prevention, protection, and preparedness. Republic of Croatia developed a National Strategy for climate change adaptation [5], which recognized sea level rise as one of the most significant climate-related factors. Furthermore, different sea level rise scenarios are presented in this Strategy for the period up to year 2100.

An analysis of different coastal flooding scenarios for the Kaštel Kambelovac area is performed following the EU Flood Directive requirements. Flooding scenarios are determined based on the combination of three different natural factors; tidal effect, atmospheric pressure and extreme coastal waves. Furthermore, coastal flooding scenarios are adapted to climate change impact and sea level rise projections for the Adriatic Sea.

Tidal effect is evaluated through harmonic analysis of the measured sea level data from a near gauging station, resulting with a frequency and period of tide events. By extracting the tidal effect from the measured sea level data, the impact of atmospheric pressure and other related effects is determined and separately evaluated. Climate change effect is implemented through sea level rise projections, reflecting through change of the mean sea level in comparison with the measured data.

Different wind and wave scenarios are independently evaluated for the analyzed area, and based on the measured data about wind direction and velocity critical wind directions are recognized. For the selected critical wind direction, different scenarios considering wind velocity are evaluated (low, moderate and high probability events) and transferred to the corresponding wave heights.

Finally, each coastal flooding scenario represents a combination of three stated factors (tide, pressure, wind). Extreme tide in combination with low atmospheric pressure and extreme waves on the coastline resulted with different flooding scenarios. Flood exposure analysis is performed based on the digital terrain model (DTM), resulting with a classification of the inundated area considering flooding probability as well as classification of the inundation depth with respect to each flooding scenario.

Acknowledgements

This work has been supported through the project preventing, managing and overcoming natural-hazards risks to mitigate economic and social impact (PMO-GATE), funded by the European Union through the programme Interreg Italy-Croatia, and the project KK.01.1.1.02.0027, co-financed by the Croatian Government and the European Union through the European Regional Development Fund - the Competitiveness and Cohesion Operational Programme.

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Fig. 2. The paper "Coastal flood exposure assessment due to sea level rise and extreme wave events"

ECCOMAS MSF 2021 THEMATIC CONFERENCE
30 June – 2 July 2021, Split, Croatia

A PROMETHEE MULTIPLE-CRITERIA METHODOLOGY FOR COMBINED SEISMIC AND HYDRAULIC RISK ASSESSMENT: THE CASE STUDY OF FERRARA (ITALY)

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Many regions worldwide are threatened by multiple natural and technological hazards, the number of this disasters significantly increase during the last decades. These disasters acted as indicators of a greater exposure to multi-risk situations and showed an increased vulnerability of our societies to more complex risks.
The awareness of this worrying trend has increased the need for appropriate supports, tools and methodologies in order to be able to address these problems and lead to sustainable risk management activities (prevention, mitigation, crisis management and recovery) [1]. Considering a joint analysis of multiple hazards numerous challenges and difficulties arise that's why the development of the modelling of multi risks analysis scheme is still in the early stages [2].
The first difficulty is linked to the comparability of hazardous events: the risk associated with different types of natural hazards are often estimated using different procedures leading to the results not to be comparable, when the events themselves could be highly correlated [3]. The second difficulty concerns the comparison of the vulnerabilities of the exposed elements.
Moreover, another issue is related to the weighting of the relevance of certain hazards of exposed elements for the territory: stakeholders may have different perceptions on the importance of each single risk. Lastly it is also necessary to take into account the difficulty to collect data and information.
The purpose of this work is to describe the methodology used for the evaluation of the combined seismic and hydraulic risk of the territory of Ferrara.
The Visual PROMETHEE software, based on outranking methods (PROMETHEE methods), was used as a tool for data implementation.
Visual PROMETHEE, known for its simplicity and an important number of applications in different fields, it is based on pair-wise comparisons and allows a decision-maker to full rank a finite set of *actions* that are evaluated over a set of *criteria*. The information related to each criterion is aggregated through the definition of preference functions, each criterion also have a weight expressed by a non-negative number that represents the importance of the different criteria: the higher the weight the more important the criterion. The weights reflect a major part of the "brain" of the decision maker. [4]
In this application the hydraulic and seismic risk have been broken down into their components: probability of occurrence of the flood, seismic hazard (PGA), exposure (land use, strategic buildings, population density) and vulnerability (age of buildings); they have been included in Visual PROMETHEE as "criteria", while the municipalities of the Ferrara territory as "alternatives". These data were collected from both the Consorzio di Bonifica Pianura di Ferrara and the Municipality of Ferrara websites.
The result of the analysis made it possible to highlight the areas most affected by the hydraulic-seismic risk (Fig. 1) but also the criteria that most positively and negatively influence the municipalities of Ferrara (Fig. 2).

These results depend on the personal choices of the individual stakeholders in the selection of parameters (weights and preference functions), however some small deviations in the determination of these values do not often induce important modifications.

Figure 1. Hydraulic-seismic risk map of the territory of Ferrara

Figure 2. Promethee Rainbow.

Acknowledgements

This work has been supported by the project "Preventing, Managing and Overcoming natural-hazards risks to mitiGATE economic and social impact" (PMO-GATE), funded by the European Union in the context of the Interreg Italy-Croatia program.

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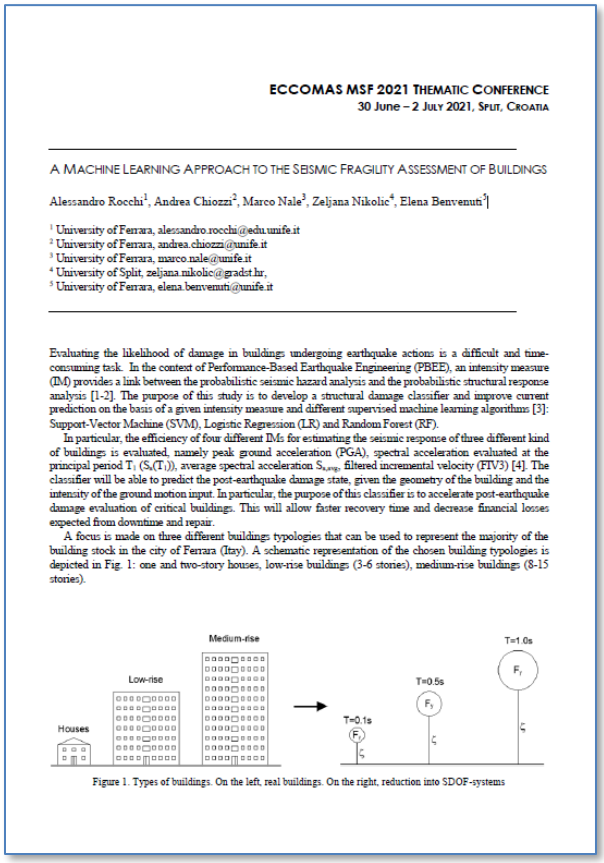
Fig. 3. The paper "A Promethee multiple-criteria methodology for combined seismic and hydraulic risk assessment: the case study of Ferrara (Italy)"



ECCOMAS MSF 2021 THEMATIC CONFERENCE
30 June – 2 JULY 2021, SPLIT, CROATIA

A MACHINE LEARNING APPROACH TO THE SEISMIC FRAGILITY ASSESSMENT OF BUILDINGS

Alessandro Rocchi[1], Andrea Chiozzi[2], Marco Nale[3], Zeljana Nikolic[4], Elena Benvenuti[5]

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Evaluating the likelihood of damage in buildings undergoing earthquake actions is a difficult and time-consuming task. In the context of Performance-Based Earthquake Engineering (PBEE), an intensity measure (IM) provides a link between the probabilistic seismic hazard analysis and the probabilistic structural response analysis [1-2]. The purpose of this study is to develop a structural damage classifier and improve current prediction on the basis of a given intensity measure and different supervised machine learning algorithms [3]: Support-Vector Machine (SVM), Logistic Regression (LR) and Random Forest (RF).

In particular, the efficiency of four different IMs for estimating the seismic response of three different kind of buildings is evaluated, namely peak ground acceleration (PGA), spectral acceleration evaluated at the principal period T_1 ($S_a(T_1)$), average spectral acceleration $S_{a,avg}$, filtered incremental velocity (FIV3) [4]. The classifier will be able to predict the post-earthquake damage state, given the geometry of the building and the intensity of the ground motion input. In particular, the purpose of this classifier is to accelerate post-earthquake damage evaluation of critical buildings. This will allow faster recovery time and decrease financial losses expected from downtime and repair.

A focus is made on three different buildings typologies that can be used to represent the majority of the building stock in the city of Ferrara (Italy). A schematic representation of the chosen building typologies is depicted in Fig. 1: one and two-story houses, low-rise buildings (3-6 stories), medium-rise buildings (8-15 stories).

Figure 1. Types of buildings. On the left, real buildings. On the right, reduction into SDOF-systems

The right panel in Fig. 1 shows the way in which these real structures can be simplified into single degree of freedom (SDOF) systems, characterized by their corresponding period of vibration (T), lateral strength (Fy), and damping ratio (ξ). The lateral strength of each system was chosen such that the proportion of collapses of each SDOF is around 5%.

We will focus on these simplified systems with T=0.1s, 0.5s, 1.0s while ξ will be kept equal to 5% as usually done in practice. The force-displacement behavior of the simplified models was based on common structural engineering parameters, having a bilinear form with a post-yield stiffness ratio of -2%.
The dataset is built from the outcomes of nonlinear dynamic analyses on the three oscillators for an unbiased set of 274 different input ground motions.

Using the app *MATLAB* Classification Learner, we create an analytic model to classify the various samples (buildings) in two categories, respectively representatives of a state of collapse or non-collapse.

We evaluate the precision of the model by analyzing the confusion matrix and calculating three different parameters for each of the two classes. Using the collected parameters, we determine the predictive reliability of the selected IMs (Figs. 2-4).

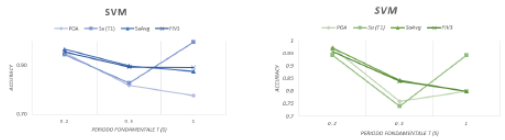

Figure 2. SVM. Accuracy vs Fundamental Period. On the left, elastic oscillator. On the right, elastic-plastic oscillator.

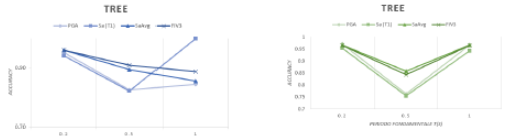

Figure 3. Tree. Accuracy vs Fundamental Period. On the left, elastic oscillator. On the right, elastic-plastic oscillator.

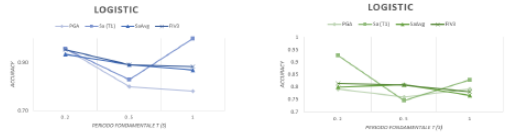

Figure 4. Logistic Regression. Accuracy vs Fundamental Period. On the left, elastic oscillator. On the right, elastic-plastic oscillator.

Acknowledgements

This work has been supported by the project "Preventing, Managing and Overcoming natural-hazards risks to mitiGATE economic and social impact" (PMO-GATE), funded by the European Union in the context of the Interreg Italy-Croatia program.

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Fig. 4. The paper "A machine learning approach to the seismic fragility assessment of buildings"

Organization of Special Issue "Natural-Hazards Risk Assessment for Disaster Mitigation" in the scientific journal “Applied Sciences”

UNIFE and UNIST staff have jointly organized Special Issue "Natural-Hazards Risk Assessment for Disaster Mitigation" in the scientific journal “Applied Sciences”.

This Special Issue addresses concepts, methods and techniques for the natural hazards risk assessment including, but not limited to, floods, earthquakes and meteotsunamis.

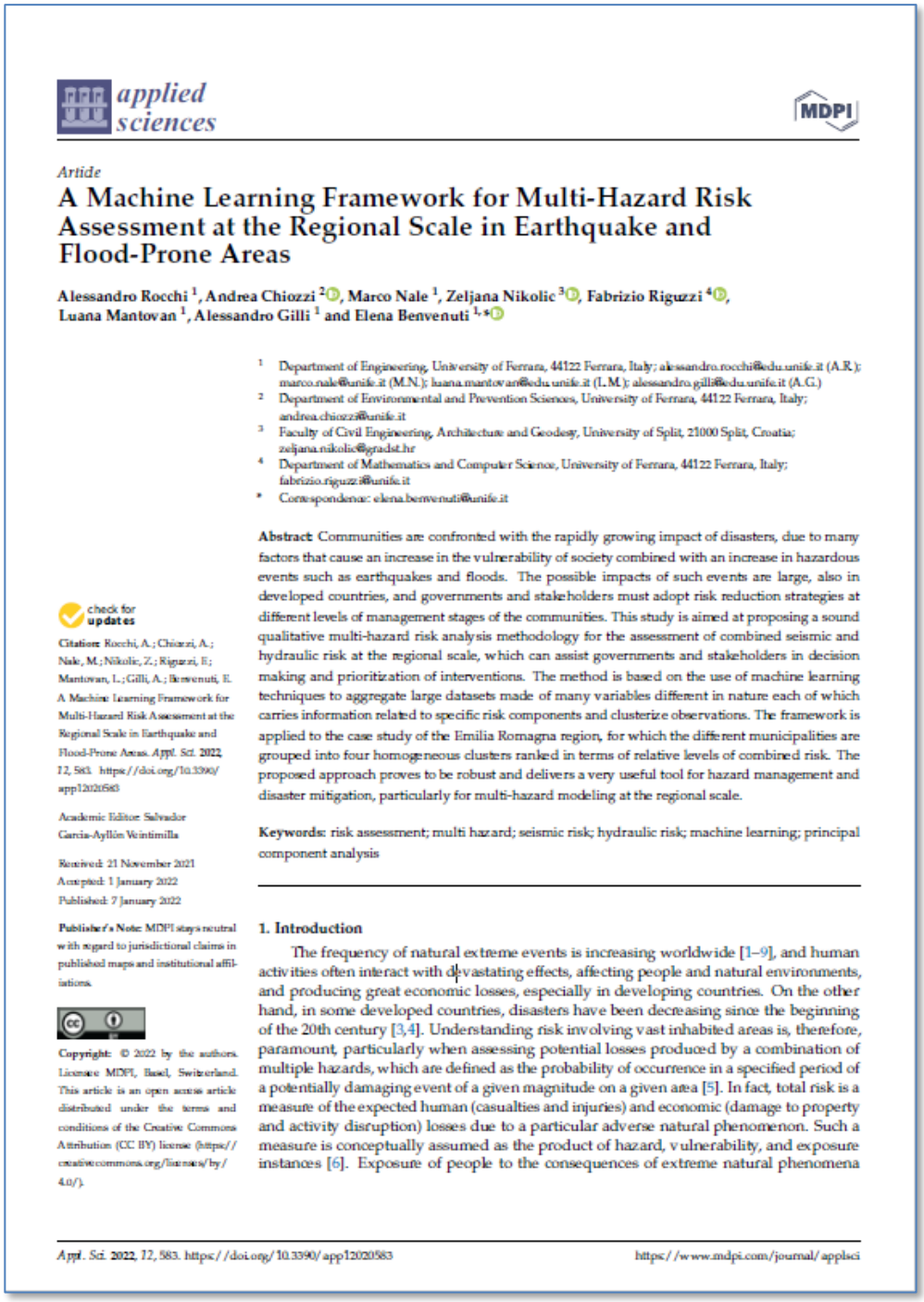
Information about the Special Issue is available at the following web-site:

https://www.mdpi.com/journal/applsci/special_issues/nhra_disaster_mitigation

So far, 12 scientific papers have been published in the Special issue. Among them are 5 papers dealing with the topics of the PMO-GATE project:

1. A Machine Learning Framework for Multi-Hazard Risk Assessment at the Regional Scale in Earthquake and Flood-Prone Areas (https://www.mdpi.com/2076-3417/12/2/583) [5], Fig. 5
2. A PROMETHEE Multiple-Criteria Approach to Combined Seismic and Flood Risk Assessment at the Regional Scale (https://www.mdpi.com/2076-3417/12/3/1527) [6], Fig. 6.
3. Seismic Risk Assessment of Urban Areas by a Hybrid Empirical-Analytical Procedure Based on Peak Ground Acceleration (https://www.mdpi.com/2076-3417/12/7/3585) [7], Fig. 7.
4. Analysis of the Seismic Properties for Engineering Purposes of the Shallow Subsurface: Two Case Studies from Italy and Croatia (https://www.mdpi.com/2076-3417/12/9/4535) [8], Fig. 8.
5. A Database for Tsunamis and Meteotsunamis in the Adriatic Sea (https://www.mdpi.com/2076-3417/12/11/5577) [9], Fig. 9.

Four project partners (UNIFE, UNIST-FGAG, OGS and INGV) participated in the published papers.



applied sciences

MDPI

Article

A Machine Learning Framework for Multi-Hazard Risk Assessment at the Regional Scale in Earthquake and Flood-Prone Areas

Alessandro Rocchi [1], Andrea Chiozzi [2], Marco Nale [1], Zeljana Nikolic [3], Fabrizio Riguzzi [4], Luana Mantovan [1], Alessandro Gilli [1] and Elena Benvenuti [1,*]

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Abstract: Communities are confronted with the rapidly growing impact of disasters, due to many factors that cause an increase in the vulnerability of society combined with an increase in hazardous events such as earthquakes and floods. The possible impacts of such events are large, also in developed countries, and governments and stakeholders must adopt risk reduction strategies at different levels of management stages of the communities. This study is aimed at proposing a sound qualitative multi-hazard risk analysis methodology for the assessment of combined seismic and hydraulic risk at the regional scale, which can assist governments and stakeholders in decision making and prioritization of interventions. The method is based on the use of machine learning techniques to aggregate large datasets made of many variables different in nature each of which carries information related to specific risk components and clusterize observations. The framework is applied to the case study of the Emilia Romagna region, for which the different municipalities are grouped into four homogeneous clusters ranked in terms of relative levels of combined risk. The proposed approach proves to be robust and delivers a very useful tool for hazard management and disaster mitigation, particularly for multi-hazard modeling at the regional scale.

Keywords: risk assessment; multi hazard; seismic risk; hydraulic risk; machine learning; principal component analysis

Citation: Rocchi, A.; Chiozzi, A.; Nale, M.; Nikolic, Z.; Riguzzi, F.; Mantovan, L.; Gilli, A.; Benvenuti, E. A Machine Learning Framework for Multi-Hazard Risk Assessment at the Regional Scale in Earthquake and Flood-Prone Areas. *Appl. Sci.* **2022**, *12*, 583. https://doi.org/10.3390/app12020583

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1. Introduction

The frequency of natural extreme events is increasing worldwide [1–9], and human activities often interact with devastating effects, affecting people and natural environments, and producing great economic losses, especially in developing countries. On the other hand, in some developed countries, disasters have been decreasing since the beginning of the 20th century [3,4]. Understanding risk involving vast inhabited areas is, therefore, paramount, particularly when assessing potential losses produced by a combination of multiple hazards, which are defined as the probability of occurrence in a specified period of a potentially damaging event of a given magnitude on a given area [5]. In fact, total risk is a measure of the expected human (casualties and injuries) and economic (damage to property and activity disruption) losses due to a particular adverse natural phenomenon. Such a measure is conceptually assumed as the product of hazard, vulnerability, and exposure instances [6]. Exposure of people to the consequences of extreme natural phenomena

Fig. 5. The paper "A Machine Learning Framework for Multi-Hazard Risk Assessment at the Regional Scale in Earthquake and Flood-Prone Areas"

applied sciences

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Article

A PROMETHEE Multiple-Criteria Approach to Combined Seismic and Flood Risk Assessment at the Regional Scale

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Abstract: Social vulnerability is deeply affected by the increase in hazardous events such as earthquakes and floods. Such hazards have the potential to greatly affect communities, including in developed countries. Governments and stakeholders must adopt suitable risk reduction strategies. This study is aimed at proposing a qualitative multi-hazard risk analysis methodology in the case of combined seismic and flood risk using PROMETHEE, a Multiple-Criteria Decision Analysis technique. The present case study is a multi-hazard risk assessment of the Ferrara province (Italy). The proposed approach is an original and flexible methodology to qualitatively prioritize urban centers affected by multi-hazard risks at the regional scale. It delivers a useful tool to stakeholders involved in the processes of hazard management and disaster mitigation.

Keywords: risk assessment; multi hazard; seismic risk; flood risk; Multiple-Criteria Decision Analysis; PROMETHEE algorithm

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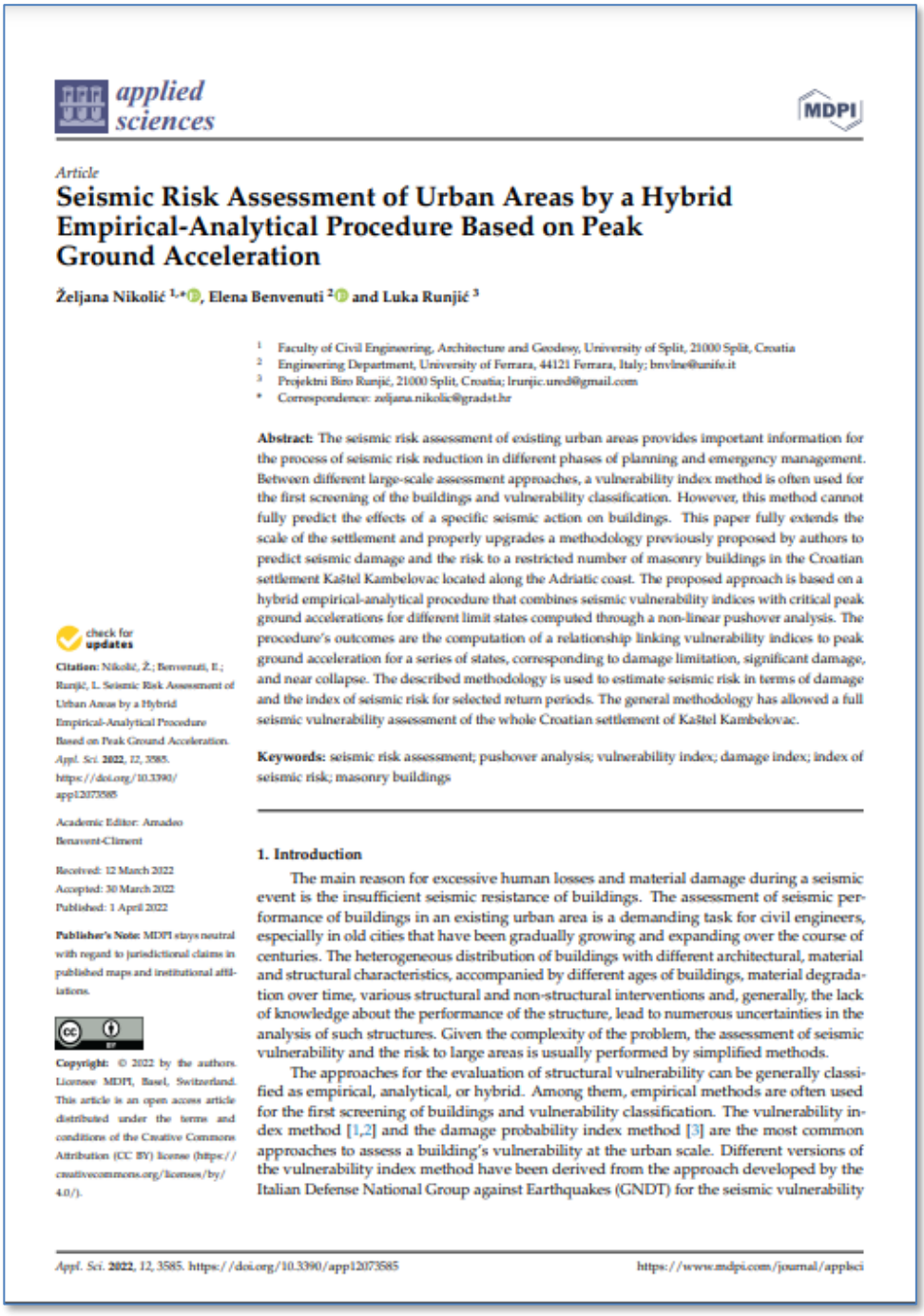
1. Introduction

Many areas in Europe and worldwide are increasingly subjected to catastrophic events. These events intensify the exposure of these territories to multi-risk events and make societies more vulnerable to entangled risks [1–7]. Globalization and climate changes are the main culprits of these multi-risk dynamics. Globalization, indeed, makes countries closely linked and interdependent, so communities are not only vulnerable to local extreme events but also to those occurring outside their national territories. Climate change increases, among others, the frequency and intensity of extreme meteorological phenomena, hydrological and flood risk, as well as the risk of fires. The awareness of this worrying trend has determined the need for adequate tools to address and mitigate these risks, as well as information campaigns to foster resilience and coping capacity of communities [5–7].

Understanding risks involving vast inhabited areas is therefore paramount, particularly when assessing potential losses produced by a combination of multiple hazards. Hereafter, a hazard refers to the probability of occurrence in a specified period of a potentially damaging event of a given magnitude in a given area [8]. Total risk is a measure of the expected human (casualties, injuries) and economic (damage to property, activity disruption) losses due to adverse natural phenomena. Such a measure is assumed to be the product of hazard, vulnerability, and exposure instances [9]. Many areas on Earth are subjected to the effects of coexisting multiple hazards, among which floods [3,8] and

Fig. 6. The paper "A PROMETHEE Multiple-Criteria Approach to Combined Seismic and Flood Risk Assessment at the Regional Scale"



applied sciences

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Article

Seismic Risk Assessment of Urban Areas by a Hybrid Empirical-Analytical Procedure Based on Peak Ground Acceleration

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Abstract: The seismic risk assessment of existing urban areas provides important information for the process of seismic risk reduction in different phases of planning and emergency management. Between different large-scale assessment approaches, a vulnerability index method is often used for the first screening of the buildings and vulnerability classification. However, this method cannot fully predict the effects of a specific seismic action on buildings. This paper fully extends the scale of the settlement and properly upgrades a methodology previously proposed by authors to predict seismic damage and the risk to a restricted number of masonry buildings in the Croatian settlement Kaštel Kambelovac located along the Adriatic coast. The proposed approach is based on a hybrid empirical-analytical procedure that combines seismic vulnerability indices with critical peak ground accelerations for different limit states computed through a non-linear pushover analysis. The procedure's outcomes are the computation of a relationship linking vulnerability indices to peak ground acceleration for a series of states, corresponding to damage limitation, significant damage, and near collapse. The described methodology is used to estimate seismic risk in terms of damage and the index of seismic risk for selected return periods. The general methodology has allowed a full seismic vulnerability assessment of the whole Croatian settlement of Kaštel Kambelovac.

Keywords: seismic risk assessment; pushover analysis; vulnerability index; damage index; index of seismic risk; masonry buildings

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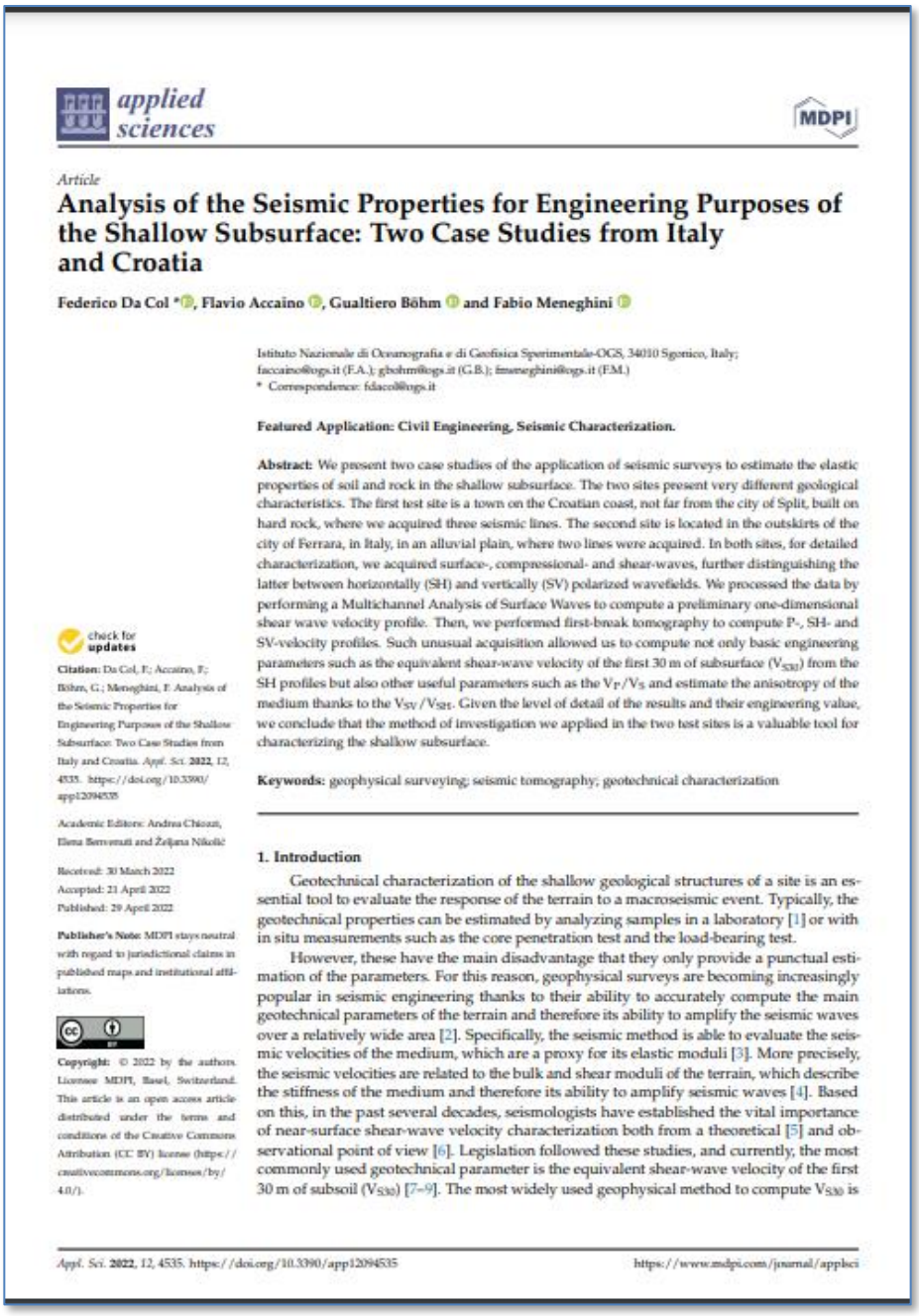
1. Introduction

The main reason for excessive human losses and material damage during a seismic event is the insufficient seismic resistance of buildings. The assessment of seismic performance of buildings in an existing urban area is a demanding task for civil engineers, especially in old cities that have been gradually growing and expanding over the course of centuries. The heterogeneous distribution of buildings with different architectural, material and structural characteristics, accompanied by different ages of buildings, material degradation over time, various structural and non-structural interventions and, generally, the lack of knowledge about the performance of the structure, lead to numerous uncertainties in the analysis of such structures. Given the complexity of the problem, the assessment of seismic vulnerability and the risk to large areas is usually performed by simplified methods.

The approaches for the evaluation of structural vulnerability can be generally classified as empirical, analytical, or hybrid. Among them, empirical methods are often used for the first screening of buildings and vulnerability classification. The vulnerability index method [1,2] and the damage probability index method [3] are the most common approaches to assess a building's vulnerability at the urban scale. Different versions of the vulnerability index method have been derived from the approach developed by the Italian Defense National Group against Earthquakes (GNDT) for the seismic vulnerability

Fig. 7. The paper "Seismic Risk Assessment of Urban Areas by a Hybrid Empirical-Analytical Procedure Based on Peak Ground Acceleration"



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Article

Analysis of the Seismic Properties for Engineering Purposes of the Shallow Subsurface: Two Case Studies from Italy and Croatia

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Featured Application: Civil Engineering, Seismic Characterization.

Abstract: We present two case studies of the application of seismic surveys to estimate the elastic properties of soil and rock in the shallow subsurface. The two sites present very different geological characteristics. The first test site is a town on the Croatian coast, not far from the city of Split, built on hard rock, where we acquired three seismic lines. The second site is located in the outskirts of the city of Ferrara, in Italy, in an alluvial plain, where two lines were acquired. In both sites, for detailed characterization, we acquired surface-, compressional- and shear-waves, further distinguishing the latter between horizontally (SH) and vertically (SV) polarized wavefields. We processed the data by performing a Multichannel Analysis of Surface Waves to compute a preliminary one-dimensional shear wave velocity profile. Then, we performed first-break tomography to compute P-, SH- and SV-velocity profiles. Such unusual acquisition allowed us to compute not only basic engineering parameters such as the equivalent shear-wave velocity of the first 30 m of subsurface (V_{S30}) from the SH profiles but also other useful parameters such as the V_P/V_S and estimate the anisotropy of the medium thanks to the V_{SV}/V_{SH}. Given the level of detail of the results and their engineering value, we conclude that the method of investigation we applied in the two test sites is a valuable tool for characterizing the shallow subsurface.

Keywords: geophysical surveying; seismic tomography; geotechnical characterization

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1. Introduction

Geotechnical characterization of the shallow geological structures of a site is an essential tool to evaluate the response of the terrain to a macroseismic event. Typically, the geotechnical properties can be estimated by analyzing samples in a laboratory [1] or with in situ measurements such as the core penetration test and the load-bearing test.

However, these have the main disadvantage that they only provide a punctual estimation of the parameters. For this reason, geophysical surveys are becoming increasingly popular in seismic engineering thanks to their ability to accurately compute the main geotechnical parameters of the terrain and therefore its ability to amplify the seismic waves over a relatively wide area [2]. Specifically, the seismic method is able to evaluate the seismic velocities of the medium, which are a proxy for its elastic moduli [3]. More precisely, the seismic velocities are related to the bulk and shear moduli of the terrain, which describe the stiffness of the medium and therefore its ability to amplify seismic waves [4]. Based on this, in the past several decades, seismologists have established the vital importance of near-surface shear-wave velocity characterization both from a theoretical [5] and observational point of view [6]. Legislation followed these studies, and currently, the most commonly used geotechnical parameter is the equivalent shear-wave velocity of the first 30 m of subsoil (V_{S30}) [7–9]. The most widely used geophysical method to compute V_{S30} is

Fig. 8. The paper "Analysis of the Seismic Properties for Engineering Purposes of the Shallow Subsurface: Two Case Studies from Italy and Croatia"

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Article

A Database for Tsunamis and Meteotsunamis in the Adriatic Sea

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Abstract: In the frame of the Interreg Italy-Croatia program, the EU has funded the PMO-GATE project, focusing on the prevention and mitigation of the socioeconomic impact of natural hazards in the Adriatic region. The Database of Adriatic Tsunamis and Meteotsunamis (DAMT) is one of the deliverables of this project. DAMT is a collection of data documenting both meteotsunami and tsunami effects along the Eastern and Western Adriatic coasts, and it was realized by starting from the available database and catalogues, with the inclusion of new data gained from recent studies, newspapers and websites. For each tsunami and meteotsunami, the database provides an overview of the event and a detailed description of the effects observed at each affected location and gives a picture of the geographical distribution of the effects. The database can be accessed through a GIS WebApp, which allows the user to visualize the georeferenced information on a map. The DAMT WebApp includes three layers: (1) Adriatic Tsunami Sources, (2) Adriatic Tsunami Observation Points and (3) Adriatic Meteotsunamis Observation Points. The database contains 57 observations of tsunami effects related to 27 tsunamis along the Italian, Croatian, Montenegrin and Albanian coasts and 102 observations of meteotsunami effects related to 33 meteotsunamis.

Keywords: Adriatic Sea; database; tsunami; meteotsunami; ArcGis; WebApp

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1. Introduction

Due to the increasing number of extreme events that are being experienced around the world, the interest of the scientific community in natural hazards has grown significantly in recent years, and one of the main targets is the prevention and reduction of risks related to natural events. The Sendai Framework for Disaster Risk Reduction (2015–2030) outlines the overall objectives to substantially reduce disaster risk and losses of lives, livelihoods, and health. It clearly states that in order to diminish the frequency and impact of disasters, it is required to better understand disaster risk (exposure to hazards, vulnerability and capacity and the hazard's characteristics) and furthermore to improve risk governance and increase resilience.

In this regard, many international projects related to the reduction of risk have been funded in the last decade, and the European Union has supported and financed some projects as well. In particular, a wide-ranging cross-border cooperation program between Italy and Croatia called Interreg has been established, focusing on the sea basin, coastal landscapes, green areas and urban areas as well.

The Adriatic Sea is the core center of the Italy-Croatia cooperation area, and it is a joint economic and environmental asset and a natural platform for combined efforts. The coastal area, both in Italy and in Croatia, is exposed to a range of natural hazards, particularly floods, strong winds, drought, earthquakes, tsunamis and meteotsunamis. Taking into account the coastal vulnerability, disaster risk reduction is a critical factor for the social and economic development of the involved countries.

In the framework of the Interreg Italy-Croatia program, Preventing, Managing and Overcoming Natural-Hazards Risks to mitiGATE economic and social impact (PMO-GATE)

Fig. 9. The paper "A Database for Tsunamis and Meteotsunamis in the Adriatic Sea"

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