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Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

DELIVERABLE

D26.6 European socioeconomic indicators and indices for integrated risk assessment

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Lead	EUCENTRE
Authors	Helen Crowley, EUCENTRE Venetia Despotaki, GEM Foundation Miguel Toquica, GEM Foundation Michael Musori, GEM Foundation Vitor Silva, GEM Foundation
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Summary

The European seismic risk framework being developed in SERA JRA4 is based on a holistic risk approach, and thus extends beyond the assessment of physical risk alone. The framework is based on the methodology proposed in the Global Earthquake Model (GEM), whereby indicators of socio-economic vulnerability, resilience and recovery (such as homelessness, poverty, corruption) are combined to produce three composite indices: 1) impact on human lives, 2) economic resilience and 3) recovery index. These indices are then mapped together with physical risk metrics (such as average annual economic losses, average annual fatalities and number of collapsed buildings) to provide a picture of the levels of integrated risk across a given country or region through so-called 'impact maps'. Databases of socioeconomic vulnerability and resilience indicators at national and sub-national/city levels are thus needed for the framework, and are being collected, as discussed and described herein. The final databases for all European countries will be included in Deliverable D24.7 (Framework for European integrated risk assessment).

1 Social Vulnerability and Integrated Risk Framework

The effects of a damaging earthquake could have a long-lasting impact on people's lives and unfortunately, recent disasters have demonstrated that vulnerable communities (low-income, children, women, elderly, minorities, etc.) suffer the largest burden. For example, lower-income or disabled residents of earthquake-stricken areas may not have the resources or the capability to promptly evacuate following a damaging event. The pace of response and recovery depends not only on the extent of the physical damage, but also on the socio-economic conditions of the community (Burton, 2015; Despotaki et al., 2017). Therefore, it is equally important, similar to the procedure of assessing the physical risk, to further measure the social exposure and vulnerability and finally combine the physical earthquake risk with the socio-economic context.

Social scientists have well documented and identified variables that can be used to represent the level of social vulnerability or resilience of a community (e.g., Cutter et al., 2010). Commonly, these variables are mathematically combined to create indices that describe the level of vulnerability of particular sectors, such as the economy, infrastructure, healthcare, amongst others. Within the Global Earthquake Model (GEM)'s social vulnerability and integrated risk framework, specific sets of variables are combined to create three composite indices (impact on human lives index, economic resilience index and recovery index) that reflect the social dimension and at the same time can each be directly compared with the most commonly used estimates of a physical risk assessment using the OpenQuake-engine (Silva et al., 2014) (i.e., average annual fatalities, average annual economic losses and average annual collapses, respectively). The flow diagram in Figure 1 depicts how the socio-vulnerability and resilience/recovery (SVR) databases will be used to structure the three SVR indices and combine them with the appropriate physical risk (PHR) metrics to produce three impact maps, namely (i) impact on human lives map, (ii) economic resilience impact map and (iii) recovery impact map.

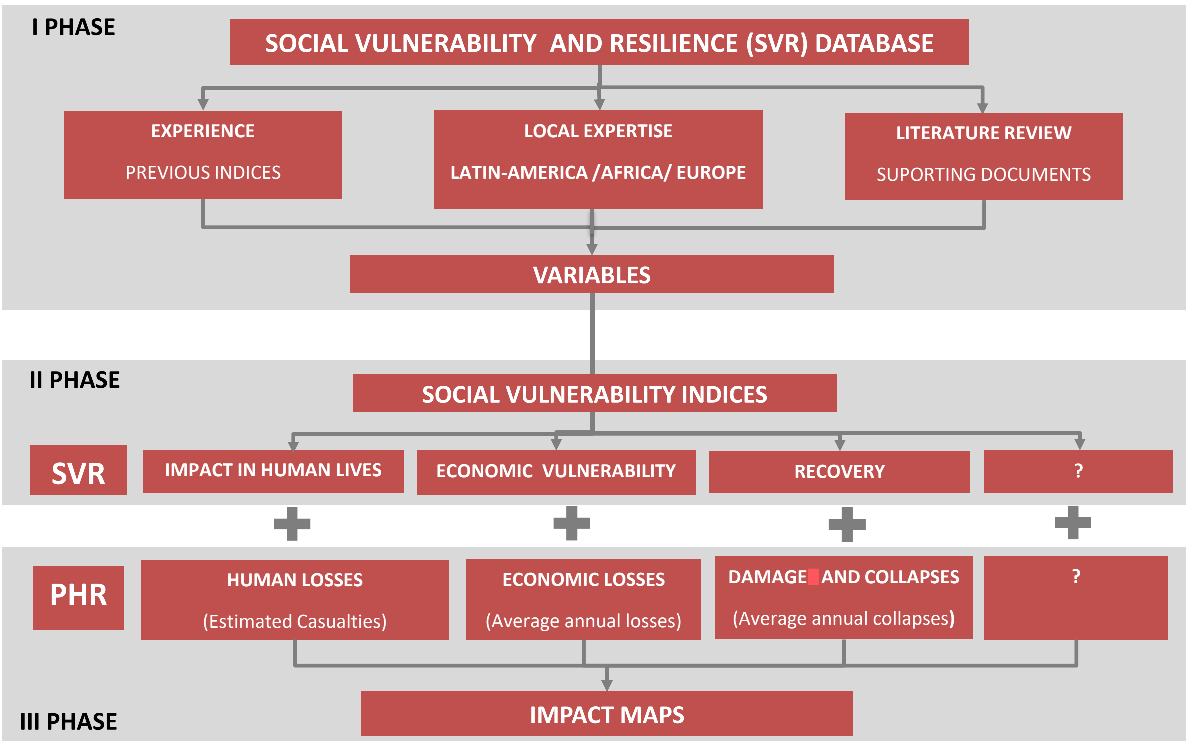

Figure 1: Structure of GEM's SVR indices and impact maps. The question marks in the boxes on the bottom right signify that other combinations of physical risk and social vulnerability might be identified in the future.

2 Social Vulnerability, Resilience and Recovery Indices

The specific variables that are used to populate each index have been selected based on an extensive literature review and previous experience on social vulnerability, resilience and recovery (e.g., Power et al., 2015) and the expertise obtained from building the SV indexes for South America, Caribbean and Central America, and Sub-Saharan Africa under the framework of GEM's SARA, CCARA and SSAHARA projects. The variables that have been selected for the development of SVR indices in Europe are shown in Table 1. As seen in this table, the SVR impact on human lives index and the variables contained in this category can be further disaggregated to select only the variables that can aggravate certain physical risk conditions such as fatalities, injuries or homelessness. This procedure will assign a more comprehensive meaning to the integrated impact map. For example, integrating the fatalities/injuries output from the OpenQuake-engine with variables on access to health facilities and the number of hospital beds per province will provide a much clear picture of the emergency response capacity within a specific country, parish, or community.

The national population statistics of each country of interest constitute the primary source of information for collecting the variables shown in Table 1 which are the driving factors that shape the vulnerability from one place to another.

The initial data selection process was based on an exhaustive review of the literature to select only data cited in previous studies as being associated with the social vulnerability of populations. It is important to note that data availability was not consistent across countries, so the number of variables collected for each country for the initial steps of composite indicators (fatalities, economic vulnerability and recovery) development was not consistent It is difficult, if not impossible, to measure social vulnerability in relative terms (Schneiderbauer and Ehrlich 2006, Cutter et al. 2010), so variables were collected as proxy measures to represent the social vulnerability concept within fatalities, economic vulnerability and recovery subcomponents. Burton and Silva (2016) provide an in-depth discussion of the theory behind the selection of the individual subcomponents, and a hierarchical approach for modelling social vulnerability was adopted here (see Tate 2012, Burton and Silva, 2016). The latter entailed collecting and employing indicators that are separated into groups (or sub-indices) that share the same dimension (e.g. fatalities, recovery etc.). Individual indicators are aggregated into sub-indices that represent final composite models.

Before the construction of sub-indices could occur, pre-processing steps were taken to render the indicators commensurate. The latter included standardizing the data into comparable scales using either percentage, per capita, or density calculations where the standardization type was based on how a particular variable was described in the literature and the authors' expert opinion. Once converted into comparable scales, the data was transformed using the MIN-MAX rescaling function to create a set of indicators that could be compared to the average annual loss values.

The steps in the analysis were divided into two key themes, a statistical approach and an expert opinion approach. Expert opinion focused on literature on social and economic vulnerability to allow for a balance in the representation of the indicators between literature and statistics. Steps towards creating proportionate indicators were accomplished by standardizing raw data into comparable measures by scaling it between 0 and 1 through the Min-Max feature. The statistical approach was then utilized to provide an arithmetic basis for the choice of indicators starting with a correlation analysis, which eliminated all highly correlated variables with a Spearman's R>0.700. This was then followed by the analysis of the common variance between the indicators through a Principal Component Analysis to determine the statistically most important indicators. This multivariate analysis aided in reducing the number of initial collected variables leaving only the ones considered as appropriate for further analysis. All this was done within the SPSS environment.

A hierarchical model was used to construct socioeconomic metrics by grouping indicators that shared the same features into sub-indices and place them into corresponding sub-components namely; Fatalities, Economic Vulnerability and Recovery using GEM's Integrated Risk Modelling Toolkit (IRMT), (Burton and Tormene, 2015). Each of these sub-components were then aggregated by averaging equally weighted sub-index scores contained within each of them (Social Vulnerability, Recovery, etc.), in order to counter the differences in numbers of variables within individual sub-indices to come up with the final composite score, in this case the various indices (Recovery etc). As stated earlier, the indicators had already been standardised by scaling them between 0 and 1 through the Min-Max feature, therefore the final social vulnerability score produced was between 0 and 1 with 0 being the least socially vulnerable and 1 being the most. One advantage of employing this method is that is allows for the indices (Fatalities, Recovery and Economic Vulnerability) to be viewed, mapped and analysed individually. An added advantage is that it is transparent and easy to understand. Equal weighting was used in this case because there was no literature that supported weighting one variable over another. Furthermore, due to budgetary constraints, no consultations or workshops with key stakeholders within these countries could be done for them to give their opinions on which variables outweighed others.

Once the variables are selected, maps can be created in order to illustrate the spatial distribution of the above indices across each European country (see Figure 3 to Figure 5 for example maps for Croatia). The combination of the variables to generate the indices is performed using the GEM OpenQuake Integrated Risk Modelling Toolkit (IRMT) plugin that is available in QGIS, following the procedure described in https://docs.openquake.org/oq-irmt-qgis/v2.8.1/.

To date the variables necessary to develop the SVR indices for the following countries have been collected: Cyprus, France, Italy, Slovenia, Spain, Malta, San Marino, The Netherlands, Germany, Croatia, Bulgaria, Montenegro, Kosovo, Romania, Republic of Macedonia, Greece, Albania, Bosnia and Herzegovina, Serbia and Portugal. The data is available at different administration levels in each country as illustrated in Figure 2. The three indices have been calculated at the Admin Level 2 across Croatia, as illustrated in Figure 3, 4 and 5. The spatial resolution to use for the final set of European data is still being discussed and evaluated as it is influenced by how people migrate during the day, or where infrastructure is located. For example, some regions will not have any hospitals or clinics, not necessarily because their infrastructure is poor, but simply because they might be located in the adjacent region. The same can be said for wealth: some regions might appear low-income only because people work in the cities and sleep in the suburbs. The final variables considered for social vulnerability for each country were not exactly the same for each country and this is as a result of data not being homogeneous across the various countries' censuses. Each country collects socio-economic data in their own way and prioritise differently the variables that they collect. In cases were some of the selected variables were missing within a country, it is to be noted that proxy variables (variables that were closer in relation to the missing ones) when available, were instead collected, selected and used. However this non uniformity poses a significant problem in the comparability between or across countries and such, this inter-country comparison was not done.

This database and index development work will continue until month 24, and the final maps and database for the whole of Europe will be made available in Deliverable D26.7 (Framework for European integrated risk assessment).

Figure 2. Administrative level at which data was collected per country

Table 1. Variables used to develop SVR indices in Europe

IMPACT ON HUMAN LIVES (FATALITIES-INJURIES-HOMELESS)	ECONOMIC RESILIENCE (DIRECT LOSSES)	RECOVERY
Average household size F I	People working in manufacturing industry, hotel/restaurant, commercial industry	Female population
Population density F I	Unemployment rate	Indigenous population
Population with disabilities F I	Population in poverty	Population with disabilities
Age dependence F I (0-14, 65+)	Population with no formal education / illiteracy rate	Women head of households
Household paying rent monthly H	No access to electrical energy	Illiteracy rate
Overcrowded households / squatters H		No access to electrical energy
Collective households H		No access to potable water
Unsatisfied basic needs I		No sanitary services
Population with no formal education I		
Illiteracy rate I		
No access to potable water I		

IMPACT ON HUMAN LIVES (FATALITIES-INJURIES-HOMELESS)	ECONOMIC RESILIENCE (DIRECT LOSSES)	RECOVERY
No sanitary services I		
Households with no radio / TV I		
Access to mobile phone I		
No access to healthcare F		
Number of hospital beds F		
No access to internet I		
KEY: F = fatalities, I = injuries, H = homeless		

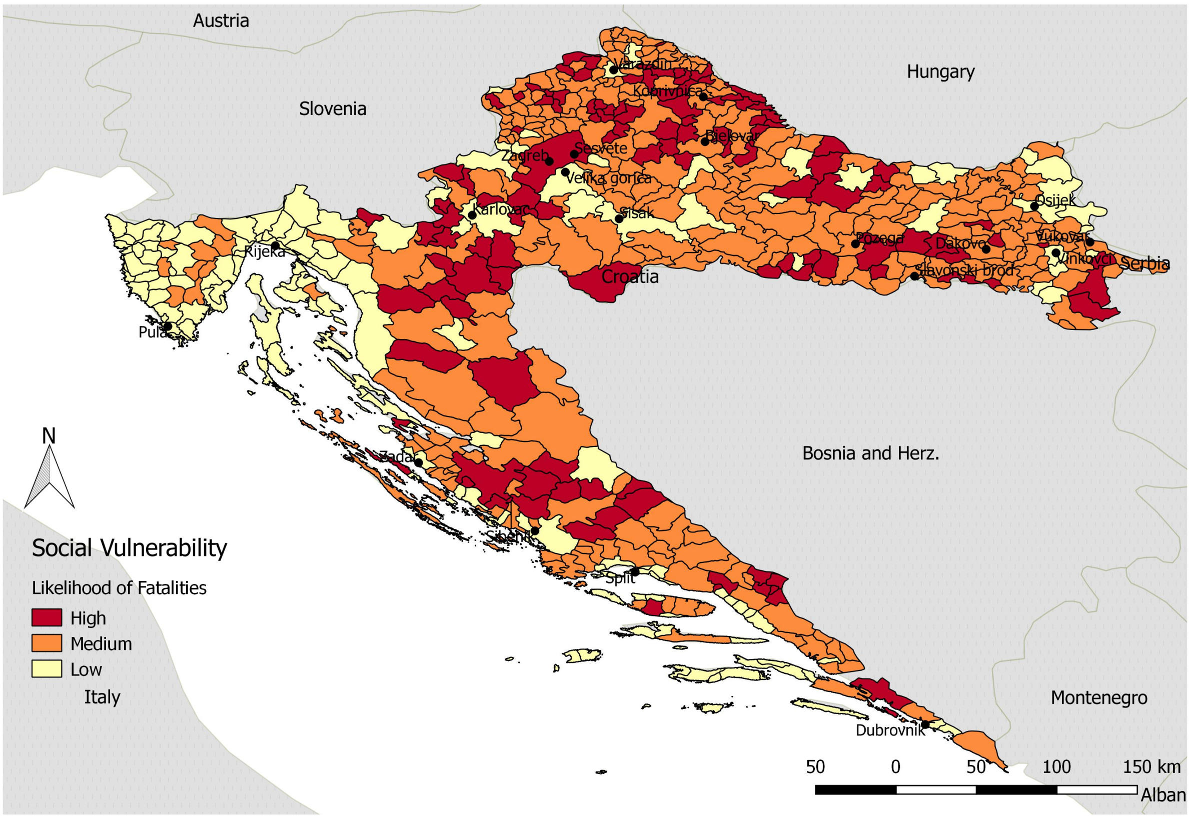

Figure 3: Spatial variation of the social vulnerability (impact on fatalities) index across Croatia

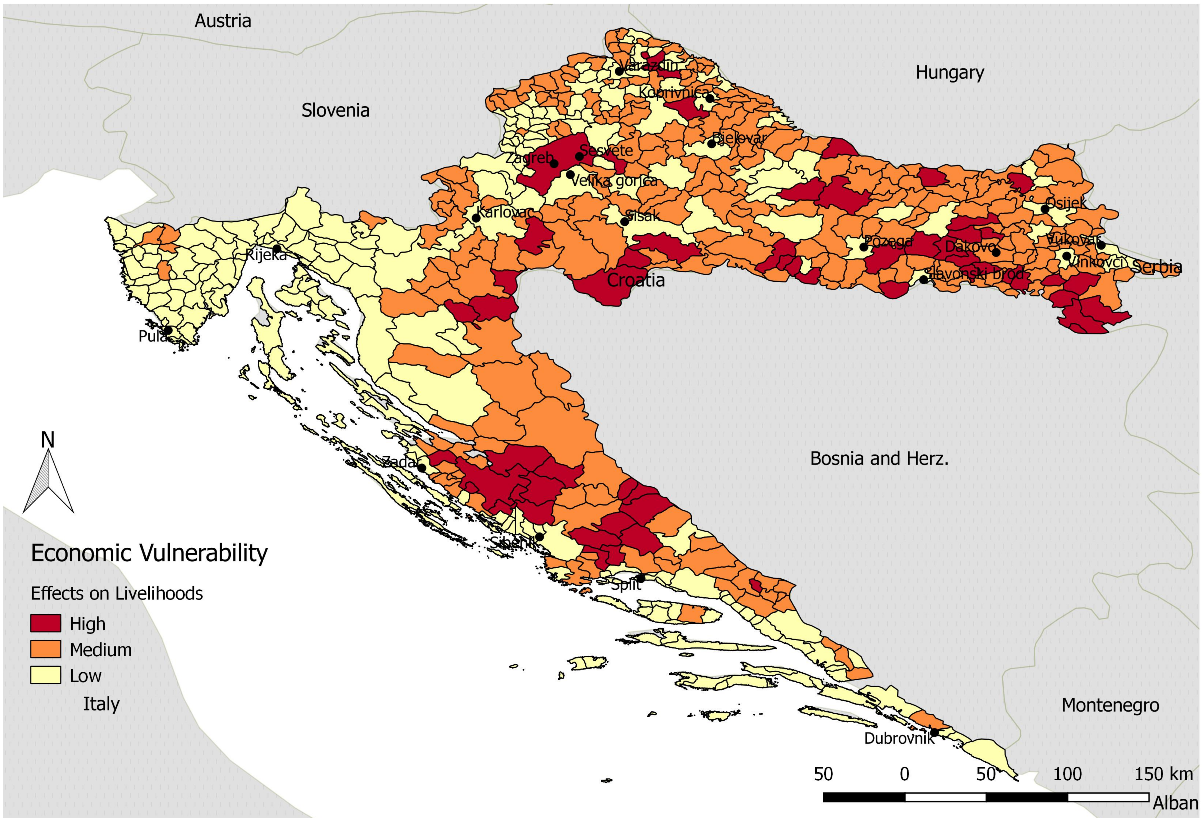

Figure 4: Spatial variation of the economic vulnerability index across Croatia

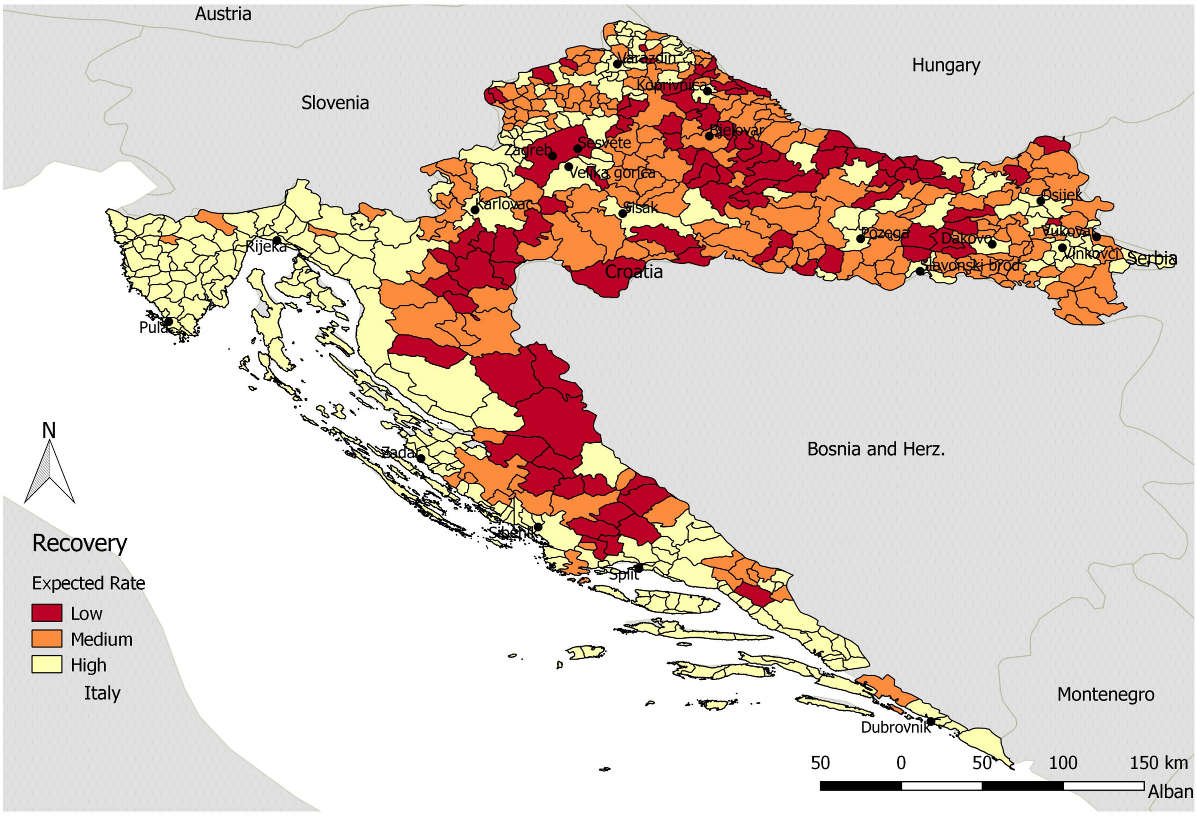

Figure 5: Spatial variation of the recovery index across Croatia

3 Impact Maps

Impact maps provide information on the socio-economic role of countries in risk reduction, and will allow end users and stakeholders to understand various socio-economic challenges regarding earthquake risk, and thus better plan and distribute resources for seismic risk mitigation. Furthermore, because they are characterised according to physical risk components, the impact maps will show the potential aggravated impact of combined earthquake risk and existing socio-economic conditions.

Figure 6, 7 and 8 illustrate the mapping techniques that will be used to present European impact maps that combine the physical risk metrics and the SVR indices. This figure shows an example of a physical risk map in terms of the average annual number of damaged/collapsed buildings, a SVR map showing the recovery rate index and the combined impact map whereby both the level of both the physical and SVR metrics are simultaneously plotted. This allows for the identification of the areas of the country where recovery is likely to be most hindered, not only because the physical risk is expected to be high (due to high physical vulnerability of the building stock and high seismic hazard) but also because the recovery rate is expected to be low (due to the combined impact of the variables/indicators that negatively influence the recovery index, as presented previously).

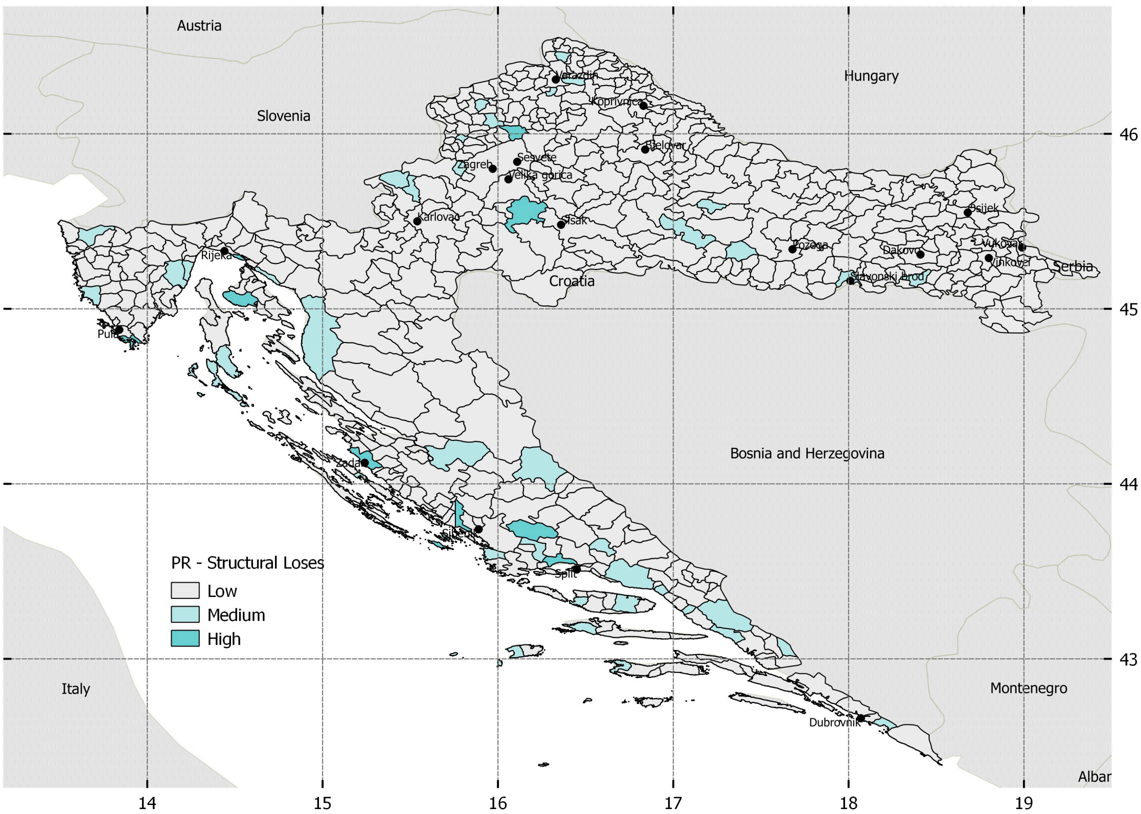

Figure 6. Spatial variation of the physical risk across Croatia

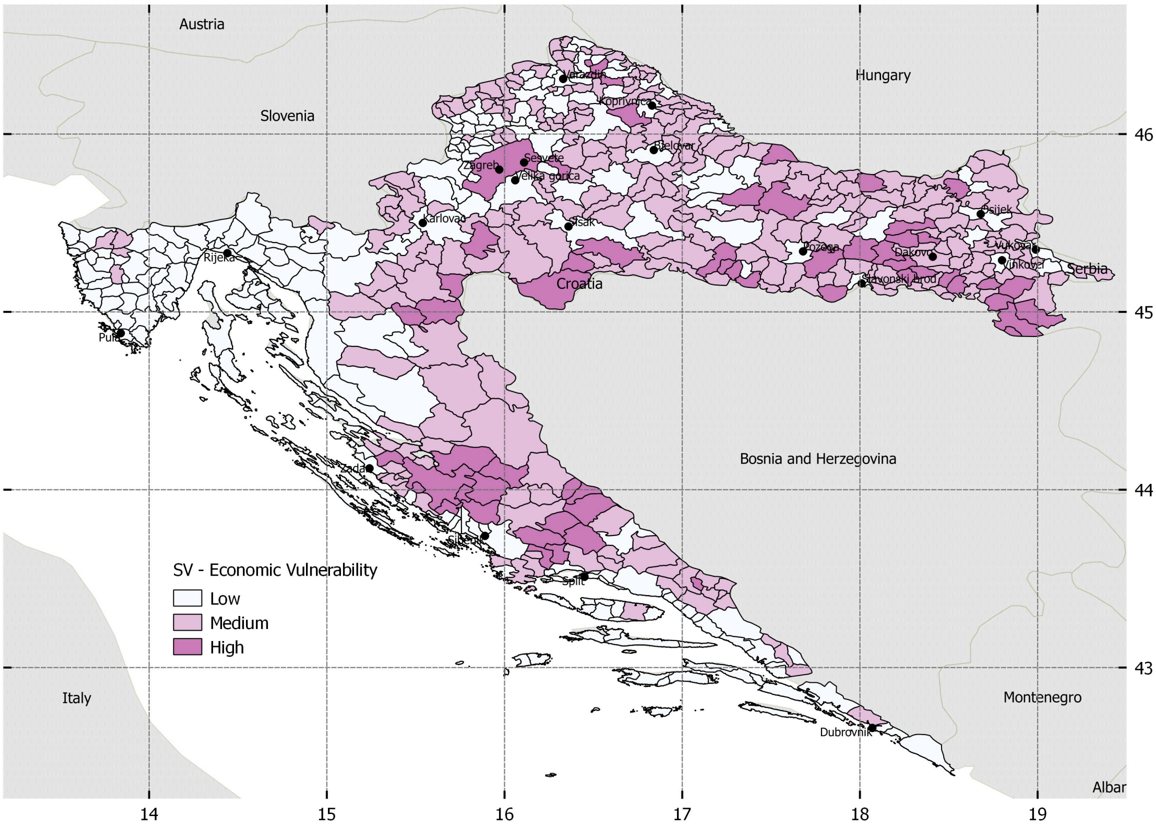

Figure 7. Spatial variation of the economic vulnerability index across Croatia

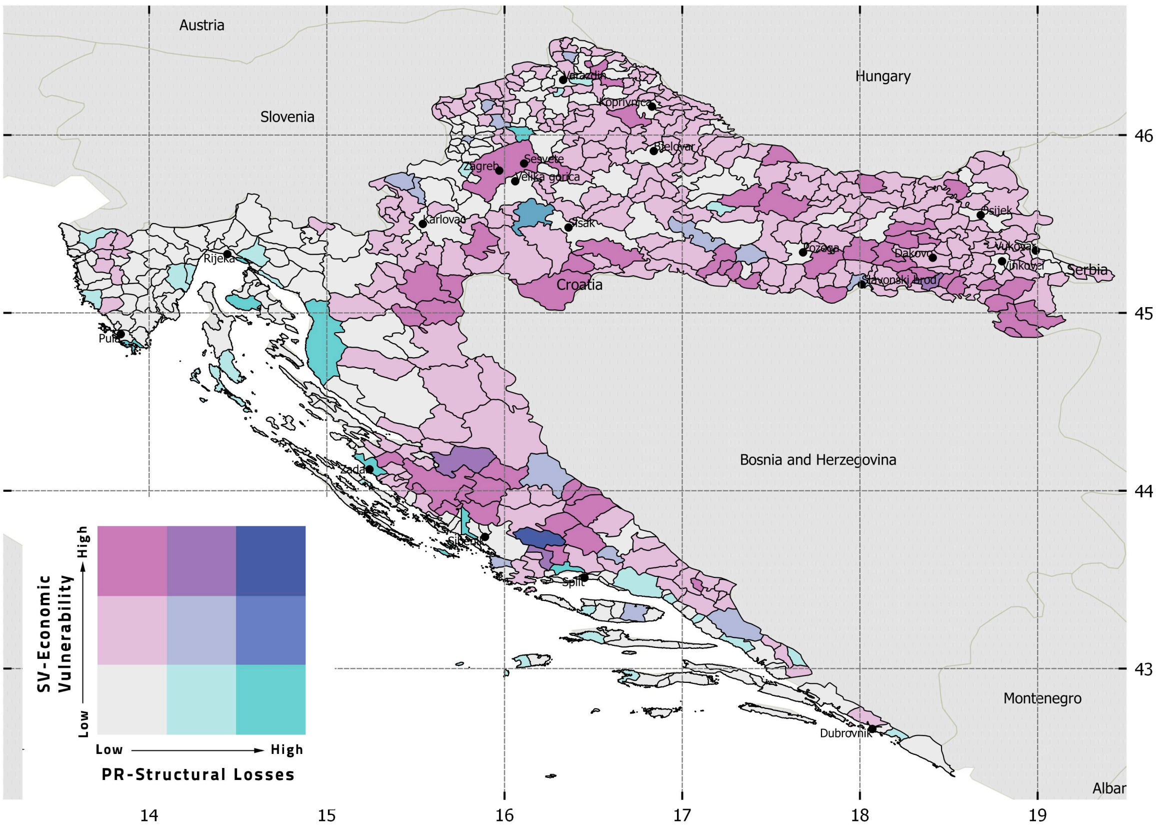

Figure 8. Impact map of the integrated risk across Croatia

4 Concluding Remarks

This deliverable outlines the framework for holistic and integrated risk assessment that will be used in the European risk model being developed in SERA JRA4. This framework makes use of the Global Earthquake Model's Social Vulnerability and Integrated Risk framework and OpenQuake Integrated Risk Modelling Toolkit.

The variables that have been selected for the development of three composite indices of social vulnerability and resilience/recovery have been presented herein and work is ongoing to develop a spatial database of these variables within each European country. The final database will be made available with deliverable D26.7 7 (Framework for European integrated risk assessment), due month 24 and through the EFEHR platform and GEM's OpenQuake platform.

It is expected that this effort to develop databases of social vulnerability, resilience and recovery variables across Europe, and to make these openly available to the scientific community, will allow local experts to develop their own thematic indices for integrated risk assessment in the future. The goal within the SERA project is thus to demonstrate the capabilities of GEM's OpenQuake Integrated Risk Modelling Toolkit and how social and physical metrics can be combined. Hence, although the outcome of this work will be an integrated risk assessment across Europe, the ultimate goal is for this first version to be built upon and improved upon in the future by local experts with more detailed knowledge of the specific issues affecting social vulnerability, resilience and recovery within each country in Europe.

5 References

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Contact

Project lead	ETH Zürich
Project coordinator	Prof. Dr. Domenico Giardini
Project manager	Dr. Kauzar Saleh
Project office	ETH Department of Earth Sciences
	Sonneggstrasse 5, NO H62, CH-8092 Zürich
	sera_office@erdw.ethz.ch
	+41 44 632 9690
Project website	www.sera-eu.org