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Seismic Risk Assessment Tools Workshop

11th – 12th May 2017

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Joint
Research
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Abstract

Held in the European Crisis Management Laboratory on 11-12 May 2017, this Workshop brought together on one side the developers of some of the most widely used modern seismic risk assessment tools and on the other a number of Civil Protection authorities from countries of the European Civil Protection Mechanism. The objective was to demonstrate the use and capabilities of the tools, explore the possible use in near-real-time impact assessment and promote their use in risk planning and disaster response.

The systems presented in the workshop demonstrated a very high sophistication and increased flexibility in accepting data from a large number of sources and formats. Systems that were initially developed on a national scale can now work on a global level with little effort and the use of global-scale exposure data is almost seamless. An urgent need for more accurate exposure data being openly available was identified, as well as the need of proper use of the fragility curves. Inter-system collaboration and interoperability in some cases to increase ease of use was greatly appreciated and encouraged. All systems participated in a real-time simulation exercise on previously unknown seismic data provided by the JRC; some additional automation might be in order, but in general all systems demonstrated a capacity to produce results on a near-real-time basis. The demonstrations were unanimously welcomed as very useful by the participating Civil Protection Authorities, most of which are either using a locally-developed system of

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1. List of Participants

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2. Concept and objectives of the workshop

Several member states of the European Union Civil Protection Mechanism (EUCPM) that are prone to seismic risk, have included earthquakes in their National Risk Assessment and have developed deep pools of knowledge on seismic hazard. Moving beyond studying just the hazard, however, in conformity to the [Sendai framework for Disaster Risk Reduction](#) and in particular the 7th Sendai Global Target that requires a greater emphasis towards estimating and reducing risk, all relevant stakeholders (from National Governments to research institutes) should be encouraged to acquire knowledge and experience in the use of Risk Assessment Tools. Some of the EUCPM member states have already been using such tools, while others are in the process of evaluating or adopting some of the available ones. The JRC in collaboration with DG ECHO and the ERCC should help member states acquire more experience in this field. In addition, it is useful to present these systems side-by-side on supplied scenarios and explore their potential use not only in risk assessment for planning but also in early impact assessment, shortly after an event.

An indicative, non-exhaustive list in alphabetic order of seismic (sometimes also multi-hazard) risk assessment tools is the following: **AFAD-RED** by the Turkish Civil Protection; **ARMAGEDOM**, by the French Geological Survey; **CAPRA**, by a partnership of a Central American institution (CEPREDENAC), UNISDR the Inter-American Development Bank and the World Bank; **EQR** by GeoScience Australia; **ELER**, developed by Bogazici University-Kandilli Observatory & Earthquake Research Inst. (BU-KOERI, Turkey); **EQVIS**, by the Mid-America Earthquake Centre and adapted for Europe by the Austrian Company VCE; **HAZUS-MH**, developed and distributed by the US Federal Emergency Management Agency (FEMA); **INASAFE** developed in Indonesia by BNPB, AusAID and the World Bank; **OpenQuake**, by GEM, the Global Earthquake Model foundation; **RASOR**, a European FP7 project by a consortium headed by CIMA foundation in Italy; **RiskScape** developed in New Zealand; **SELENA**, developed for Norway by NORSAR.

The overall purpose of this technological workshop was to **present and promote the use of seismic risk assessment tools in the EUCPM countries**. The particular objectives can be listed as follows:

1. To **demonstrate the capabilities, installation and use** of a number of the seismic risk assessment tools available today to interested national authorities of countries of the EUCPM and to the relevant services of the European Commission.
2. To explore the possibilities of using the systems¹ not only for risk assessment in the usual sense, i.e. for long-term planning and risk mitigation, but also as **near-real-time tools for early impact assessment**, immediately after an event. It is true that most of these systems were not built for this type of use; typical data set-up and run-times for a scenario at a particular place can take a long time. However, it would be of particular interest to European policy makers the possible use of the tools in this sense; an example would be the incorporation of one or more risk assessment tools in [GDACS](#), a system whose role is to alert the humanitarian community on rapid-onset disasters, based on the possible losses by calculating (in quite a coarse mode, currently) the risk of the event. Systematic use of Risk Assessment tools in a "fast", real-time mode would render the alerts of GDACS much more accurate.
3. To evaluate the **flexibility** of these systems in using different types and formats of exposure and vulnerability data, and particularly currently available datasets on a global scale. The possibility to use the tools in scenarios involving developing countries (that do not have the capacity to model risk and for which only coarse data-sets on exposure and vulnerability exist) would be useful to European or International (UN etc) policy makers that handle the distribution of international

¹ The terms "tool" and "system" are used interchangeably in this report, to avoid repetition.

aid. To achieve this, the use scale of Risk Assessment tools should be extended to global rather than local (country-wide) and it should be possible to easily upload and use currently available global layers of exposure and vulnerability ([GHSL](#) builtup layer, [GAR](#) data etc.).

4. To **evaluate the risk assessment capabilities** of the systems by applying them on specific earthquake scenarios, that would be provided by the JRC, either beforehand or in real-time.

To achieve the above objectives, the Disaster Risk Management Unit and Knowledge Centre (E1) of the Directorate for Space, Security and Migration tried to bring together

- **Developers** of risk assessment tools (Private companies, Universities, Research Consortia, etc). They were invited to present the general principles and algorithms of their system, the user interface, the requirements in hardware, software and training, and examples of use on a scenario prepared by the JRC. Application on a real earthquake event and comparison with real loss values are of great interest. Another very interesting focus point is the ease of incorporation and use of currently available global exposure and vulnerability layers, such as [Global Assessment Report of 2015](#) (UNISDR).
- **Actual** and **potential** users of currently available seismic risk assessment tools with particular focus on **national civil protection authorities** of earthquake-prone EUCPM countries. Actual users were invited to present the use of the tools, positive and negative points, the user-friendliness, the ease of using available exposure and vulnerability data, the level of support from the developer, scenarios tested on the system for planning and preparedness etc.
- The relevant **Commission directorates** - JRC E1 and E4 Units and relevant services of DG ECHO.

3. Participants, structure, and real-time simulations

The participants at the workshop included seven (7) separate seismic risk assessment tools, civil protection authorities of five (5) countries, one (1) scientific institution and a number of other national and European Commission experts. On the system developers side, the following tools were presented: **HAZUS, CAPRA, OpenQuake, RASOR, AFAD-RED, EQIA** and **SELENA. ARMAGEDOM** was presented in the interactive session (see below). Civil Protection representatives from Italy, Greece, Turkey, Portugal and Romania were present. Turkey presented AFAD-RED in the Systems Presentation sessions, Italy and Portugal presented locally developed seismic risk assessment systems. The National Observatory of Athens presented some results of its own system (part of MASSIVE European project) on seismic risk studies for the city of Athens. Finally, a JRC-developed system on Critical Infrastructure impact assessment (RAPID-N) was presented.

For most tools in the programme, a formal 40-min presentation was followed by a 15-20 minute "live demonstration", where the parameters of a simulated earthquake was provided at that time by the JRC (Fig 1). The presenters of the tool then entered the parameters, let the system run in front of the audience and displayed the results, that typically took a few minutes to be completed. The geographic domain of the simulated event (at region or country level) was decided by the system developers and was passed to the JRC beforehand. Exposure data selection and use was left to the discretion of the developers, although the JRC encouraged the use of low-resolution and globally available open data sets, such as GAR2015. The events supplied by the JRC to each system, are shown in the map and table below and the available results are summarised in Annex 2. All of them were real relatively low-impact events taken from the USGS database, but shifted spatially either along a fault or by a small distance to a densely populated area, so

that they remained realistic and at the same time more interesting with respect to potential impact.

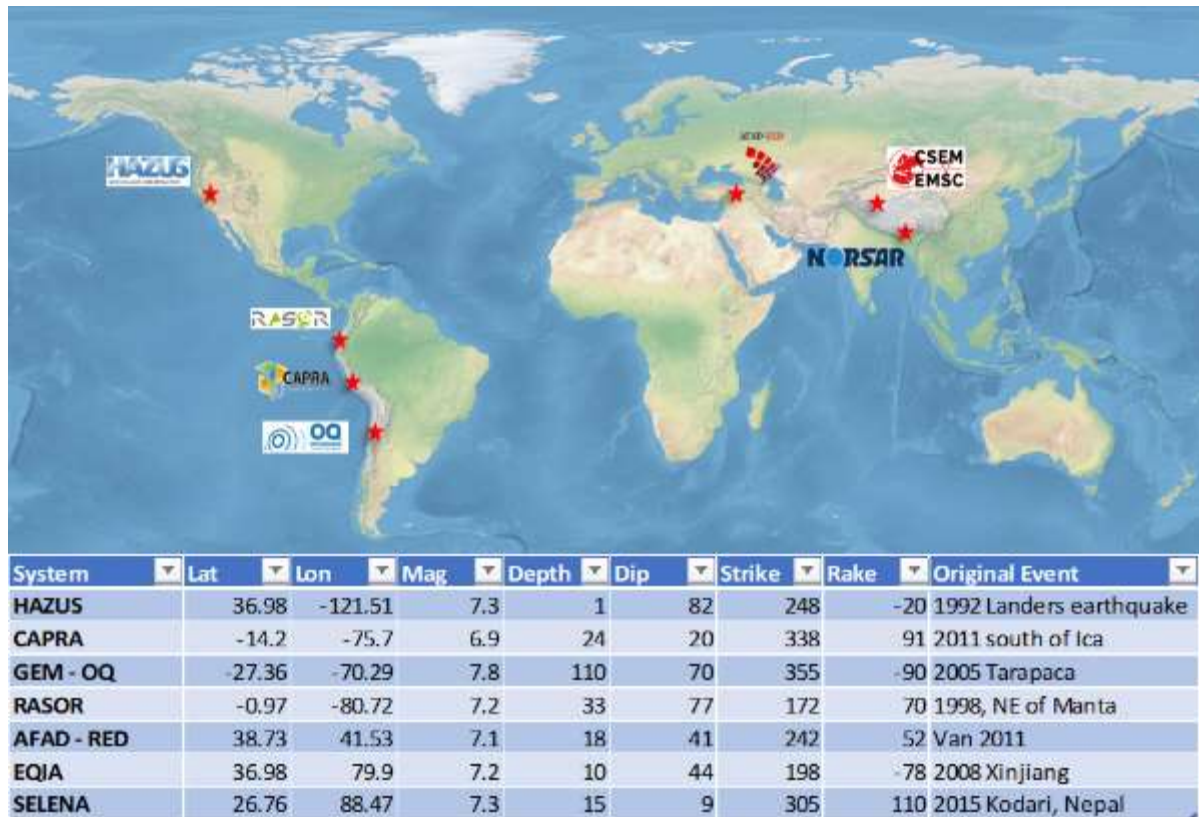


Fig 1 – Real-time earthquake scenarios provided to system developers by the JRC

In the afternoon session of the workshop an interactive, “Marketplace Session” was organised; in this, system developers were assigned a “speaker’s corner” where participants could ask additional questions and get to know the system’s functionality better.

4. Presentations of Seismic Risk Assessment Tools

In this section we have compiled short summaries of the presentations of each system, written by the authors of this report based on each speaker's slides. The full content of the presentations in PDF form can be found in the website the JRC's Disaster Risk Management Knowledge Centre (DRMKC)². A one-page "technical factsheet" of each system, kindly prepared by the developers, is given in the Appendix of this report.

4.1 HAZUS

Jesse Rozelle (FEMA, United States)

Initially used as mitigation tool, Hazus has been increasingly deployed for response and recovery. Hazus assesses a variety of hazards, including hurricane wind, riverine and coastal floods, earthquakes and tsunamis (active from 2017, the tsunami model has the fewest outputs so far, while the earthquake model is more robust and consolidated). This risk assessment tool relies on a strong multidisciplinary coordination. Engineers, seismologists, geologists and social scientists collaborate with decision makers to provide a comprehensive risk assessment (from mitigation strategies to inventory modelling). Additionally, Hazus relies on nationwide databases and it is used for, *inter alia*, preparedness exercises in the U.S. International applications are also worth mentioning; for example, a collaborative study that was carried out in Egypt with NRIAG (National Research Institute of Astronomy and Geophysics).

The disaster response information timeline is of particular relevance as it points to one of the most critical aspects of crisis communication management: when and how decision makers should be informed. When, for example, an earthquake occurs, the preliminary Hazus models are run after 45 minutes. After the first hour, significant information (e.g. buildings, casualties, debris, shelter needs) is shared in a dashboard (Fig. 2). An update on losses and products (e.g. utilities and essential facilities) is provided two hours after the event when additional data is available. To avoid information overload, updates are kept at minimum.

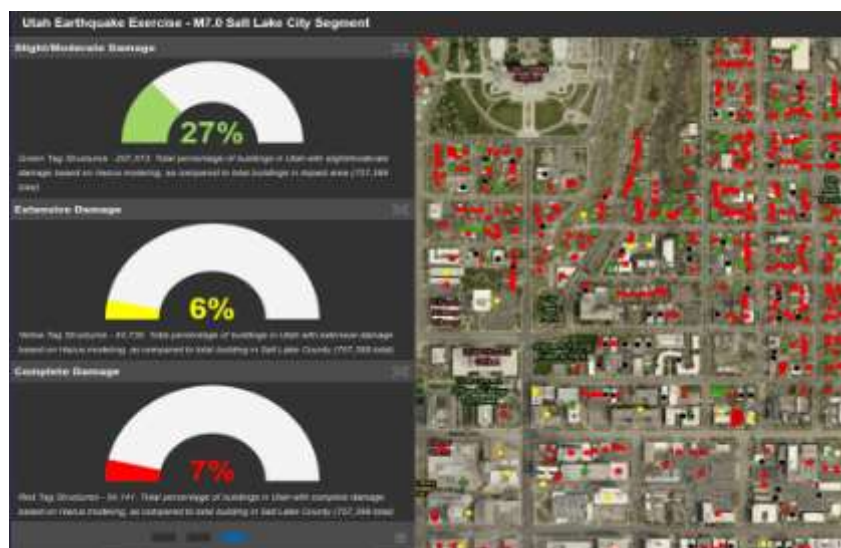


Fig. 2 – Example of the dashboard to share significant information 1 hour after an event (e.g. buildings, casualties, debris, shelter needs).

² <http://drmkc.jrc.ec.europa.eu/>

4.2 CAPRA

Mario Ordaz, (Univ. Nacional Autonoma de México) and Mario Salgado (Ingeniar Ltda. Colombia)

CAPRA is a fully probabilistic and peril-agnostic risk assessment system. In the probabilistic risk assessment approach used by CAPRA the exposure, hazard and vulnerability are in fact represented in the same methodological framework, regardless of the peril.

Overall, the CAPRA initiative aims at developing both risk assessment and communication tools to:

- guide decision-makers about the potential impact of disasters associated to natural hazards
- formulate comprehensive disaster risk management strategies at sub-national, national and regional level
- develop a common, open and modular methodology to assess and quantify disaster risk from multiple perils
- provide access to state-of-the-art fully probabilistic hazard and risk assessment tools to local institutions, mainly needed in developing countries
- develop a flexible methodology in which updates and improvements can be incorporated by universities, research centres etc.

Not only is the methodology flexible and the licence is open source, but the system can directly integrate several databases at the same time and the users can select different taxonomies (e.g. GAR15 hazard, exposure and vulnerability files) to perform the fully probabilistic risk assessments. User-customized versions are also available (e.g. CAPRA Team PocketRC without a graphical interface for expert users) that operate in different OS such as Windows, Linux and Mac.

Although originally developed for disaster risk management (DRM) and disaster risk reduction (DRR) planning activities, CAPRA's risk assessment tools can be used for rapid post-event damage and loss assessments at different scales depending on information availability, having been tested with events in Asia, Europe and Latin America. So far, the tools have been used in different DRM activities, for example seismic hazard maps for building codes in Mexico, Colombia and Spain and input data for seismic microzonations in Mexico, Colombia and Ecuador (Fig 3).



Fig.3 - First integrated and fully probabilistic seismic hazard and risk model for Latin America and the Caribbean (29 countries): ASLAC.

4.3 AFAD – RED

Can Çetin (Turkish Civil Protection)

It is the national operational tool Seismic Risk Assessment for prevention, preparedness and response phase. The project is funded by the Turkish Government.

In its real-time, operational configuration the system receives seismic data either as source parameters and attenuation functions, or engineering parameters (PGA, PGV). Combined with an extensive inventory of buildings, critical facilities, population and geological data like fault maps and soil conditions, it gives damage and fatality loss estimates. The event assessment is done in three consecutive stages, with increasing level of sophistication as more data are received. Custom-developed graphical user interfaces are used throughout to insert parameters and monitor results.

The system outputs consists of number of buildings in light, medium and heavy damage, people in need of shelter as well as possible numbers of lightly injured, seriously injured and fatalities (Fig. 4).

County	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum	43037	7097	6910	6853	838	400097	4221	1600	832	443	49391

County	District	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum	Aznıye	6925	1072	937	798	79	45796	293	111	53	28	3934
Erzurum	Çat	63	7	4	1	0	0	0	0	0	0	0
Erzurum	Palandöken	10496	1711	1820	2121	324	167499	2349	890	479	255	25462
Erzurum	Pasinler	245	19	8	1	0	729	0	0	0	0	2
Erzurum	Yakutiye	25308	4288	4141	3932	435	186073	1579	599	300	160	19993
TOPLAM		43037	7097	6910	6853	838	400097	4221	1600	832	443	49391

County District	Town	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum Azıziye	Adecey Mh.	47	8	8	9	1	156	1	1	0	0	17
Erzurum Azıziye	Alaca Mh.	160	12	5	1	0	388	0	0	0	0	1
Erzurum Azıziye	Alaybeyi Mh.	77	7	3	1	0	239	0	0	0	0	1
Erzurum Azıziye	Ağören Mh.	67	11	8	4	0	291	1	0	0	0	10
Erzurum Azıziye	Beypınarı Mh.	122	18	13	7	0	432	1	0	0	0	13
Erzurum Azıziye	Demirgöçü Mh.	85	10	6	2	0	436	0	0	0	0	6
Erzurum Azıziye	Döğöprak Mh.	37	4	2	1	0	39	0	0	0	0	0
Erzurum Azıziye	Çöz Köyü OSB	151	26	26	23	2	0	0	0	0	0	0
Erzurum Azıziye	İlice Mh.	1788	281	206	115	5	10305	19	7	2	1	363

Fig. 4 – Example of the AFAD-RED output.

4.4 Earthquake Qualitative Impact Assessment (EQIA)

Rémy Bossu, (EMSC)

The Earthquake Qualitative Impact Assessment (EQIA) uses a methodology developed at the European-Mediterranean Seismological Centre (EMSC) for rapidly collecting *in-situ* observations on earthquake effects from eyewitnesses. This methodological choice depends on the uncertainties, emerged at a global scale, to evaluate with accuracy earthquake impact assessment. The latter can in fact be ambiguous even when building stock and vulnerability are relatively well constrained. The pervasive use of smartphones has changed the ways in which citizens and decision makers alike provide and have access to rapid earthquake information. Eyewitnesses can play an important role in the aftermath of an earthquake by providing real-time geo-located pictures and videos.

EQUA is a fully automatic real-time tool calibrated per country and in operation since 2007. It offers real-time “heads-up” alerts for global earthquakes and uses earthquake data (location and magnitude) and modelling (fault geometry, slip distribution, directivity effects, wave propagation, site effects etc.). Spatial distribution of strong motion is included in areas where dense real time accelerometric network data are available (e.g. Italy, California, Japan, Taiwan etc.). Empirical approaches are also considered to assess the impact based on past earthquakes. The impact is estimated through the number of people subjected to various estimated peak ground acceleration (PGA) and the results are

calibrated per country using post-1950 earthquakes. LastQuake is the official EMSC app which collects information on felt earthquakes (Fig. 5). It allows customizable notifications, access to comments, photos and videos by witnesses as well as the sharing of information on social media. Moreover, it provides post-earthquake safety tips.

At global scale, impact scenarios are intrinsically uncertain due to the lack of accurate exposure and vulnerability information. This is even more true where shakemaps are not constrained by dense accelerometric networks (which remains an exception at global scale). The integration of in situ information (testimonies, geo-located pictures, information harvested on social media etc) is a way to reduce these uncertainties.



Fig. 5 – 914 EQIA felt reports received for M5.3 earthquake in Central Italy on Jan 18, 2017.

4.5 SELENA

Dominik Lang, (NORSAR Norway)

The development of the SELENA Open risk tool started in 2004 as a joint collaboration between NORSAR and the University of Alicante under the umbrella of the International Centre of Geohazards (ICG). The initial purpose was to develop a tool with the key attributes of adaptability (e.g. open to any user input), flexibility (e.g. can be applied to any region in the world), independence (from any proprietary software), and openness (e.g. open source code, open documentation, and freely accessible). Further, SELENA provides an high level of versatility allowing the user to easily implement their own methodologies or input algorithms (i.e. ground-motion prediction equations, earthquake demand spectra following various international seismic building codes), choose whether site and/or topographic amplification effects shall be taken into account, or to choose between various damage computation methodologies (Figure 6).

An important technical feature of the tool is the tripartite loss computation sequence, i.e. using deterministic earthquake scenarios, simulated ground motion shake maps, or shake maps based upon recorded ground motion data. The outputs of the computation sequence are classified as follows:

- Ground motion shake maps (in case of deterministic computation)
- Damage probabilities and absolute damage extents
- Debris estimation
- Shelter estimation
- Human loss
- Economic loss

Each computation output is provided on the level of the smallest geographical unit (geounit) and, in case of building damage, structural building typology (Figure 7). A feature of SELENA is the implemented logic tree computation scheme which allows the handling of the intrinsic uncertainties in each input parameter (i.e. focal parameters, soil conditions, fragility models, economic and human loss models, etc.).

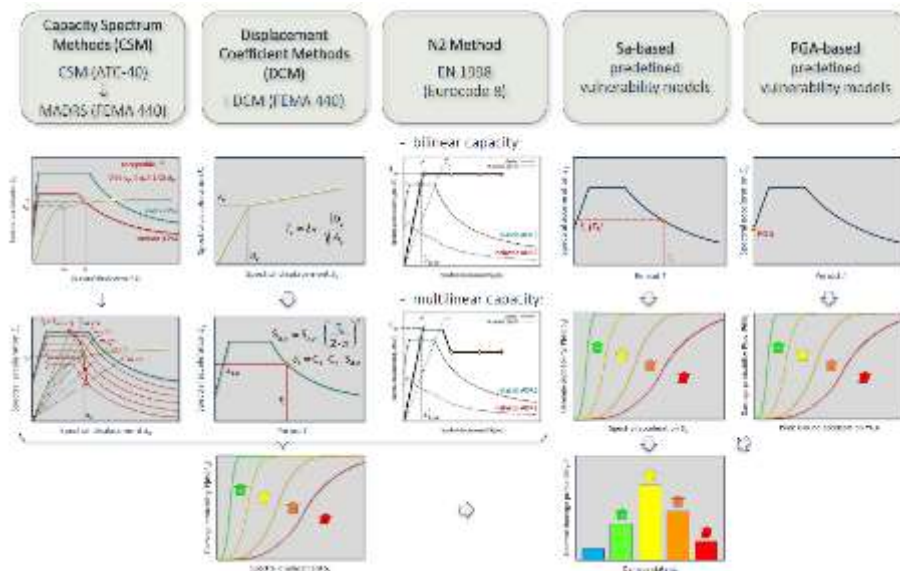


Fig. 6 – SELENA Implementation of various damage computation procedures.

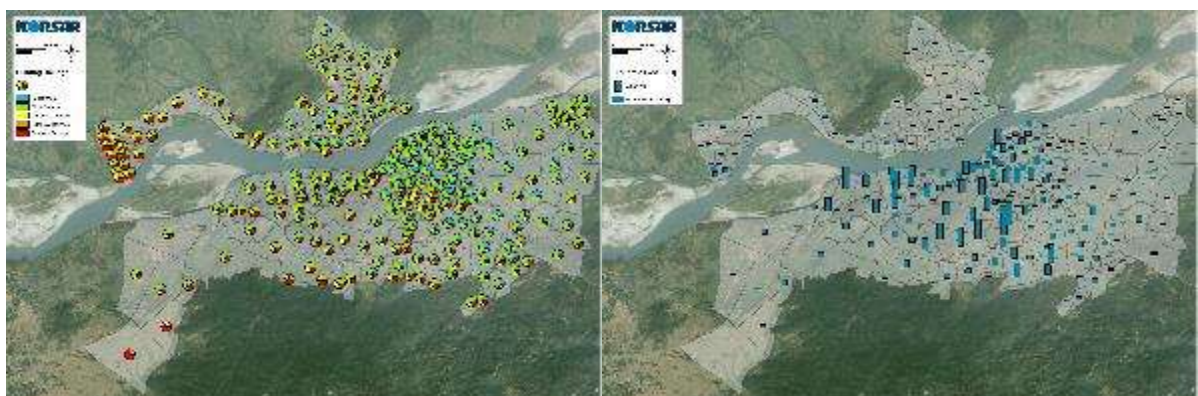


Fig. 7 – SELENA Example: Absolute damage extent and resulted economic loss over all building typologies of the city of Guwahati (Assam, Northeast India) for a deterministic earthquake scenario (Mw 7.3) in approximately 40 km distance southeast to the city centre.

4.6 OpenQuake

Marco Pagani, (GEM Foundation)

OpenQuake is an open-source multi-purpose tool entirely written in Python. The code is covered by Quality Assurance and end-to-end tests run by two independent continuous integration systems. Considerable effort has been put in testing OpenQuake (unique testing, a comparison against other PSHA - probabilistic seismic hazard analysis codes, and a comparison against real-cases are carried out every day).

Used for the calculation of earthquake hazard and physical risk, OpenQuake carries out both scenario hazard and event-based analyses. For scenario hazard analyses, the tool can consider spatial correlation in the ground shaking, in particular ground motion field for peak ground acceleration with or without spatial correlation. For event-based analyses, the tool generates a stochastic set of ruptures and for each rupture a scenario is calculated. Furthermore, classical probabilistic damage/loss analyses can be also done.

The OQ engine is used in many national and regional seismic hazard mapping programs. The use in projects at regional level allowed to develop a global fragility/vulnerability database. For example, the South American Risk Assessment, SARA project, considers building fragility modelling by fragility functions developed for 57 building typologies (Fig. 8). The outcomes for loss assessment considered the average annual economic losses at provincial level of the largest urban centres. This methodology allows flexibility as far as exposure is concerned and fragility input formats. A comprehensive database of hazard, exposure, fragility and vulnerability models is available.

The next step would be to use OpenQuake for real-time assessment. This opportunity will be explored in the near future.

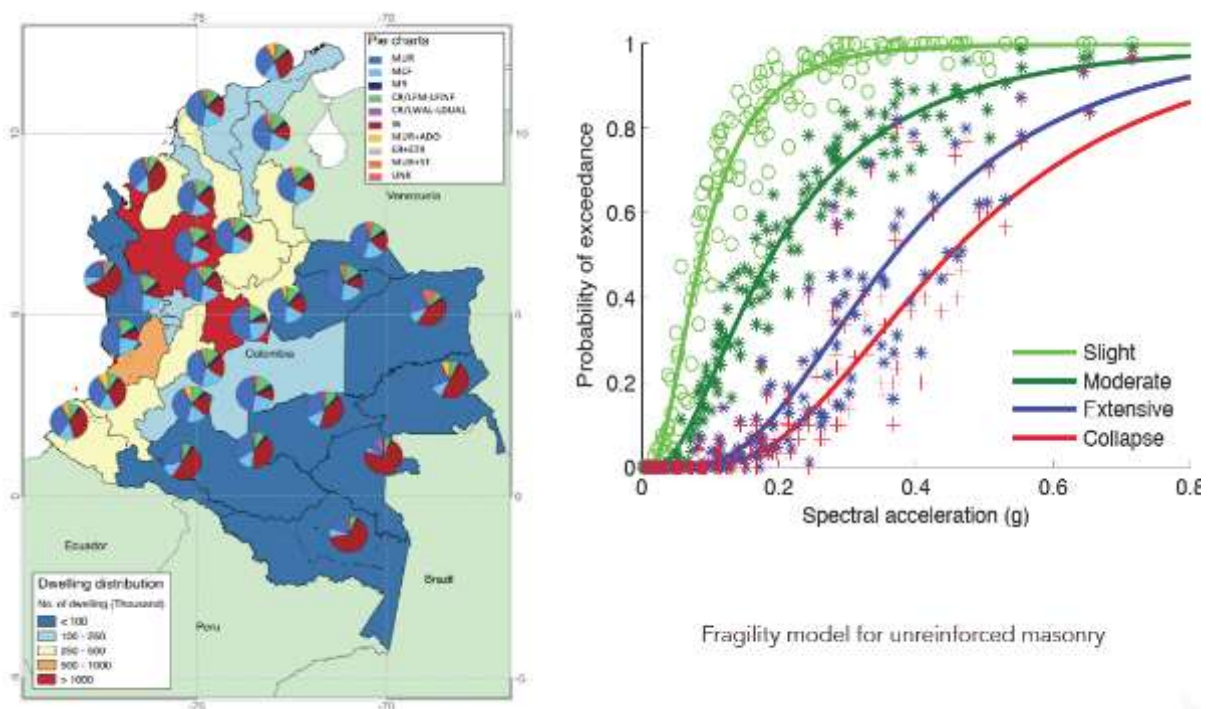


Fig. 8 – Building fragility modelling in OpenQuake: example of fragility functions developed for 57 building typologies within the South American Risk Assessment (SARA) project.

4.7 RASOR

Roberto Rudari, Lauro Rossi and Eva Trasforini (CIMA Foundation)

The objective of the RASOR Platform (Rapid Analysis and Spatialisation of Risk) is to transform advanced EO/non-EO products into Multi-Hazard risk assessment services for the final end user in an easy and usable way. RASOR is an open project that sits on a network of scientists/practitioners/users. It receives exposure, hazard and vulnerability input fields in a great variety of formats, through simple “drag and drop” functions; much importance is put on the use of Earth Observation data such as HR SAR, VHR optical, COPERNICUS products and high-res Digital Elevation Models to provide Policy Makers with tools to identify and assess risk (Fig. 9). RASOR can support the full risk cycle and models multiple risks. It is an open source platform, intended to be simple and interoperable. It can act as an interface system using the risk calculation engines of other systems, OpenQuake by GEM. Permanently connected to the USGS shake maps repository, RASOR also enables the user to import shake maps related to past earthquake events and use them to compute losses. Interoperability with other risk assessment platform (such as CAPRA) was also shown. The final output is a formatted detailed report of losses, including the economic damage and people affected per building usage category.

Example applications shown include an earthquake scenario in Santorini, the 2010 earthquake in Haiti, and floods in Bandung, Indonesia.

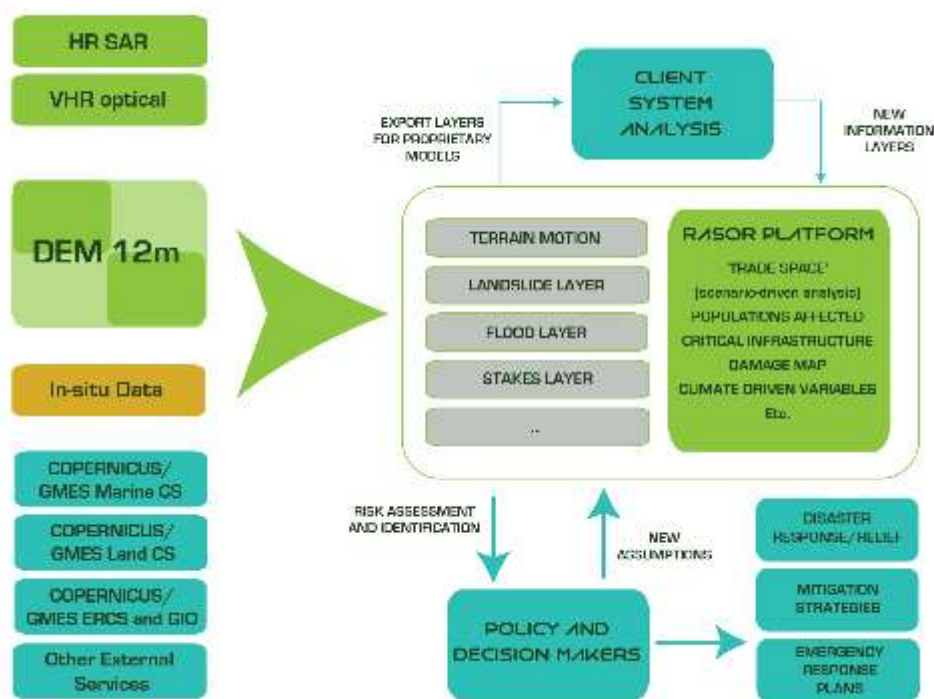


Fig. 9 – RASOR Structure.

4.8 Rapid-N

Serkan Girgin (Joint Research Centre)

Major accidents at industrial plants, which are triggered by natural hazards and result in the release of hazardous materials, so-called Natech accidents, can have serious consequences on the population, the environment, and the economy. Following calls by national authorities, the JRC has developed the RAPID-N tool for rapid Natech risk assessment and its application in seismic risk on industrial chemical facilities (Fig.10).

RAPID-N is a Web-based, publicly available decision-support tool for Natech risk assessment and mapping. It unites natural-hazard assessment, damage estimation and consequence assessment in one tool, featuring a modular architecture, easy and quick data entry, automated data estimation, rapid and scalable analysis and visualization. It is composed of four modules: Scientific, Plants, Hazards and Assessment. A Property Estimation Framework in the Scientific module can estimate missing data, build dynamic models and can accept custom properties of installations. The final Risk Assessment is supported by an extended global database of more than 56,000 earthquake catalog data, 5,500 industrial facilities (power plants and refineries) and 64,500 plants units (storage tanks) data. Extensions of RAPID-N into hazards other than seismic such as floods and lightning as well as other industrial facilities such as pipelines are under development.

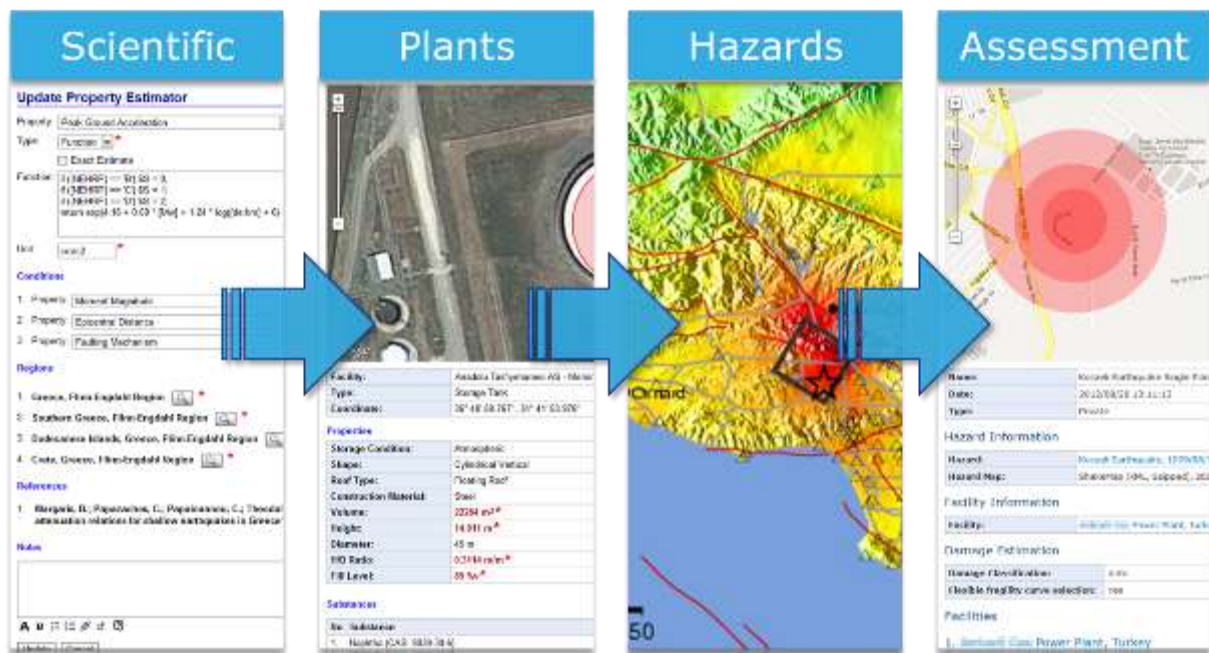


Fig. 10 – Modular structure of RAPID-N.

5. National Authorities and Scientific Institutions Views

5.1 Italian Civil Protection Department

Mauro Dolce, (Italian Civil Protection Department)

The probabilistic seismic risk analysis and damage scenarios for civil protection purpose and the related needs, implementations and critical issues were presented. Regarding the needs and the use of Probabilistic Seismic Risk Analysis (PSRA) for civil protection purposes, the following considerations were made:

- Prevention policy set up: comparison of losses expected from different hazard risks for which probabilistic risk analyses are available
- Prevention strategy set up: comparison of losses expected from the same hazard risk in different areas and /or for different elements at risk
- Contingency planning: at national and sub-national level

In Italy, the PSRA has been used for policy issues, in particular for the allocation of seismic prevention funds at national level.

The Civil Protection Department uses seismic damage scenarios either before an event occurs or in the immediate aftermath. In particular, simulated seismic scenarios are helpful to support prevention activities (from enhancing emergency planning to facilitating *ad hoc* technical training and exercises) and to assess the impact of a just occurred event, before collecting information on the effects of the earthquake from affected areas.

In case of an earthquake of magnitude 4+, an automatic procedure is immediately activated using *SIGE - Information System for Emergency Management and simulated scenarios* to produce data, maps, and information concerning the description of the area, the exposure, the hazard and a preliminary evaluation of damage and losses.

SIGE is based on an empirical approach, using a magnitude-macroseismic intensity conversion, an intensity attenuation relationship, and Damage Probability Matrices providing the probability of a damage level given the intensity and the building vulnerability class. All the input data are the ones immediate available after an earthquake (Fig 11).

Lessons learned from previous relevant events are (2009 Abruzzo EQ, 2012 Emilia EQs, 2016 Central Italy EQs):

- The most sensitive use of SRS (seismic risk scenario) is for emergency management, especially in the first few hours after an event, when information from the affected territory is non-existent or very scarce.
- The extremes of the uncertainty interval differ by one order of magnitude and sometimes are yet insufficient to include the real value of the assessed quantity.

Evaluations from SRS should be complemented with data from the territory and remote sensing. The capability of a scenario simulator to update and re-calibrate the output accounting for additional information of the consequences would be of great value.

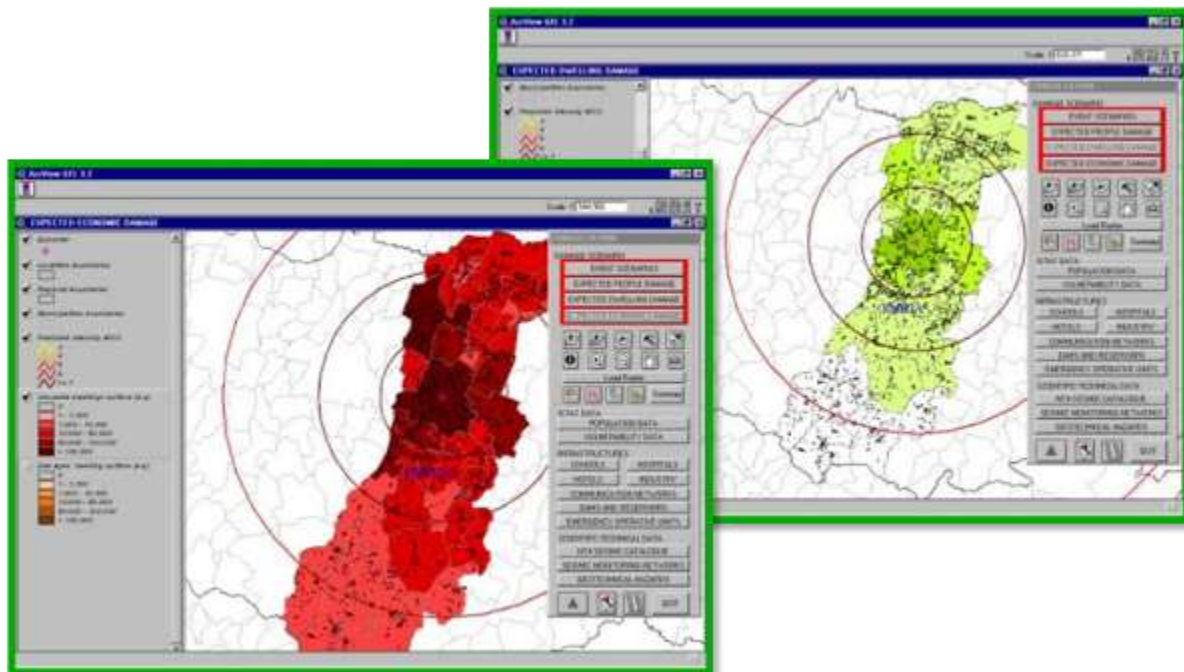


Fig. 11 – Output of the SIGE tool of the Italian Civil Protection Department.

5.2 National Observatory of Athens (Greece)

Gerassimos Papadopoulos, National Observatory of Athens

MASSIVE is an EU FP7 research programme, whose outcomes have been used to model the seismic risk in cities, following the classical risk equation paradigm with custom-driven scenarios.

Two events have been used to validate the algorithms, namely a M=5.9 in Athens (1999) and the M=6.3 in L'Aquila (2009). Attenuation functions and vulnerability models were custom-developed for these two cases. The modelled hazard fields and damage distribution were found to correspond satisfactorily to the observed ones.

The system has been implemented in GIS environment and Automatic application is possible for operational use by end-users (Fig. 12).

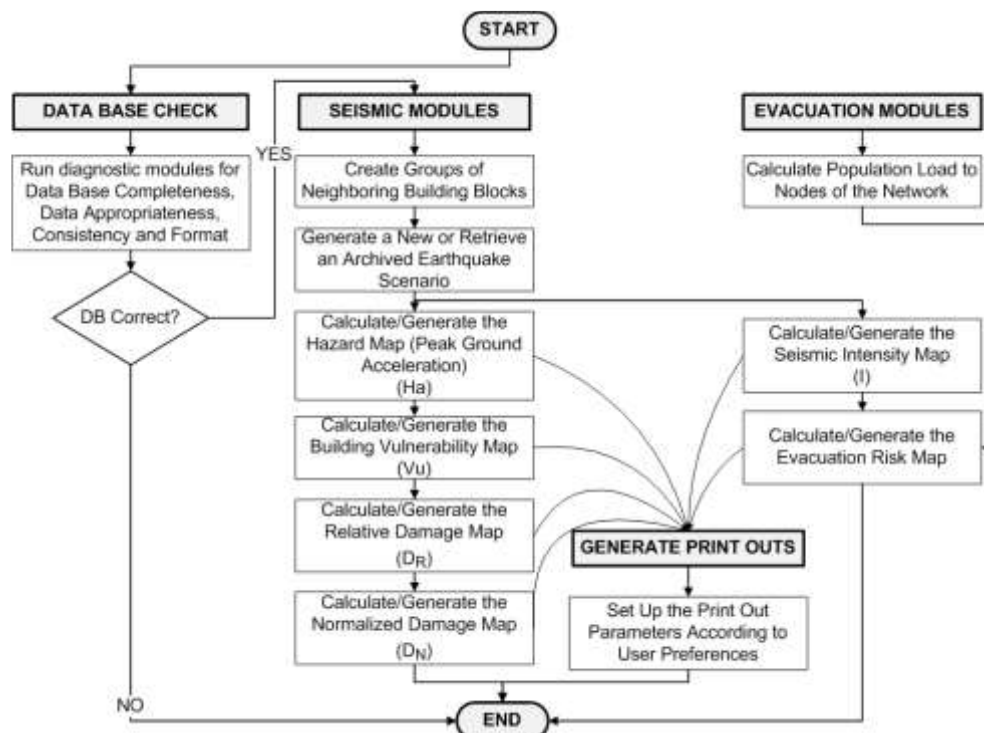


Fig. 12 – Workflow implemented in the MASSIVE GIS system.

5.3 Greek Civil Protection

Andreas Antonakos (General Secretariat for Civil Protection of Greece - GSCP)

The Seismic Risk Assessment Tools and their Probable Use by the Greek Central Civil Protection Authority was presented. While, on the one hand there is no “official” platform developed or used by GSCP for seismic hazard and risk assessment, on the other there is a considerable interest in tools that can be useful immediately after an event.

The GSPC was one of the supporting partners of the RASOR project. A pilot case study was developed to explore the capabilities and the obstacles of the platform used in RASOR, access the minimum data needs for hazard and risk assessment and compare the outcomes of the platform with regards to hazard and impact with the outcomes from other methods/platforms.

The pilot study was focused on Santorini Island where an active volcano is located (last unrest in 2011). The scenario used in RASOR revolved around an earthquake of magnitude 5.5 inside the caldera. A comparative analysis of the physical damage to structures calculated by RASOR and other similar platforms like Risk-UE was carried out. From the analysis, it emerged that damage was 8% higher for the items in the damages houses and

2% higher for structure when PGA was simulated by RASOR. This mainly depends on different fragility curves used (Fig. 13). The following suggestions for improvement may enhance RASOR:

- Give the possibility to use exposure information at building block level.
- Give the option to upload new vulnerability libraries, not only to modify existing ones.
- Give the option to simulate PGA distribution based on seismic source/fault characteristics and not only on point source data.

Future steps include:

- The compilation of an exposure database for the whole country in the block level from already existing data (National Statistical Authority)
- The compilation of a National Vulnerability Library with custom fragility curves
- Running a scenario based on a past earthquake event, in an area where detailed impact assessment exists, from field survey (Kefhalonia Earthquake 26-01-2014) in order to be able to verify the results and calibrate the procedure
- Running the same scenario with other publically available platforms (HAZUS, OPENQUAKE, CAPRA ETC.) to assess which one fits best the needs of the Greek Civil protection.

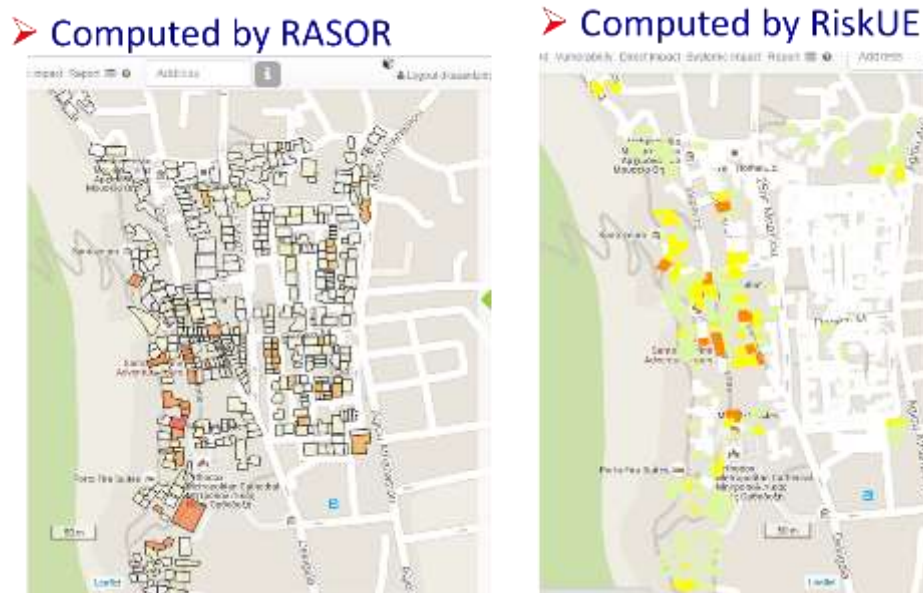


Fig. 13 – Outcomes of the comparative analysis of the physical damage to structures calculated by RASOR and by Risk-UE.

5.4 Portuguese Civil Protection

Patrícia Pires (Portuguese National Authority for Civil Protection-ANPC)

The national perspective on seismic risk was presented and in particular, the ongoing national activities related to the UNISDR Sendai Framework with the National Platform for DRR chaired by the Minister of Internal Affairs. ANPC coordinates seismic and tsunami hazard studies and related damage assessment studies using a Near Real Time System for Estimating the Seismic Losses. Disaster loss databases are online and available in real time for seismic risk assessment (Fig. 14).

All these activities are integrated in national and local investment strategies for disaster risk reduction and resilience (e.g. Resilient cities in Portugal 2016). ANPC is also responsible for the development of an emergency plan for seismic and tsunami risk at local (e.g. city as Lisbon), provincial (e.g. Algarve) and national level.

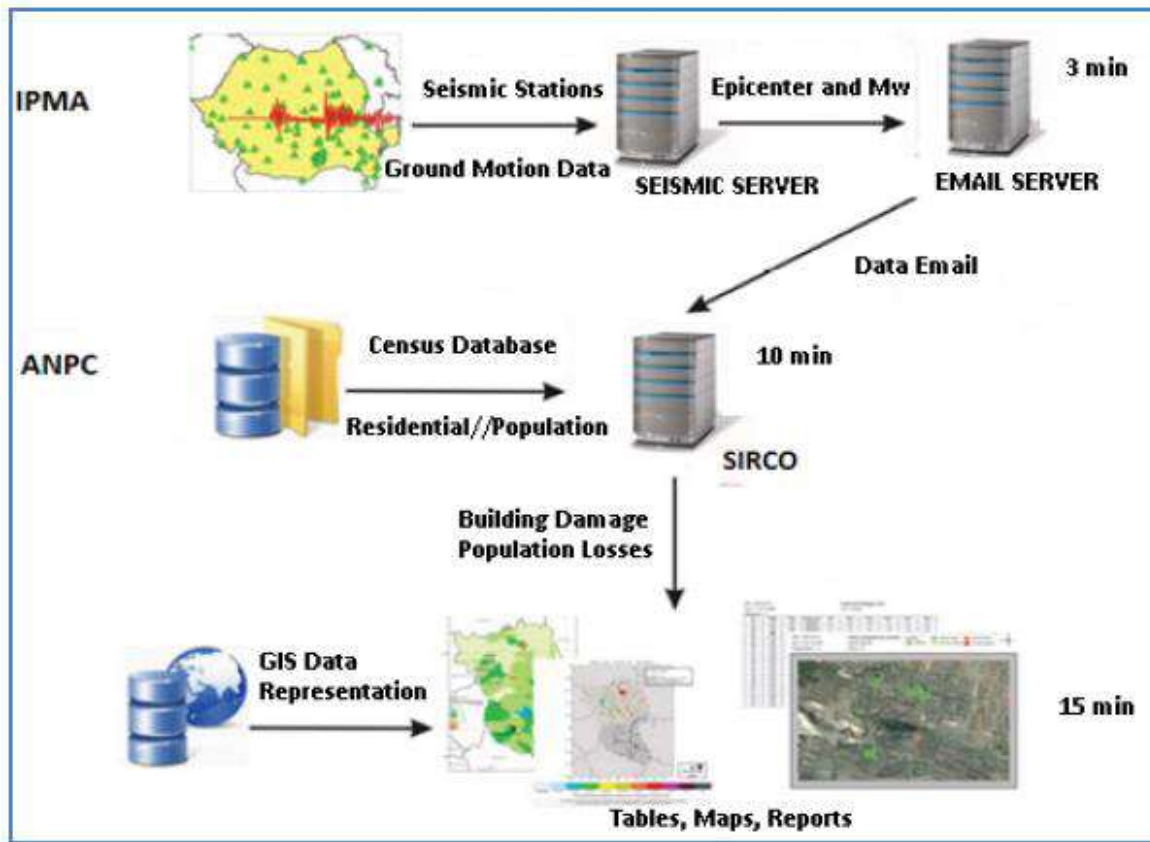


Fig. 14 - Near Real Time System of the Portuguese Civil Protection for estimating the seismic losses.

6. Discussion of objectives and key outcomes

Hereby we list the basic objectives of the workshop and a summary of the conclusions concerning each one of them.

i. Demonstrate the capabilities and promote use of the tools

The developer institutions answered eagerly the call to present their systems and as a result a large part of the modern tools in use around the world were present. Installation, requirements and operational use was amply demonstrated, in most cases for both deterministic and probabilistic mode. Listing of the predicted losses on real earthquake events was extremely interesting, showing that, in general, human casualties are often overestimated while the order of magnitude of the economic cost is reliably predicted. Additional and valuable insight on the functionality was offered through the live demonstration and the “marketplace” interactive sessions. The ease of use and the necessary training or the need for expert staff to aid operation varies a lot, however. An effort to more intuitive input methods and user interfaces would bring high benefits to all parts involved.

ii. Evaluate the near-real time impact assessment capacity

Through the “live demonstration” carried out by all systems presented, it was possible to judge the timings and complexity involved in entering the seismic parameters (shakemap polygons or point-source data) and obtaining the estimated loss data. With exposure data pre-loaded (either global GAR15 data or detailed local data obtained from national authorities previously) the time needed ranged from 5 to 15 minutes for the complete outcome report. Consequently, even systems that were never conceived or developed with real-time operations in mind, with the proper preparation can give results on short time-scales, totally appropriate for early impact assessment. With some rather trivial automation these times can become even shorter.

The JRC, as noted in the conception note of this workshop, will actively pursue the inclusion of the output of at least two seismic risk assessment systems in the [GDACS](#) events pages. The estimates would not be visible to the general public but only to password-equipped users at the level of international organisations such as the European Commission, the UN OCHA or the Red Cross.

In this respect, the JRC will seek to establish which systems would be willing to participate in this effort, either with an automatic calculation through an API triggered after an event, or by a manual update by the system developers in a dedicated space.

iii. To evaluate the flexibility in using different types and formats of exposure and vulnerability data

Significant effort seems to have been invested in this aspect for many of the systems presented; a point has been reached where some of the tools will accept datasets by drag-n-drop and try to guess the format and ask the user to confirm the classes, categories etc. There seemed to be no particular difficulty in integrating (beforehand) global extent public data. The vulnerability field seems to be also quite uniform and many tools have simply adopted the first vulnerability formats used by HAZUS. In conclusion, data flexibility is on the right track and well addressed by almost all systems.

6.1 Key outcomes

All the above outcomes of the workshop objectives, discussions and individual comments can be summarised in the following Key messages:

1. In the past 5-10 years, seismic risk assessment tools have moved into **increasing sophistication** and detail and are able to take full advantage of the newest developments in hazard, exposure and vulnerability data. All systems are non-

commercial and most are **open-source** and their components can be freely downloaded. The common approach based on the risk equation renders them easily interoperable, but on the other hand this entails significant duplication of effort.

2. Most systems are either ready or are adapting fast to a **real-time use**, as early impact assessment and warning mechanisms. This was amply demonstrated during the real-time scenarios submitted to all systems participating, where within a few minutes at most values for predicted human and material losses were available. A correct and comprehensible representation of the uncertainty in these figures is still to be developed. Additionally, the lack of accurate globally available exposure and vulnerability data is hampering this effort, so a joint effort to collect these data sets would be an enormous benefit to the global risk assessment and – eventually – risk reduction effort.
3. Confrontation of the estimated losses versus real losses on actual earthquake events shows encouraging results for the economic cost, while human casualties are usually overestimated. However, the cases where a direct comparison was carried out are few. Therefore, large-scale, common **validation campaigns** using detailed loss data from recent seismic events would help greatly to reduce uncertainties and increase reliability.
4. **Interoperability** in the input data format and **shared metrics** in the output risk assessment results, preferably following the Sendai Indicators (Target A-D, related to disaster loss data) would be one of the recommended ways forward and would increase use and credibility of the systems. The collaboration example of two of the systems presented, where one's calculation engine can be called through the other is particularly welcome.
5. The Civil Protection Authorities are highly interested in the use and outputs of seismic risk assessment systems; even those who have already developed their own would like to have access to the results of other systems. Others are already moving to use one or more of the tools presented in the workshop.
6. System developers should take advantage of this momentum and **adapt** to the high demand by rendering the tools easier to use, more **automated, with ready-to-use datasets** and default options that can give results with a minimum of effort, even of low resolution and relatively high uncertainty. Ease of use and necessary training varies a lot across different systems, and an effort to facilitate the use by non-technical experts would be very welcome.
7. Ever-increasing accuracy and detailed loss categories are not absolutely necessary to the national authorities, especially in a real-time, early impact assessment context; a **coarse range** of predicted losses can be perfectly acceptable. In many cases, "too accurate" output numbers are not very meaningful when the uncertainty is of the same order of magnitude as the figure itself.
8. All developers have demonstrated a high willingness to adapt their systems to work in a **global context**. Examples include working for long periods with national experts to collect local exposure data and carry out risk assessments of particular events in cities, or adapting the systems to accept new exposure datasets in very simple ways (even drag-n-drop) with minimum requirements regarding format.
9. A few points that can have significant repercussions on the assessment outcomes might still need to be addressed, such as high **sensitivity** to the chosen set of vulnerability curves and added uncertainty due to poorly known **local conditions** and still-unaddressed aspects of the hazard layer.

Annex 1 – Technical sheets of Seismic Risk Assessment tools

Following a JRC request, most system developers kindly agreed to supply a one-page “technical fact-sheet” of their systems, to be found in the following pages.

Hazus Earthquake Model

The Hazus earthquake model, developed by the U.S. Federal Emergency Management Agency (FEMA) estimates damage and loss of buildings, lifelines, and essential facilities from scenario and probabilistic earthquakes, including:

- Ground shaking and ground failure
- Estimates of casualties
- Displaced households and shelter requirements
- Damage and loss of use of essential facilities
- Estimated cost of repairing damaged buildings
- Quantity of debris
- Damage to buildings
- Direct costs associated with loss of function (e.g., loss of business revenue)

Building Damage Methodology:

- Capacity-Response Spectrum method provides the *maximum* (Spectral) displacement that a building will undergo in the event of an earthquake
- Fragility curves estimate the likelihood of damage for any given maximum displacement
- There are over 16,000 fragility curves that utilize a combination of seismic design level, and 36 different building construction types

Hazus Earthquake Hazard Data Integration:

- Beginning with Hazus version 3.2, the earthquake model now includes a direct integration tool for quickly importing ShakeMap grid.xml files from real events and scenarios
- Now has the ability for utilizing geomean or max direction ShakeMap ground motions, both with or without ShakeMap betas for uncertainty

Additional Information:

- In addition to earthquake, the Hazus model can be used to estimate damages sustained from floods, hurricanes, and tsunamis
- The most recent version of Hazus (4.0) is freely available for download at <https://www.fema.gov/hazus-software>. It currently requires that the user have ArcGIS version 10.4 installed

For any questions please feel free to contact:

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CAPRA
COMPREHENSIVE APPROACH TO
PROBABILISTIC RISK ASSESSMENT



The CAPRA initiative started in 2008 with the objective of serving as a basis and a tool for the development of regional strategies, expected to be versatile and effective, in the development of multi-hazard probabilistic risk assessments. Initially applied in Central America, its different modules have been used in more than 45 countries for the development of national and local probabilistic hazard and risk assessments, considering that its implementation has been accompanied by more than 50 workshops.

The initiative has been designed as a set of open-source tools, arranged in a modular scheme, where the different components needed for a comprehensive and fully probabilistic risk assessment are covered (i.e. hazard, exposure, vulnerability and loss assessment). All modules have implemented state-of-the-art methodologies and are improved and updated on a regular basis. Additionally, CAPRA provides wide flexibility to the user by allowing developing input data for any of the components in separate modules and/or tools by using simple, open and flexible formatting characteristics, being therefore able to use said data in the loss assessment tool.

CAPRA's loss assessment methodology can be considered as peril agnostic, that is, it follows the same methodology for quantifying risk arising from any considered hazard and is not restricted, neither limited, to one in particular. This characteristic has allowed the consideration, nowadays, of other perils than the ones initially implemented and to date users can assess catastrophe risk in different types of components due to: earthquakes, tsunami, landslides, floods, hurricanes, volcanic activity, hail and droughts, among others, with the possibility of accounting for losses occurring in a simultaneous manner (e.g. strong wind and storm surge; earthquakes and landslides triggered by them).

CAPRA has also scale flexibility, which means that the same loss assessment methodology can be applied at different resolution levels, a matter of relevance when considering data and resources availability together with the issue of why the risk assessment is being performed. It has been used for high resolution (element by element) risk assessments at urban level where results have been integrated in land planning activities and in the design and implementation of risk transfer/protection schemes and also for coarse-grain national assessments, such as the one developed in the framework of the UNISDR's Global Assessment Report on Disaster Risk Reduction for 216 countries between 2013 and 2015 and in the recently launched GAR Atlas.

Although initially thought as a tool for the planning of disaster risk management and reduction activities, CAPRA's loss assessment tool can be also used for rapid post-event damage and loss assessments, at different scales (depending again on the information availability), having been tested, with acceptable results in terms of physical and human losses, with earthquakes and hurricanes in Latin America, the Caribbean, East Asia and Europe using openly available global exposure and vulnerability databases, a capabilities that makes this tool unique and useful for civil protection agencies from where valuable information can be obtained in a simple, direct and almost real-time manner.

Earthquake Qualitative Impact Assessment (EQIA)

Scope: Since 2007, EQIA provides real time (within minutes) automatic impact assessment for all global crustal earthquakes with magnitude of 5 or greater (1 500/year)

Method: Impact is estimated through the number of people subjected to various estimated PGA (Peak Ground Acceleration). The results have been calibrated per country using past (post 1950) earthquakes (See Samardjieva and Badal, 2002).

Up to magnitude 7, the model is a point source. For larger magnitude, it is a 2D model (the rupture length being derived from magnitude). Six scenarios are computed: 3 for each nodal plane of the focal mechanisms (2 unilateral rupture from epicenter, 1 bilateral rupture). The tectonic setting generally allows the seismologist to exclude of the possible fault plane. Information such as felt reports, or information harvested from social media can identify the most likely scenario.



The results are presented by this diagram. The red line represents the most likely scenario with the distribution of possible scenario. In green: no expected fatality, yellow: a few, light orange: tens, orange: hundreds, red: thousands, purple: tens of thousands.

EMSC does not provide a number of expected fatalities because uncertainties are too large but only the scope of possible impact.

Specificities: EQIA explores the uncertainties domain and offers a real-time head-up. Uncertainties are intrinsically large. At global scale earthquake real time location uncertainty is typically 10 to 20 km. By moving the epicenter of the M5.9 1999 Athens earthquake (143 fatalities) by 10 km from its final location, the number of people affected by PGA of 0.25g (a damaging ground motion) jumps from 1 000 to 300 000, and the number of victims would change in similar proportion. And this is assuming that magnitude, population exposure, building vulnerability is perfectly known.

Performances: EQIA identifies with great accuracy the earthquakes which have no impact (80%) and the ones with significant impacts.

Improvements: EMSC has been working on the integration of in-situ information to reduce uncertainties on damage scenario. For example, during the 2015 Nepal earthquake, all scenarios had forecasted major damage in Kathmandu. Within 5 min, we were able to exclude this possibility thanks to the large number of visitors originating from this city hitting our website. We are also working on the integration of felt reports and data on the use of our LastQuake smartphone application.



Republic of Turkey Prime Ministry
Disaster and Emergency
Management Authority
Earthquake Department



AFAD RED
AFAD Rapid Earthquake
Damage and Loss Estimation
Software

AFADRED
(Rapid Earthquake Damage and Loss Estimation Software)

TECHNICAL FACT SHEET

The technological advances in seismic instrumentation and telecommunication permit the development of rapid estimation of earthquake losses in order to enhance the rapid response and emergency operation after the earthquake.

Current earthquake rapid loss estimation methodologies have different approaches to measure and estimate the ground shaking of earthquake area, in order to estimate the intensity and damage maps. The first approach uses the seismic source parameters (hypocenter, magnitude, intensity) in order to compute the ground shaking and potential damage.

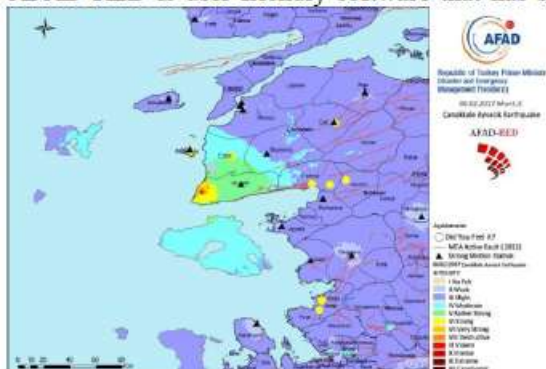
The second approach use the direct engineering parameters such as peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration (SA), spectral displacements (SD) and Intensity maps to compute the potential damage. The second approach requires a large number of seismic stations (strong motion instruments), which are distributed uniformly over an urban area.

AFAD-RED system are planned to estimate the earthquake risk loses all over Turkey. Therefore, combination of the above two methodologies are adopted. The existing online accelerometers operated by AFAD are integrated into the system. Therefore AFAD-RED system is designed to utilize both weak and strong earthquake monitoring systems that operated by AFAD.

AFAD-RED system can also be utilized to run earthquake scenarios for the risk assessment due to a scenario earthquake. The output of risk assessment analysis is used for planning and execution of the management and mitigation of the seismic disaster and damage within the study area. Knowing the seismic risk and potential losses allows for proper budgetary planning, raising public awareness, assessment and allocation of the necessary manpower for mitigation and disaster management operations, educating the public and professionals on preparedness and mitigation, and prioritization of retrofit applications. AFAD RED is integrated to an information system it is called AYDES (Disaster Management and Decision Support System) designed and developed by AFAD to monitor and conduct all stages of disaster and emergency management on a common platform in a fast and effective way.

AFAD RED system is developed for all Turkey where the country districts have different population density, life culture, tectonics and earthquake potential to estimate the losses in disaster area as nearly in real time after a major earthquake.

AFAD RED is user friendly software that has simple interface and online monitoring for the weak



motion and strong motion systems in AFAD. The software is working in both online and offline modes and can be able to automatically generate shake and risk maps. AFAD RED system is developed under VB-Net and C# environments for the system design and the Arc-Object is used for mapping and geographic information system. Different attenuation relationships can be used as a weighted average and the calculation of structural damage for different building types, a lot of fragility curves can be used and defined simultaneously for both intensity and spectral-

based. The casualties loss can be estimated based on both intensity and damage level of buildings. Example of intensity map that results for earthquake combing the estimated and recorded strong motion parameters data is provided in Figure .

RASOR is one of a new generation of informatics platforms that supports risk analysis, but **RASOR** differs from other platforms in a number of ways:

- it addresses the full cycle of disaster risk management, although its main focus is risk assessment;
- it's a multi-hazard platform, allowing users to consider cascading risk across hazards;
- it addresses cost-benefit issues of particular interest to governments interested in disaster risk reduction trade-offs;
- it's an open and freely available platform.

HOW DOES RASOR WORK?

RASOR is a web-based platform used for impact analysis. Users can examine hazard information, exposure information and vulnerability information, and simulate actual events to determine possible impacts, in terms of both direct damage and other impacts: social, environmental or systemic. Users also have access to historical records showing past events, which can be used to simulate the current impact of the same event or as a basis for new simulations. This rapid analysis can be performed in minutes and updated several times over several hours.

RASOR platform interface has the ability to change key parameters and quickly re-run simulations that enables **RASOR** users to model the specific impact of dedicated risk reduction measures. In this way, **RASOR** users can prioritise government or private sector investment in risk reduction. Previously run scenarios can also be accessed in real time during an event to better estimate damage and plan response efforts. **RASOR** allows managers to use real scenarios when determining new mitigation or prevention measures, and integrate new, real-time data into their operational systems during response activities. For example, users can access a database of historical hurricane tracks in the Caribbean to simulate past events or model new ones using a simple drag and drop system.

RASOR has its embedded multi-peril hazard simulator, but it is conceived to operate other libraries able to produce hazard fields to be used then for impact evaluations.

Although **RASOR** is designed around a What-If philosophy, its engine can be employed to run full probabilistic analysis in Batch mode.

SEISMIC ANALYSES USING RASOR

The current version of **RASOR** allows the user to simulate/assess different effects of an earthquake:

- Ground Shaking
- Co-seismic ground displacement
- Seismically triggered landslide
- Post-event stress-loaded seismic faults

Ground Shaking can be computed through two simulation engines: **ShakeMap** by the US Geological Survey and the **OpenQuake** Hazlib engine the by GEM Foundation. The user can choose among different Ground Motion Prediction Equations (GMPEs) embedded in **OpenQuake** engine.

Also **RASOR** has the possibility to connect to the USGS database of historical events and retrieve already computed ground shaking fields in terms of MMI, PGA, PGV, PSA 0.3s, PSA 1.0s, PSA 3.0s.

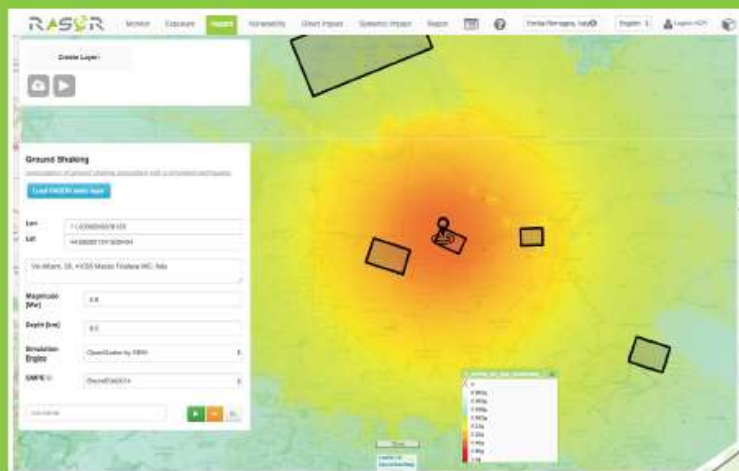


Figure 1:
Ground Shaking interface
embedded in the RASOR platform.



For more information:
www.rasor-project.eu

The SELENA Open Risk software

(Seismic Loss Estimation using a Logic Tree Approach)

NORSAR

 Universitat d'Alacant
Universidad de Alicante

The seismic risk assessment software SELENA is open to any user-defined input data and thus can be applied to any part of the world. The main idea behind the development of SELENA was to provide institutions (both governmental and non-governmental organizations) in charge of disaster management and emergency response planning with an easy-to-use tool that can provide reliable estimates on the physical damage distribution, human losses, and the potential short- and long-term socioeconomic consequences to a city or region stricken by an earthquake.

SELENA is independent of any Geographic Information System (GIS), adding versatility to the software, so that it can be used across operating systems and platforms. In order to make end-users more comfortable in its usage and to make the whole computation process as transparent as possible, all input files required by SELENA and the generated output files are in plain ASCII text format and can easily be imported to MS-Excel or MS-Access. SELENA's output files are geo-referenced allowing end-users to use their favorite GIS platform for displaying the results.

The strength of SELENA comes not only from the use of a transparent coding or its simplicity of preparing input files as well as handling output files, but also from a complete flexibility which is offered to the user by a variety of choosing options. This applies to various state-of-the-art methods and procedures for the computation of seismic ground-motion parameters, the estimation of physical damage and losses, and the possibility for end-users to use of different types of vulnerability models for different ground motion intensity measures. Since vulnerability models are the type of information much sought-after in the framework of earthquake loss estimation studies, SELENA basically accepts analytical vulnerability models of any type thereby adding the utmost level of flexibility and efficiency.

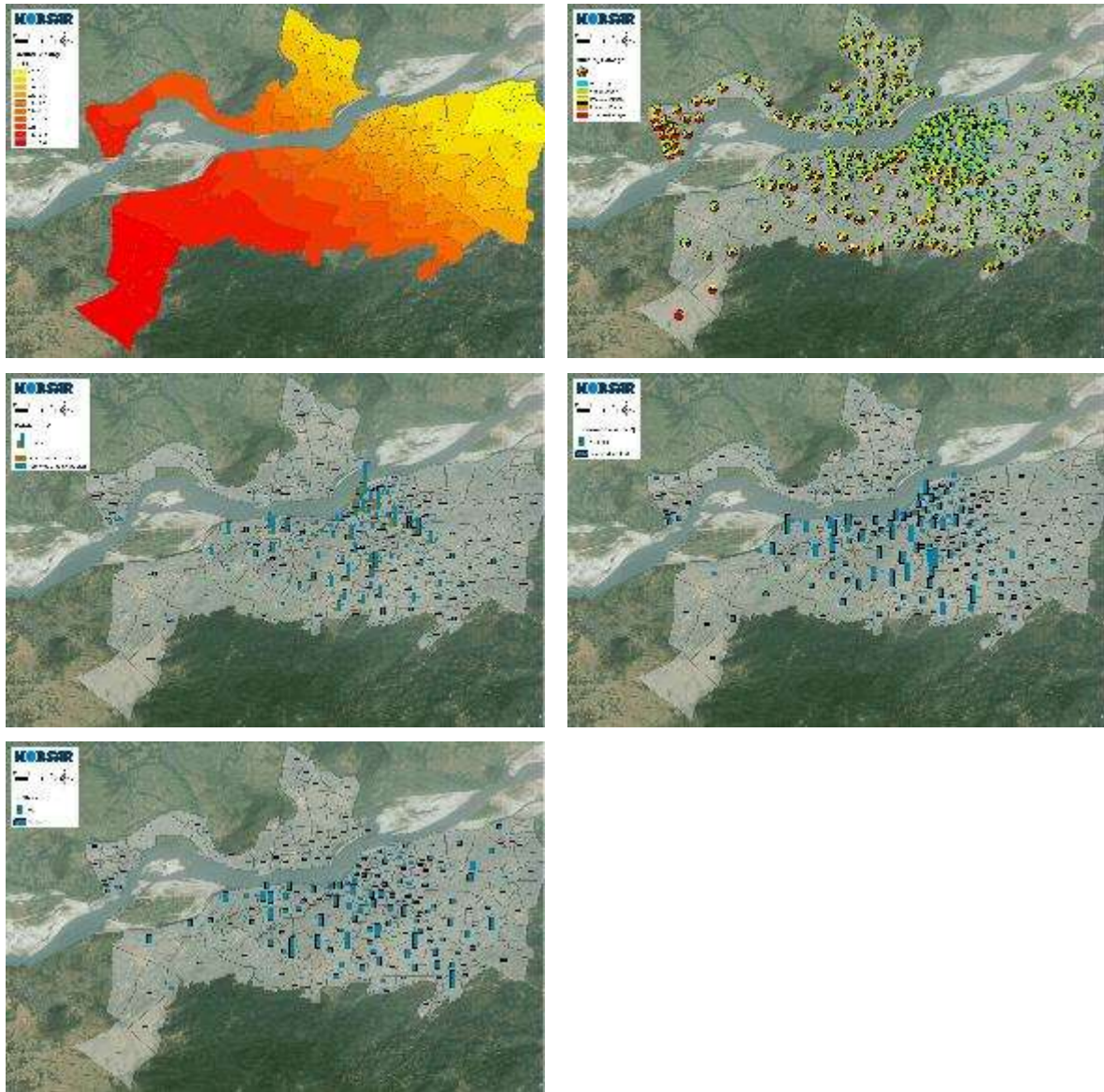
Irrespective of the way the seismic ground motion is provided (through deterministic scenarios, existing shake-maps or real ground motion data recorded at local monitoring stations) SELENA will compute the following main results on the level of geographical units:

- simulated ground shaking and related parameters that can be generated from the three different analysis options (deterministic scenario, shake-map, or real recorded data)
- probability of damage (disaggregated over five different damage states: no, slight, moderate, extensive and complete) on the level of building typology
- absolute numbers of damaged buildings and damaged building floor area on the level of building typology
- direct and indirect economic losses
- human casualties disaggregated by injury severity level as well as total numbers of affected people
- amount of debris resulting from the severely damaged buildings
- total number of uninhabitable buildings, displaced households, and shelter requirements

The main innovation of SELENA is the implementation of a logic tree the computation scheme, allowing the consideration of epistemic uncertainties related to the different input parameters to be properly included. In the course of the computation process, SELENA calculates damage and loss estimates for each branch of the logic tree separately before a statistical analysis over all logic tree branches is done. The final results are then provided as statistical mean with corresponding confidence levels (i.e., median value as well as 16% and 84% fractiles).

Since its first release in early 2007, SELENA has been undergoing a constant further development with an updated version being released at least once every year. One of the more recent features being included in SELENA is the possibility to address topographic amplification of seismic ground motion. More recently, under the framework of the ongoing HORIZON 2020 LIQUEFACT project, SELENA will be extended to allow the consideration of liquefaction-induced ground deformations and the related structural damage.

The SELENA open risk software is an open-source tool and its source code is freely redistributable under the terms of the GNU General Public License (GPL) as published by the Free Software Foundation (<http://www.gnu.org>). The SELENA program can be obtained free of charge.



Annex 2 – Outcomes of the real-time simulation

The system developers kindly agreed to perform a “live demonstration” of their tools, where the parameters of a simulated earthquake was provided at that time by the JRC. The presenters of the tool then entered the parameters, let the system run in front of the audience and displayed the results, that typically took a few minutes to be completed. Here follow the results of the systems whose developers kindly sent them for the completion of this report.

Earthquake scenario results summary CAPRA



In the framework of the seismic risk assessment workshop organized by the JRC in Ispra on May 11-12th, risk resulting from a hypothetical scenario was computed using the CAPRA-GIS program; the loss assessment tool of the CAPRA Platform.

Ground motion for three spectral ordinates (PGA, 0.3 and 1.0s) was provided by JRC and said data was quickly transformed (rasterized) into the *.AME format required by the CAPRA-GIS for the hazard representation and also scaled in order to have compatibility between the hazard and vulnerability units.

The hypothetical event was set near the coast of Peru, with epicenter approximately at -75.75° , 14.23° , producing a maximum PGA of 0.9g as shown in Figure 1.

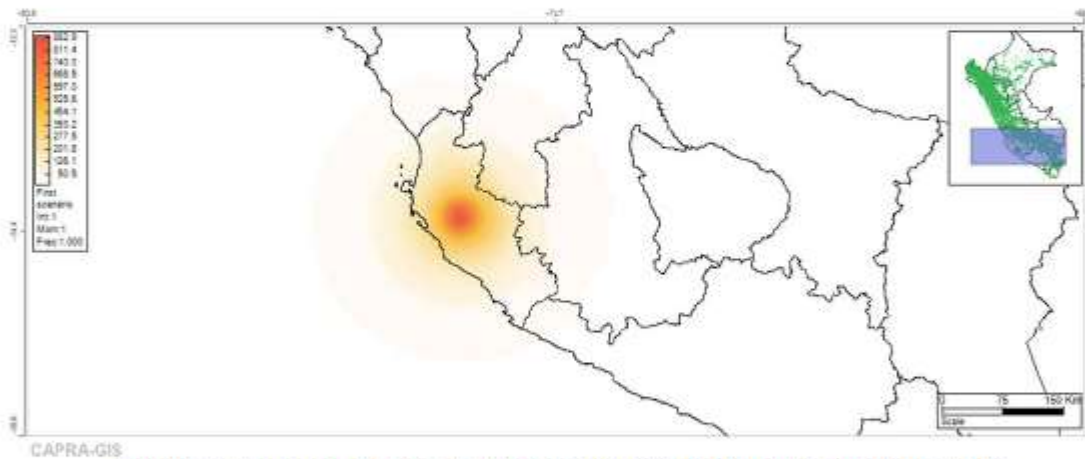


Figure 1. Shakemap (cm/s²) in terms of PGA for the hypothetical event

Aligned with the objective of the workshops, the exposure and vulnerability datasets used in this case correspond to those developed in the framework of UNISDR's GAR15 Global Risk Model. Exposure is available at a coarse-grain 5x5km resolution level (see Figure 2) whereas physical vulnerability is represented by means of continuous and probabilistic loss functions.

The exposure database includes public and private buildings located in urban and rural areas. For the economic appraisal of the components, capital stock has been chosen as a reference value.

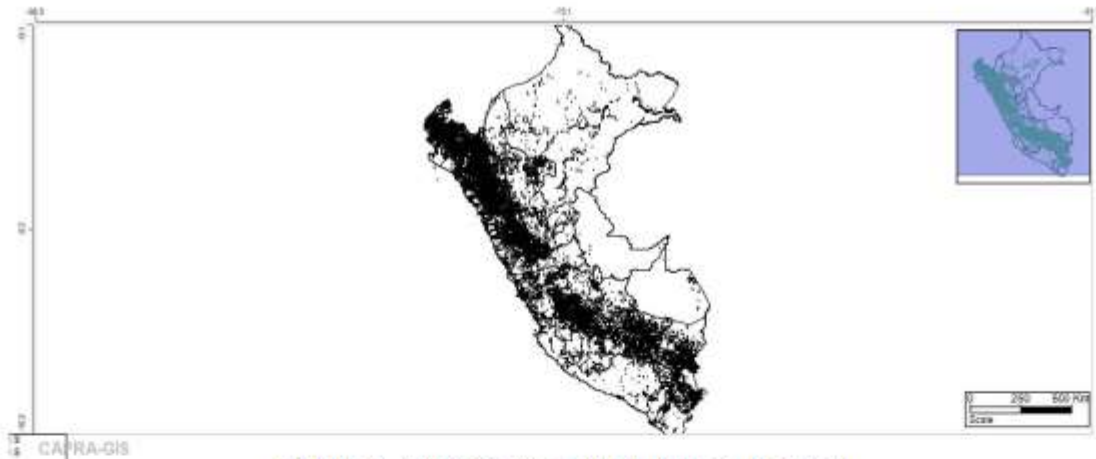


Figure 2. GAR15 exposure database for Peru

With all ingredients ready, the probabilistic loss assessment was performed in 28 seconds accounting for a fully probabilistic approach in which the uncertainties associated to the hazard (assumed) and vulnerability (provided in GAR15 datasets) were propagated. The obtained results cover both the physical and the human dimensions and are summarized in Table 1.

Summary of the results

Physical dimension		Human dimension	
Expected loss (US Million)	\$ 3,880	Casualties	1450
Exposed value for the event (US Million)	\$ 378,227	Exposed population	19,146,400
Relative loss	1.03%	% of affected population	0.01%

Using the results and directly from the CAPRA-GIS, the display of the geographical distribution of the damages inflicted by this earthquake was done, as shown in Figure 3 where in the vicinity of the epicenter, relative losses of up to 85% were obtained.

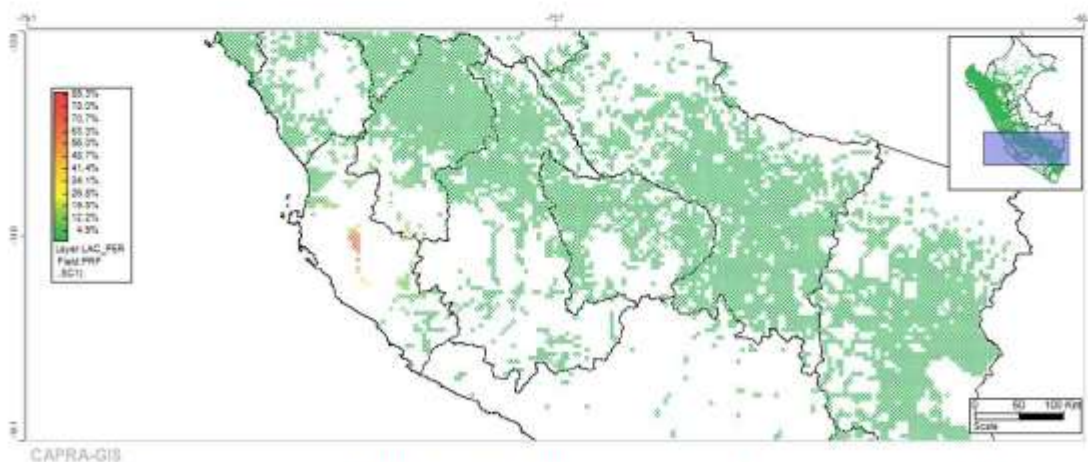


Figure 3. Geographical distribution of the relative loss due to the event in Peru

Since a fully probabilistic approach has been used for the loss assessment in the exposed assets due to the occurrence of this event, the probability density functions for both, physical and human losses can be obtained as shown in Figure 4.

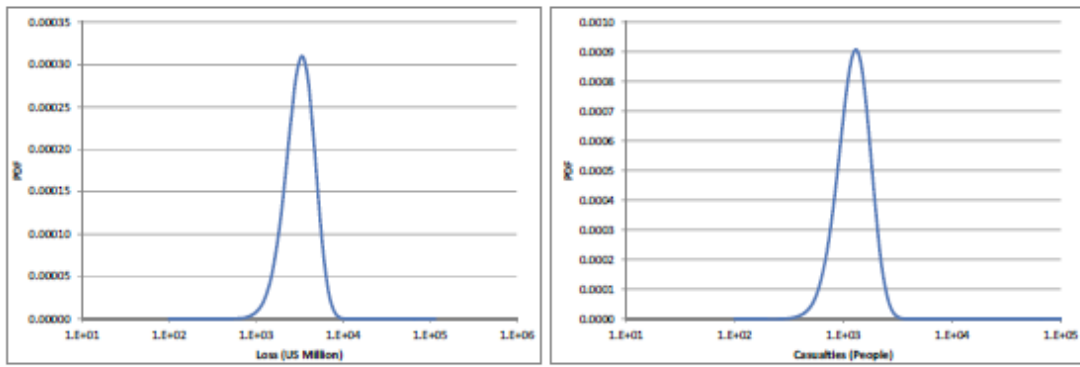


Figure 4. Probability density functions for physical (left) and human (right) losses for the considered event



AFAD RED
(Rapid Earthquake Damage and Loss Estimation Software)

SAMPLE SYSTEM OUTPUTS

AFAD RED can give results on county, district, and town basis (Table 1,2,3) ;

Basic outputs are; structural damage level (Light, Medium, Heavy, and Complete Damage), number of patients who need outpatient treatment, number of minor injuries, number of seriously injured, number of life lost, number of people requiring temporary shelter service

Table 1 Sample County level loss estimation results

County	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum	43037	7097	6910	6853	838	400097	4221	1600	832	443	49391

Table 2 Sample District level loss estimation results

County	District	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum	Aziye	6925	1072	937	798	79	45796	293	111	51	28	3934
Erzurum	Çat	63	7	4	1	0	0	0	0	0	0	0
Erzurum	Palandöken	10496	1711	1820	2121	324	167499	2349	890	479	255	25462
Erzurum	Pasinler	245	19	8	1	0	729	0	0	0	0	2
Erzurum	Yakutiye	25308	4288	4141	3932	435	186073	1579	599	300	160	19993
	TOPLAM	43037	7097	6910	6853	838	400097	4221	1600	832	443	49391

Table 3 Sample Town level loss estimation results

County	District	Town	Number of Buildings	Light Damage	Medium Damage	Heavy Damage	Complete	Effected Total Population	Outpatient Treatment	Minor Injuries	Seriously Injured	Life Loss	Temporary shelter (Num. Of People)
Erzurum	Aziye	Adaçay Mh.	47	8	8	0	1	156	1	1	0	0	17
Erzurum	Aziye	Alica Mh.	160	12	5	1	0	388	0	0	0	0	1
Erzurum	Aziye	Alybeyi Mh.	77	7	3	1	0	230	0	0	0	0	1
Erzurum	Aziye	Ağören Mh.	67	11	8	4	0	291	1	0	0	0	10
Erzurum	Aziye	Boşpınarı Mh.	122	18	13	7	0	432	1	0	0	0	13
Erzurum	Aziye	Demirgedi Mh.	85	10	6	2	0	420	0	0	0	0	6
Erzurum	Aziye	Dutlörak Mh.	37	4	2	1	0	39	0	0	0	0	0
Erzurum	Aziye	Gez Köyü OSB	151	29	26	23	2	0	0	0	0	0	0
Erzurum	Aziye	Ilca Mh.	1788	201	206	119	5	10395	19	7	2	1	363

It also provides estimates (%) of the Lifelines and critical facilities structural damage rates and forecasts of direct economic losses. (Figure 1 and Table 4)

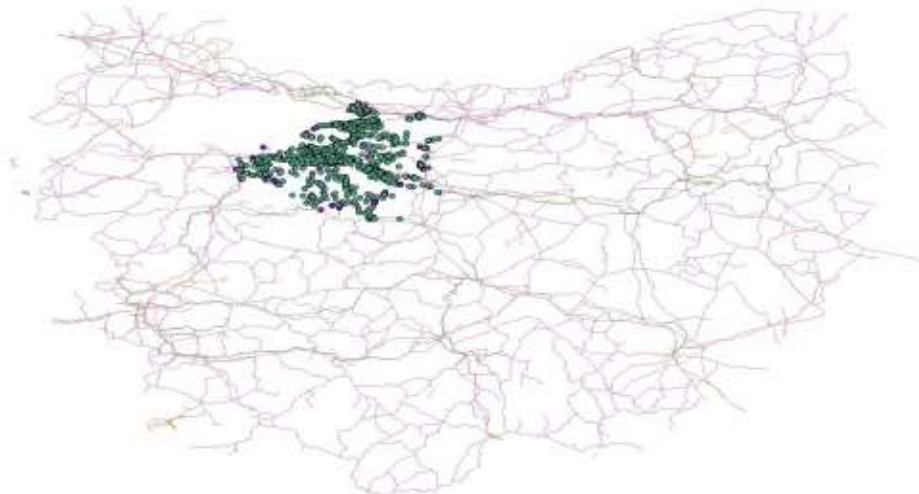


Figure 1 AFAD RED map output of critical facilities and lifelines

Table 4 Sample damage result of roads

INTENSITY	ROAD LENGHT (Km)	ROAD DAMAGE RATIO %	DAMAGE (Km)
7.76	32.82	% 1.24	0.407
7.74	83.4691	% 1.21	1.010

Another basic output of the system is maps. AFAD RED generates Intensity, PGA and PGV maps (Figure 2,3 and 4);

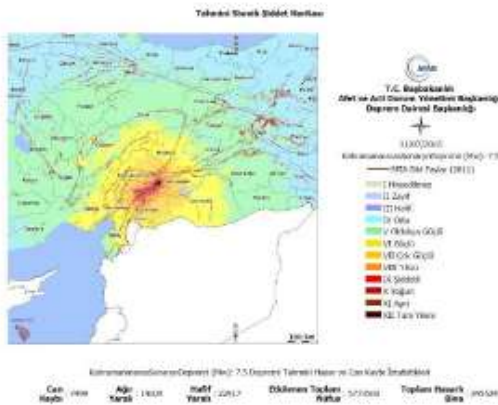


Figure 2 Sample Intensity Map

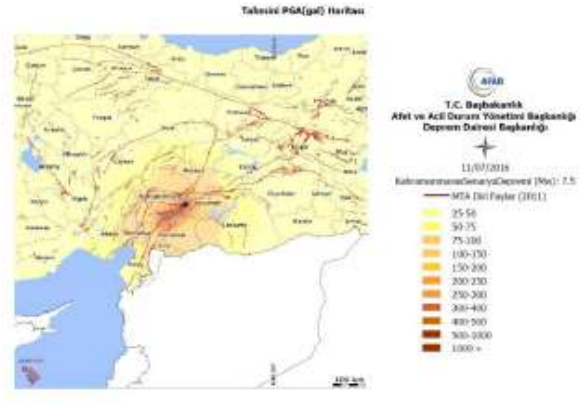


Figure 3 Sample PGA Map

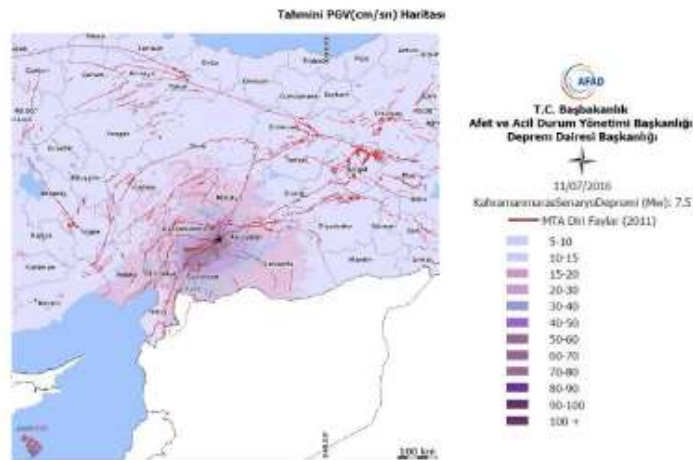


Figure 4 Sample PGV Map

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