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DELIVERABLE

PROJECT INFORMATION

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DELIVERABLE INFORMATION

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Abstract

We present the achievements and heritage of on-going and completed EU projects, which are relevant to the topics developed in the STREST project. Focus is made on projects from the Seventh Framework Programme (FP7) from energy, environment, infrastructure and security themes. First, we describe a strategic selection of projects and how knowledge can be transferred from those projects (GEISER, MATRIX, NERA, REAKT, SHARE, SYNER-G) to the STREST project. Second, we investigate the possible interactions with other projects from the FP7 2013 call (ASTARTE, INFRARISK, INTACT).

Keywords: Knowledge transfer, project interactions, FP7

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1 Introduction

The STREST project builds upon some of the ideas and methods developed in previous European projects, to which several of the STREST partners have participated or do participate. The present report is proposed to facilitate (i) knowledge transfer from one project to another one as well as (ii) interactions between parallel on-going projects. We present the achievements and heritage of on-going and completed EU projects, which are relevant to the topics developed in the STREST project. Focus is made on projects from the Seventh Framework Programme (FP7) from energy, environment, infrastructure and security themes.

First, we describe a strategic selection of projects and how knowledge can be transferred from those projects (GEISER, MATRIX, NERA, REAKT, SHARE, SYNER-G) to the STREST project. Second, we investigate the possible interactions with other projects from the FP7 2013 call (ASTARTE, INFRARISK, INTACT). The list of projects is given in Table 1.1, in alphabetical order. The information compiled in the present report is based on data from project websites, fact sheets, Descriptions of Work (DoW), newsletters, deliverables and peer-reviewed articles funded by the respective EU projects.

Table 1.1 List of selected FP7 projects.

Acronym	FP7 call	Start/End	Website	Keywords
ASTARTE	ENV2013 6.4-3	2013-2016	www.astarte-project.eu	Tsunami Coastal impacts Structural performance Social resilience
GEISER	ENERGY-2009-1	2010-2013	www.geiser-fp7.fr	Induced seismicity hazard Uncertainties
INFRARISK	SEC.2013.4.1-2	2013-	www.infrarisk-fp7.eu	Earthquake, flood, landslide, drought hazards LP-HC events Uncertainties Cascades Operational analysis
INTACT	SEC.2013.2.1-2	N/A	N/A	Extreme weather Critical infrastructures Resilience
MATRIX	ENV.2010.1.3.4-1	2010-2013	matrix.gpi.kit.edu	Multi-hazard Multi-risk LP-HC events Cascades Time-variant vulnerability
NERA	INFRA	2010-2014	www.nera-eu.org	Earthquake risk Earthquake risk mitigation
REAKT	ENV.2011.1.3.1-1	2011-2014	www.reaktproject.eu	Real-time earthquake risk mitigation
SHARE	ENV.2008.1.3.1.1	2009-2012	www.share-eu.org	Seismic hazard
SYNER-G	ENV.2009.1.3.2.2	2009-2012	www.vce.at/SYNER-G/	Earthquakes Systemic vulnerability Socio-economic vulnerability

2 Completed EU projects

2.1 GEISER: GEOTHERMAL ENGINEERING INTEGRATING MITIGATION OF INDUCED SEISMICITY IN RESERVOIRS

2.1.1 Description

The Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs (GEISER) project addressed several of the major challenges the development of geothermal energy is facing, including the mitigation of induced seismicity to an acceptable level (GEISER Newsletter, May 2010). The goals of GEISER were:

- To understand why seismicity is induced in some cases but not in others;
- To assess the probability of seismic hazards depending on geological setting and geographical location;
- To propose licensing and monitoring guidelines for local authorities, including a definition of acceptable ground motion levels;
- To investigate strategies for 'soft stimulation' that sufficiently improve the geothermal reservoir's hydraulic properties without producing earthquakes that could be felt or cause damage.

The GEISER consortium was composed of 13 partners, including TNO, ETH Zurich, AMRA and INGV - also present in STREST.

2.1.2 Knowledge transfer

GEISER relates to STREST on the following topics: induced seismicity, hazard assessment and epistemic uncertainties. Of particular interest to STREST is the Work Package (WP) 5 of GEISER on seismic hazard assessment, led by ETH Zurich. Unfortunately the Groningen gas extraction site of Netherlands, first considered as an optional site in the GEISER WP2 (Sites), has not been investigated in the project (pers. comm., D. Kraaijpoel, December 2013). Therefore there is no result available for the STREST CI-B2 site (Gasunie national gas storage and distribution network). The results of the following GEISER tasks are considered:

- *Task 5.2: Assessment of seismic hazard associated to EGS induced seismicity;*
- *Task 5.3: Assessment of seismic hazard associated to EGS triggered seismicity;*
- *Task 5.4: Shaking and damage scenarios from EGS induced and triggered events;*
- *Task 5.5: Guidelines for best practice in seismic hazard assessment for site selection and licensing.*

It should first be noted that the hazard assessment methods developed for Enhanced Geothermal Systems (EGS) should apply reasonably well to other technologies, such as gas extraction (STREST CI-B2). Mignan et al. (in revision, a) present the results of these tasks,

with application to the Basel 2006 EGS project. The authors describe a probabilistic risk analysis for the Basel EGS, combining induced seismicity time-dependent hazard (Mena et al., 2013) with the RISK-UE macroseismic method. The main purpose of the study was to capture epistemic uncertainties and their role in risk mitigation, using a logic tree approach. Figure 2.1 shows the proposed logic tree. Here only the hazard levels of the logic tree are shown, since only hazard was strictly considered in the GEISER project. The sensitivity to three parameters was tested: the rate forecast (time-dependent forecast models of Shapiro type and modified ETAS type, Mena et al., 2013), the maximum magnitude M_{max} and the hazard intensity (different intensity prediction equations (IPEs) and ground motion prediction equations (GMPEs)). These last two parameters are of particular interest to STREST. M_{max} is a crucial parameter in stress tests of nuclear power plants (NPPs) and therefore in stress tests of non-nuclear critical infrastructures. What is the value of M_{max} for induced seismicity in the Groningen gas field? is one question STREST needs to address in the case of the CI-B2 site. It is however debated in the case of induced seismicity with one view being that M_{max} is related to the size of the induced seismicity cloud (e.g., $M_{max} \sim 3.5$ for Basel) and the other view being that M_{max} matches the tectonic M_{max} (e.g., $M_{max} \sim 7.0$ for Basel). The latter view allows events at very small probabilities (i.e., tail of the Gutenberg-Richter law) that are much larger than the volume influenced by high fluid pressures, thus capturing also the possibility that earthquakes are triggered prematurely on larger and potentially unknown faults pre-loaded by tectonic stresses. Regarding GMPEs, Mignan et al. (in revision, a) tested the 36 models developed specifically for induced seismicity in the scope of GEISER by Douglas et al. (2013) (Fig. 2.1 inset). For Switzerland, Mignan et al. (in revision, a) refined the choice of GMPEs to only 8 models based on regional constraints. Models not considered are shown in grey in Figure 2.1.

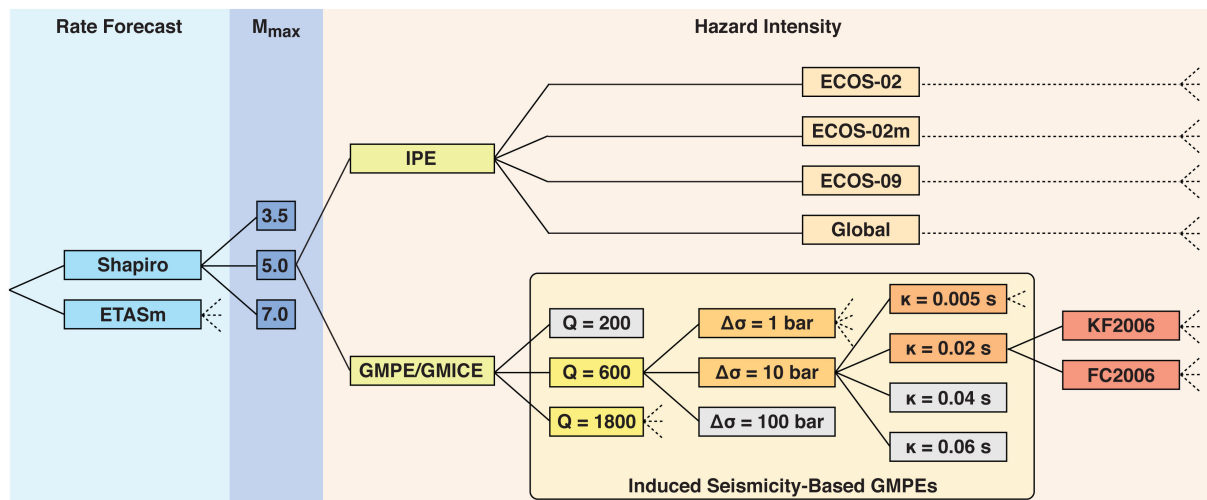


Fig. 2.1 GEISER hazard logic tree, following Mignan et al. (in rev., a)

We envision that the GEISER results can be used as baseline for the following STREST WP3 tasks:

- *Task 3.1: Measuring the effects of epistemic uncertainties on the definition of low probability-high consequences (LP-HC) events* - The logic tree structure proposed by Mignan et al. (in revision, a) (Fig. 2.1) can be used for the exploration of epistemic uncertainties in the case of induced seismicity hazard (for CI-B2 site) but could also

be generalized to any seismic hazard (other sites). Specifically, similar sensitivity tests on M_{max} and on the Douglas et al. (2013) GMPEs should be realized for induced seismicity in the Groningen gas field. Bayesian inference and expert elicitation may be used to weight the different proposed values of M_{max} (equal weights were given in Mignan et al. (in revision, a) for simplicity reasons).

- *Task 3.4: Integrating regional and site-specific hazard assessments* - Selection of specific GMPEs based on regional constraints, as done by Mignan et al. (in revision, a), is one example of possible uncertainty reduction. While the selection was based on tectonic constraints in Switzerland as described in the literature, one could use a similar approach with the aim of selecting the best GMPE parameters for Netherlands (CI-B2 site).
- *Task 3.6: Integrating hazard assessment for natural and induced seismicity* - The framework developed by Mignan et al. (in revision, a) is available from the lead author in a R program and could be translated in the Python programming language used in the OpenQuake software. The R program includes the definition of the logic tree structure and the computation of hazard (and risk) based on alternate input parameters and input models (e.g., Douglas et al. (2013) GMPEs and possible conversions to hazard intensities). Depending on the OpenQuake data model characteristics, various parameters from Douglas et al. (2013) can be used (peak ground acceleration PGA, peak ground velocity PGV or spectral acceleration at various periods).

2.2 MATRIX: NEW MULTI-HAZARD AND MULTI-RISK ASSESSMENT METHODS FOR EUROPE

2.2.1 Description

The New Multi-Hazard and Multi-Risk Assessment Methods for Europe (MATRIX) project investigated multiple natural hazards and risks in a common theoretical framework. It integrated new methods for multi-type assessment, accounting for risk comparability, cascading hazards, and time-variant vulnerability. Three natural sites were tested (Cologne in Germany, Naples in Italy and the French West Indies) as well as a synthetic site (concept of Virtual City). The main goals of MATRIX (MATRIX Fact sheet) were:

- Determine and demonstrate under what conditions multi-type risk assessment provides (or not) better results compared with considering only single-type hazards;
- Provide tools for analysing multi-type risk problems within a European context;
- Establish a European knowledge base on multi-type risk in Europe;
- Disseminate multi-type risk concepts to potential end-users and other relevant members of the broader community;
- Provide support for the decision-making necessary by civil protection and disaster management authorities on the basis of probabilistic information.

The MATRIX consortium was composed of 12 partners, including AMRA and ETH Zurich - also present in STREST.

2.2.2 Knowledge transfer

MATRIX relates to STREST on the following topics: Multi-hazard and multi-risk assessment methods, LP-HC events due to cascade phenomena and time-variant vulnerability. Of particular interest to STREST are MATRIX WP4 (time-dependent vulnerability led by BRGM) and WP7 ("Virtual City" and test cases, led by ETH Zurich). It should be noted that AMRA also participated actively to WP4. Although MATRIX WP3 (Cascade effects in a multi-hazard approach, led by AMRA) and WP5 (Framework for multi-type risk assessment, led by NGI) are also of interest, a comprehensive multi-hazard and multi-risk framework was developed in the scope of WP7, providing a better baseline framework for STREST. As a consequence, the following MATRIX tasks are considered:

- *Task 4.1: Physical vulnerability to multiple hazards;*
- *Task 7.1: Common IT framework for test case analysis;*
- *Task 7.2: Implementation and analysis of the "virtual city".*

One important result of task 4.1 is a model of damage accumulation for simple structural systems. It consists in state-dependent modelling of vulnerability when seismic structural performance is affected by damage accumulation (Iervolino et al., 2013a; b). The state-dependent model of reliability is based on Markov chains. Figure 2.2 illustrates the accumulation of damage with respect to kinematic ductility for elastic-perfectly-plastic systems.

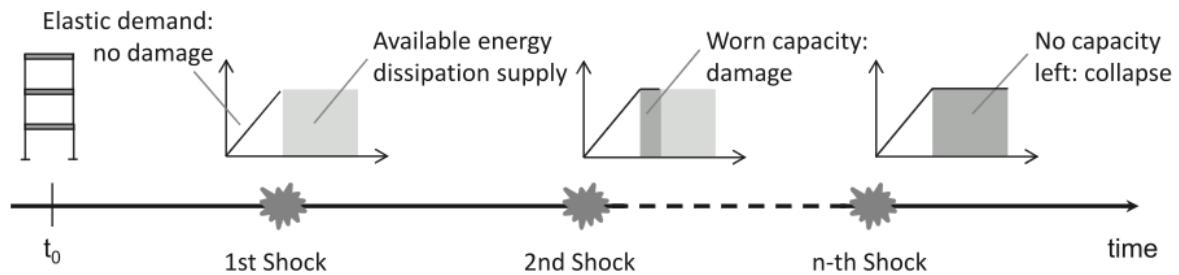


Fig. 2.2 Damage accumulation model, from Iervolino et al. (2013a)

The main result of tasks 7.1 and 7.2 combined is a generic multi-hazard and multi-risk framework based on the sequential Monte Carlo method to allow for a straightforward and flexible implementation of coinciding and cascading events (Mignan, 2013; Mignan et al., in revision, b). Validation of the framework was based on the testing of generic data and interaction processes (Mignan et al., in revision, b). For a presentation of the framework to stakeholders, another set of data and interaction processes was used, based on the concept of virtual city (Mignan, 2013; Komendantova et al., 2014). Figure 2.3 describes the multi-hazard part of the proposed framework. Figure 2.3a represents simulated time series (grey rectangles) in which hazardous events (stars) occur. The simulation set S_0 represents the null-hypothesis of having no interaction in the system while S_1 represents any hypothesis considering multi-hazard. Multi-hazard is implemented using a "hazard correlation matrix", as shown in Figure 2.3b. It is a variant of a Markov chain with the probability of occurrence of any event potentially conditional of the occurrence of previous events.

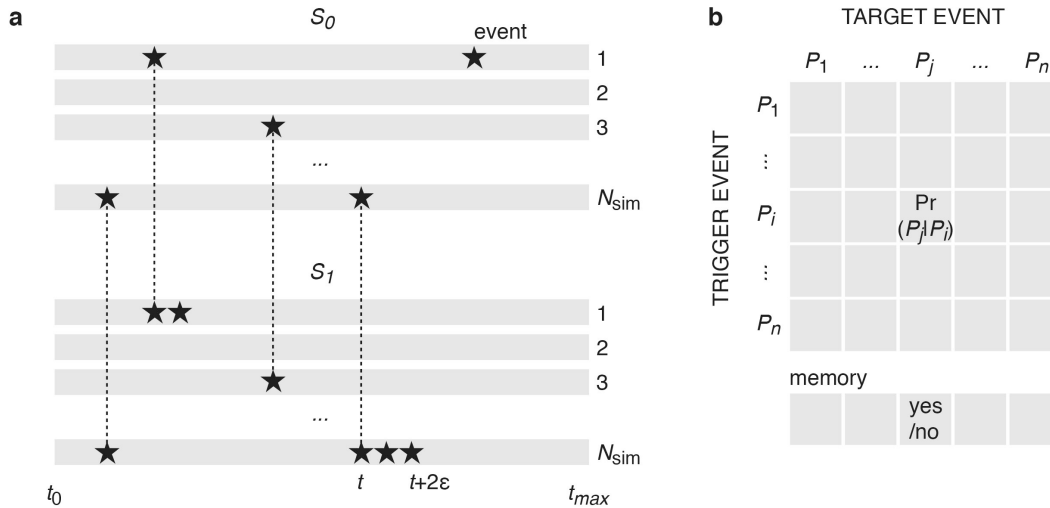


Fig. 2.3 Generic multi-hazard framework, from Mignan et al. (in rev., b)

We envision that the MATRIX results will apply to the following STREST tasks:

- *Task 3.5: Multi-hazard assessment and cascading effects* - The R program providing the generic multi-hazard framework of MATRIX, as described by Mignan et al. (in revision, b) and in the appendix of Komendantova et al. (2014), will be used as basis of this task, as explicitly stated in the STREST DoW. The concept of Virtual City could also be used in a first phase to investigate interaction processes in selected test sites by using simplified input data.
- *Task 4.3: Post-event short-term performance and resilience of CIs* – The model of damage accumulation developed by Iervolino et al. (2013a; b) and based on Markov chains will be further developed. It could also be used in Task 4.1 (*Performance and loss assessment of non-nuclear CI classes*). The model could also be tested using, as input, the event clustering results of Task 3.5.
- *Task 5.1: Defining an engineering risk assessment methodology for stress tests of non-nuclear CIs* - It remains unclear if the full multi-risk framework of Mignan et al. (in revision, b) will be used as basis for the design of stress tests. It was indicated during a STREST technical workshop (Feb. 2014, Utrecht, Netherlands) that it is indeed a viable option.

2.3 SHARE: SEISMIC HAZARD HARMONIZATION IN EUROPE

2.3.1 Description

The Seismic Hazard Harmonization in Europe (SHARE) project delivered the first ever complete state-of-the-art hazard model for the European region, replacing the ESC-SESAME 2003 map. SHARE contributes its results as a regional program to the Global Earthquake Model (GEM). The SHARE map describes potential shaking associated with future earthquakes in Europe and serves as input for risk assessment and mitigation policies (e.g., earthquake resistant designs). These results will serve as a benchmark for the revision of the European seismic building code (EuroCode8). SHARE is based on a time-

independent probabilistic approach and fully characterizes hazard with different ground motion parameters (0-10 seconds accelerations, ground velocity and displacement) for return periods ranging between 25 and 5,000 years. The GEM OpenQuake hazard engine was used to compute hazard for an average rock condition (shear wave velocity $V_{s30} = 800$ m/s) (Giardini et al., 2013; Pan European Networks – Government, 2013).

The SHARE consortium was composed of 18 partners, including ETH Zurich, INGV, UJF, AUTH and KOERI – also present in STREST.

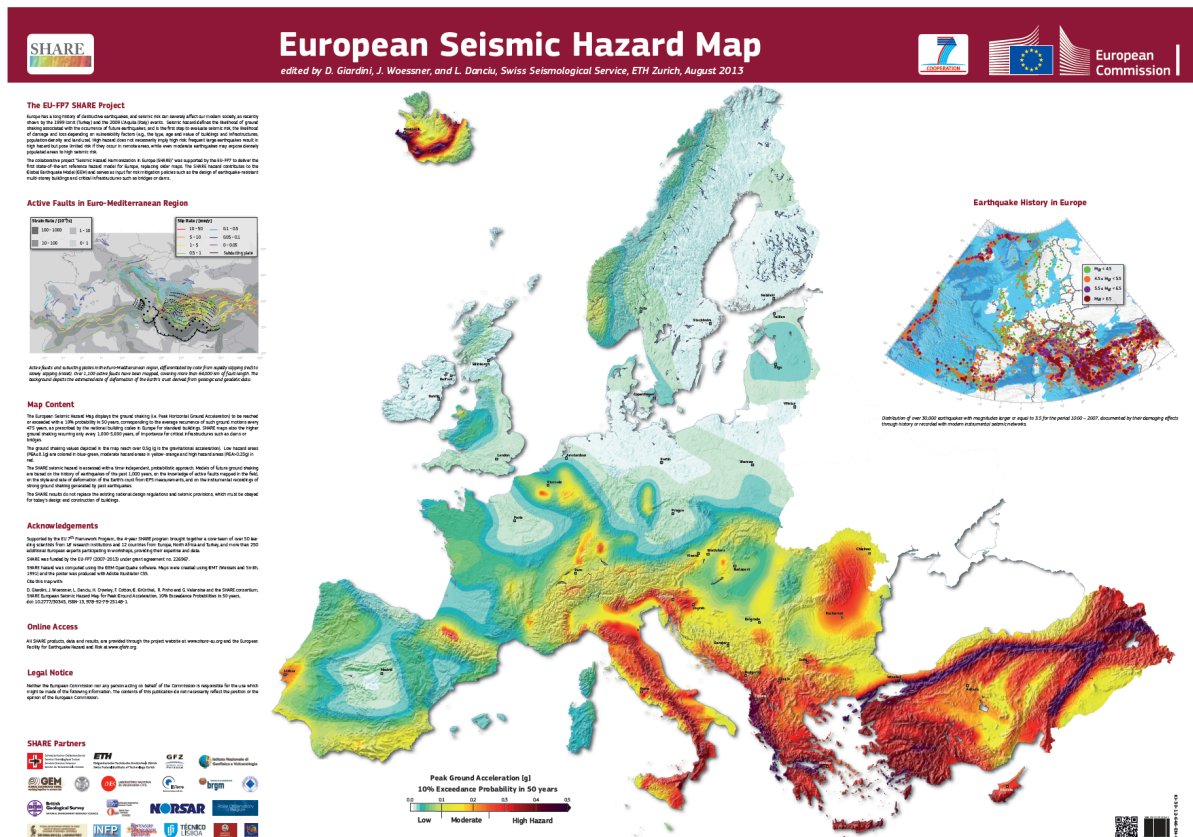


Fig. 2.4 SHARE European Seismic Hazard Map, from SHARE website

2.3.2 Knowledge transfer

The SHARE seismic hazard results will be used as background information (or to “fill in the gaps”) for the different STREST sites involving earthquakes. SHARE expertise is available from ETH Zurich (SHARE coordinator), UJF, EUCENTRE and BU-KOERI (also involved in the EMME project). In particular, the fault catalogue of Turkey will be made available from the EMME Active Faults project, which is the same regional data set as in SHARE. It can be used for the CI-B1 site (major hydrocarbon pipelines). EUCENTRE will provide the GEM computation capabilities with seismic hazard footprints defined from the OpenQuake software. This could be used for any task in the STREST WP3 on hazard assessment. Other fault catalogues for Italy and Greece, necessary in Task 3.5 (earthquake interactions), are available at ETH Zurich in the context of SHARE/GEM. The Share project has also been trying to capture epistemic uncertainties. The SHARE strategy has the particularity of combining two complementary and independent approaches: expert judgment

and data testing (e.g. Musson et al., 2012; Delavaud et al., 2012). The SHARE methodologies to take into account expert opinions and estimate the epistemic uncertainties will be used in STREST Task 3.1. SHARE has also initiated the discussion related to the cost-benefit analysis of site investigations, which will be addressed in STREST Task 3.4.

2.4 SYNER-G: SYSTEMIC SEISMIC VULNERABILITY AND RISK ANALYSIS FOR BUILDINGS, LIFELINE NETWORKS AND INFRASTRUCTURES SAFETY GAIN

2.4.1 Description

SYNER-G developed an innovative methodological framework for the assessment of physical as well as socio-economic seismic vulnerability at the urban/regional level. The built environment is modelled according to a detailed taxonomy into its component systems, grouped into the following categories: buildings, transportation and utility networks, and critical facilities. Each category may have several types of components. The framework encompasses in an integrated fashion all aspects in the chain, from regional hazard to fragility assessment of components to the socioeconomic impacts of an earthquake, accounting for all relevant uncertainties within an efficient quantitative simulation scheme, and modelling interactions between the multiple component systems in the taxonomy. The layout of SYNER-G methodology and software tools is illustrated in Fig. 2.5. The prototype software developed in SYNER-G provides several tools for pre- and post-processing to estimate seismic losses and to evaluate post-seismic needs and priorities. The SYNER-G methodology and tools have been tested to selected case studies at the urban level: the city of Thessaloniki in Greece and the city of Vienna in Austria, at the system level: the gas system of L'Aquila in Italy, the road network of Calabria region in Southern Italy and the electric power network of Sicily, as well as in complex infrastructures: a hospital facility in Italy and the harbour of Thessaloniki, accounting for inter- and intra-dependencies among infrastructural components and systems. The main goals of SYNER-G were to:

- Encompass all past and on-going knowledge and know-how on this topic at a European and International level;
- Develop a unified taxonomy, typology and inventory for all elements at risk and systems;
- Review and select the most advanced fragility functions and methods to assess the physical and societal-economic vulnerability of all assets, improving and further developing new ones where necessary, considering European distinctive features;
- Propose the most appropriate means for seismic hazard assessment at system level (including spatial correlation of ground motion, site effects and geotechnical hazards) adequate to SYNER-G;
- Develop a unified methodology to assess vulnerability at a system level considering interdependencies between elements at risk, belonging within systems and between different systems as a whole at different scales (local, city, regional, national...);
- Build an appropriate open-source software and tool to deal with systemic vulnerability, risk and loss assessment;

- Validate the effectiveness of the methodology and tools to selected case studies at city and regional scale;
- Build appropriate dissemination schemes for all products of the project at European and International level;

The SYNER-G consortium was composed on 14 partners, including AUTH (coordinator), AMRA, University of Pavia (EUCENTRE) and JRC – also present in STREST.

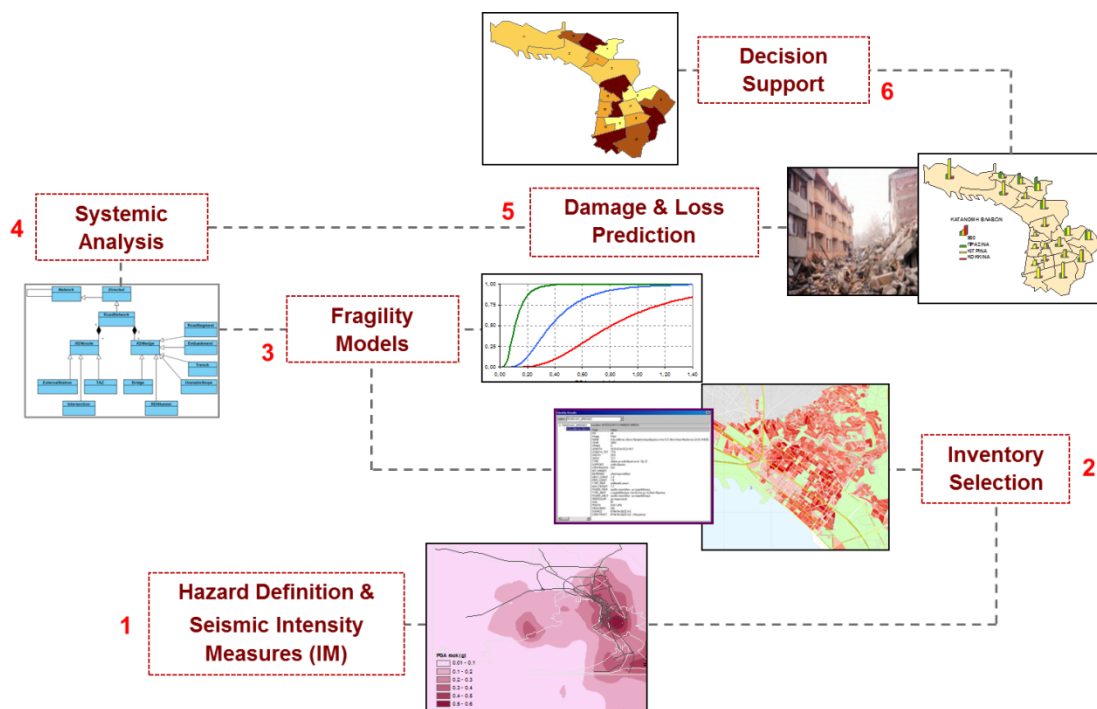


Fig. 2.5 Layout of SYNER-G methodology and software tools

2.4.2 Knowledge transfer

SYNER-G relates to STREST on the following topics: taxonomy/typology of buildings, utility and transportation networks and infrastructures; vulnerability assessment under seismic loading (fragility curves); systemic analysis of networks and infrastructures; hazard assessment and epistemic uncertainties. Of particular interest to STREST are the following WPs of SYNER-G: WP2 on general methodology of systemic vulnerability analysis including taxonomy of networks and infrastructures, and on seismic hazard assessment; WP3 on fragility curves for all elements at seismic risk, WP5 on specifications of systemic analysis for each particular network/infrastructure; WP6 on applications, including gas and pipeline networks, harbour of Thessaloniki and others.

In particular, the results of the following SYNER-G tasks are mainly considered:

- *Task 2.1: Development of the general methodology of the systemic vulnerability accounting for all elements at risk, considering interdependences;*
- *Task 2.3: Typology definitions of European elements at risk (including data collection, archiving and processing);*
- *Task 2.4: Seismic scenarios;*

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- *Task 3.1 Fragility of buildings; Task 3.2 Fragility of elements/components within utility networks; Task 3.3 Fragility of elements within transportation infrastructures; Task 3.4 Fragility of elements within critical facilities;*
 - *Task 4.1 Definition of socio-economic fragility and coping capacity indicators for each socio-economic sector: shelter, emergency health, transportation and energy distribution; Task 4.3 Definition of socio-economic impact models for each sector.*
 - *Task 5.1 General identification of each system specificities; Task 5.2 Systemic vulnerability assessment and loss of buildings and aggregate (city scale); Task 5.3 Systemic vulnerability assessment of utility networks; Task 5.4 Systemic vulnerability assessment of transportation infrastructures; Task 5.5 Systemic vulnerability assessment and loss of critical facilities;*
 - *Task 6.1 Application and validation study in the city of Thessaloniki (Greece); Task 6.5 Application and validation study to a gas pipeline network; Task 6.6 Application and validation study to a harbour system (Thessaloniki, Greece).*

In particular, the SYNER-G results will apply to the following STREST tasks (tentative):

- *Task 3.2: Definition of hazard measures and extreme event scenarios for distributed CIs* – The “shakefield” procedure which allows for the generation of samples of ground motion fields for both single scenario events, and for stochastically generated sets of events needed for probabilistic seismic risk analysis will be employed. For a spatially distributed infrastructure of vulnerable elements, the spatial correlation of the ground motion fields for different measures of the ground motion intensity is incorporated into the simulation procedure. This is extended further to consider spatial cross-correlation between different measures of ground motion intensity as well as secondary geotechnical effects from earthquake shaking (Weatherill et al. 2014);
- *Task 4.1: Performance and loss assessment of non-nuclear CI classes and Task 4.2: Loss propagation and cascading effects in interconnected CIs* – The performance indicators proposed in SYNER-G as well as the specifications for systemic analysis of each network will provide a basis for these tasks (Modaressi et al. 2014);
- *Task 4.3: Post-event short-term performance and resilience of CIs* – The framework for socioeconomic loss assessment will provide input to the STREST resilience modeling framework (Khazai et al. 2014);
- *Task 4.4: Defining a taxonomy of CIs* – The SYNER-G taxonomy will be used as a basis for the taxonomy of the STREST CI case studies (Hancilar and Taucer, 2013);
- *Task 5.1: Defining an engineering risk assessment methodology for stress tests of non-nuclear CIs* – The extensive literature review performed within SYNER-G as well as the developed methodology and software/simulation tools on systemic analysis will provide a valuable platform for the STREST methodology (Franchin 2013, 2014);
- *Critical Infrastructure B1: Major hydrocarbon pipelines, Turkey* – The experience from SYNER-G case study for gas network will be transferred in this STREST application (Esposito and Iervolino 2014);
- *Critical Infrastructure B3: Port infrastructures of Thessaloniki, Greece* – The same infrastructure has been used as case study in SYNER-G. The available technical

details and the experience from SYNER-G will be transferred into the STREST application (Kakderi et al. 2014).

3 On-going projects (previous FP7 calls)

3.1 NERA: NETWORK OF EUROPEAN RESEARCH INFRASTRUCTURES FOR EARTHQUAKE RISK ASSESSMENT AND MITIGATION

3.1.1 Description

The Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA) project aims at integrating significant seismic and engineering infrastructures to establish an effective network of European research infrastructures for earthquake risk assessment and mitigation. The main objectives of NERA are (from the NERA website):

- To integrate the key research infrastructures in Europe to monitor, assess and prevent earthquake hazards;
- To cover analytical vulnerability assessment tools and mobile facilities for site characterization of constructions;
- To develop instruments, hazard and risk assessment, data processing and data dissemination;
- To support the reduction of vulnerability of European citizens and constructions to earthquakes;
- To foster international collaboration activities and further integration of the research field.

The NERA consortium consists of 28 participants, including ETH Zurich, INGV, EUCENTRE, UJF, KOERI, AMRA and AUTH – also present in STREST.

3.1.2 Knowledge transfer

From the scientific part of the first reporting period of the NERA project (NERA, 2012), the main results potentially of interest to STREST are (1) the establishment of an open data collection for the Euro-Mediterranean region: e.g., WP2 on seismic waveforms; WP3 on accelerometric data; WP5 on near-fault observatories' data; WP6 on ambient vibration data; WP7 on building stocks; and (2) models related to instrumental seismology: e.g., WP11 on site coefficients for basin response and topography; WP13 on coherence of near-fault ground motion spatial distribution.

Since correspondence between the NERA test sites (building or building element level) and the STREST ones is not obvious from the available documentation, it is difficult to identify which particular data are relevant to the STREST project. STREST participants with specific technical requirements for data should directly check for data availability from the NERA project. The different models developed in NERA could find applications in the following STREST tasks:

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- *Task 3.2: Definition of hazard measures and extreme event scenarios for distributed CIs* – NERA WP13 will provide new statistical models of earthquake and ground-motion properties (e.g. Song et al., 2013) that may help to assess the spatial variability and correlation of hazard intensities.
 - *Task 3.3: Near-source hazard variability* – NERA WP13 (JRA3) focuses in the very near field, where observed ground motions are sparse. The resulted synthetic GMPE will account source terms that include stress drop, rupture speed, directivity, hanging wall, footwall, buried rupture and surface-rupturing. NERA WP13 also provides results that help evaluating the variability of earthquakes properties and build earthquake scenarios (e.g. Causse et al., 2013).
 - *Task 3.4: Integrating regional and site-specific hazard assessments* – Possible use of models on site effects developed in NERA WP11 (e.g. Sandikayya et al., 2013).

3.2 REAKT: STRATEGIES AND TOOLS FOR REAL TIME EARTHQUAKE RISK REDUCTION

3.2.1 Description

The Strategies and Tools for Real Time Earthquake Risk Reduction (REAKT) project aims at improving the efficiency of real-time earthquake risk mitigation methods and their capability of protecting structures, infrastructures and populations. In that purpose, methodologies are being developed to enhance the quality of information provided by earthquake forecasting, early warning and real-time vulnerability systems. Best practices will also be established for a unified use of information. The main objectives, as indicated on the REAKT website, are:

- A better understanding of physical processes underlying seismicity changes on a time scale from minutes to months;
- The development, calibration and testing of models of probabilistic earthquake forecasting and the investigation of its potential for operational earthquake forecasting (OEF);
- The development of time-dependent fragility functions for buildings, selected infrastructures, and utility systems;
- The development of real time loss estimation models over the lifetime of structures and systems due to foreshocks, main shocks and their subsequent aftershock sequences;
- The construction of a detailed methodology for optimal decision making associated with an earthquake early warning system, with OEF and with real time vulnerability and loss assessment in order to facilitate the selection of risk reduction measures by end users;
- The study of the content and way of delivering public communication, recognizing the value of a degree of self organization in community decision making;

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- The application of real time risk reduction systems to different situations (trains, industries, hospitals, bridges, schools, etc.).

The REAKT consortium is composed on 23 partners, including AMRA, ETH Zurich, INGV, AUTH, EUCENTRE and KOERI – also present in STREST.

3.2.2 Knowledge transfer

Although short-term earthquake forecasting does not relate directly to the work to be done in STREST, the section on time-variant fragility functions is of high interest. It corresponds to the REAKT WP5 *Real time-dependent risk assessment*. The task to be considered is:

- *Task 5.4: Time-dependent loss estimation.*

In this scope, a closed-form age dependent modelling of vulnerability for reliability assessment of structures subject to both ageing and cumulative earthquake damage was undertaken. Moreover, starting from the MATRIX results, a closed-form (again, age-dependent) model for reliability assessment of elastic-perfectly-plastic structures during aftershock sequences was also developed (Iervolino et al., 2013a; b).

Results from REAKT could be used and methods extended in the following STREST tasks:

- *Tasks 4.1/4.3: Performance and loss assessment of non-nuclear CI classes / Post-event short-term performance and resilience of CIs* - In these tasks, the models developed in REAKT will be generalized to obtain a time-variant framework, which can accommodate both age- and state-dependent vulnerability. This is something presently missing from the earthquake engineering literature.

4 On-going projects (2013 FP7 calls)

The European Commission will organize an inter-project meeting in Brussels in 2014. Possible interactions between STREST and SEC projects will be explicitly addressed there. For the present report, relevant on-going FP7 projects from the ENV and SEC calls are described and possible interactions envisioned based on early discussions with participants from the other projects and on the information contained in the DoWs, fact sheets and other introductory documents. The proposed interactions remain in a draft form (not binding) and are based on the STREST consortium recommendations if not stated otherwise.

4.1 ASTARTE: ASSESSMENT, STRATEGY AND RISK REDUCTION FOR TSUNAMIS IN EUROPE

4.1.1 Description

The goals of the Assessment, Strategy and Risk Reduction for Tsunamis in Europe (ASTARTE) project are to reach a higher level of tsunami resilience, to improve preparedness of coastal populations and to help saving lives and assets. The main objectives are (ASTARTE Fact sheet, 2013):

- Assessing long-term recurrence of tsunamis;
- Improving the identification of tsunami generation mechanisms;
- Developing new computational tools for hazard assessment;
- Ameliorate the understanding of tsunami interactions with coastal structures;
- Enhance tsunami detection capabilities, forecast and early warning skills in the North-East Atlantic region, which includes the Mediterranean Sea;
- Establishing new approaches to quantify vulnerability and risk and to identify the key components of tsunami resilience and their implementation in Europe.

4.1.2 Possible interactions

Interactions between the ASTARTE and STREST projects are expected, as indicated in their respective DoWs, with INGV being the contact point. The collaboration should be in both hazard and vulnerability assessments. The following recommendations have been given by INGV (pers. comm., J. Selva, November 2013), based on discussions that took place during the 2013 ASTARTE kick-off meeting:

- In regards of the tsunami hazard, INGV is responsible for the development of innovation in probabilistic tsunami hazard assessments (PTHA), the assessment of epistemic uncertainties in hazard and risk assessment, and the development of PTHA in the ASTARTE test site of Siracusa, Eastern Sicily. Several studies will be done about possible resonance effects of tsunami waves in harbours. Collaborations

are expected between INGV and the Middle East Technical University (METU, A. Yalciner) on the Thessaloniki test site, which is also considered in STREST (CI-B3).

- In regards of the tsunami vulnerability, there is no immediate plan for the development of new fragility curves in ASTARTE. An update on this matter is expected after Year 1 of the project. In the related WP5, several experiments will be developed in view of the response of coastal defence systems, with focus on the erosion of the basements and stability of sea walls. A review will however be made on the SoA on fragilities (referred to as “*quantitative vulnerability assessments*”, National Observatory of Athens, NOA, G. Papadopoulos). A repository of past works on tsunami fragility and future collaborations are envisioned between INGV and other partners. In particular, the RAPSODI (Risk Assessment and Design of Prevention Structures for Enhanced Tsunami Disaster Resilience, Norwegian Geotechnical Institute, NGI, F. Lovholt) project runs in parallel to STREST and has similar goals (including risk for CIs). The Instituto Portugues do Mar e da Atmosfera (IPMA, R. Omira) will develop new fragility curves for their respective ASTARTE test site. METU has interest in collaborating on the subject for the Thessaloniki test site.

4.2 INFRARISK: NOVEL INDICATORS FOR IDENTIFYING CRITICAL INFRASTRUCTURE AT RISK FROM NATURAL HAZARDS

4.2.1 Description

The main goal of the Novel Indicators for Identifying CI at risk from natural hazards (INFRARISK) project is similar to the one of STREST since both projects answer the same FP7 call. Some of the main objectives may slightly differ, and are (INFRARISK fact sheet, 2014):

- Identifying LP-HC events, which have a potential impact on CIs;
- Developing a stress test structure for specific natural hazards on CI networks and a framework for linear infrastructure systems with wider extents and many nodal points (roads, highways and railroads);
- An integrated approach to hazard assessment considering interdependencies and cascading effects;
- Facilitating implementation through the development of GIS-based and web-based stress test algorithms for complex infrastructure networks;
- Testing the framework developed through simulation of complex case studies;
- Exploitation strategies at disseminating the added knowledge (e.g., training courses to industry).

4.2.2 Possible interactions

While ETH Zurich is represented in both projects, the participants are from different institutes. Contacts are directly established between the coordinators of both projects (Roughan & O’Donovan Limited, Dublin in the case of INFRARISK). Based on the

information available from INFRARISK, it seems that both projects are complementary, with different expected outcomes: developing a GIS-based stress test tool for INFRARISK versus enabling the implementation of European policies for the implementation of stress tests for STREST; transportation network sites in INFRARISK versus various CI site topologies in STREST. The inter-project meeting to be organized by the European Commission in the second quarter of 2014 should clarify which types of interactions can be envisioned.

4.3 INTACT: IMPACT OF EXTREME WEATHER ON CRITICAL INFRASTRUCTURES

4.3.1 Description

The INTACT project investigates the impact/resilience of extreme weather events (EWE) on critical infrastructures. Growing scientific evidence suggests that more frequent and severe EWEs such as heat waves, hurricanes, flooding and droughts have an increasing impact, with the range and effects on society exacerbated when CIs are disrupted or destroyed. INTACT offers a cross-disciplinary, multi-jurisdictional systematic approach and expertise across the full range of technical disciplines, geographical regions, climatic conditions and infrastructure types (INTACT introductory presentation, 2013, courtesy of INTACT consortium). The objectives of INTACT are:

- To assess regionally differentiated risk throughout Europe associated with EWEs;
- To identify and classify on a Europe-wide basis CIs and to assess the resilience of such CIs to the impact of EWEs;
- To raise awareness of decision-makers and CI operators about the challenges (current and future) EW conditions may pose to their CI;
- To identify potential measures and technologies to consider and implement, be it for planning, designing and protecting CIs or for effectively preparing for crisis response and recovery.

4.3.2 Possible interactions

TNO is the contact point between the INTACT and STREST projects. WPs of interest to STREST are:

- *WP3: Vulnerability and Resilience of European CIs* – In particular, the categorization of CIs in INTACT and STREST (*Task 4.4: Defining a taxonomy of CIs*) should be harmonized or at least not incompatible with each other;
- *WP4: Risk and Risk Analysis* – Both projects may learn from each other on the various risk analysis methods employed;
- *WP7: Stakeholder Engagement and Dissemination* – Joint stakeholder workshops may be envisioned, in collaboration with the STREST WP7.

Due to the many parallels between STREST and INTACT, we foresee close interactions between the two projects. This should be discussed at depth during the inter-project meeting to be organized by EC in the second quarter of 2014. No more detail can be given since the INTACT project has not started at the time of the writing of this report.

5 Conclusions

We reviewed the main results of past and on-going EU projects of the Seventh Framework Programme (FP7), in particular in terms of methods in hazard and risk assessment, which are relevant to the STREST project. Projects considered are: GEISER (induced seismicity hazard), MATRIX (multi-risk), SHARE (probabilistic seismic hazard), SYNER-G (systemic seismic vulnerability), NERA (seismic risk assessment and mitigation) and REAKT (time-dependent earthquake risk assessment and mitigation). We showed that numerous methods could be directly transferred to a number of tasks in WPs 3 and 4, which will provide the backbone for additional improvements. This is summarized in Table 5.1. This transfer is facilitated by the participations of various STREST partners to these other EU projects. It should be noted that focus was made on projects related to seismic hazard and risk, which is also a priority in STREST.

We described projects from the 2013 FP7 calls, which run in parallel to STREST. Those are ASTARTE (tsunami risk), INFRARISK (same call as STREST) and INTACT (impact of extreme weather on critical infrastructures). Based on preliminary discussions with participants to these projects and on the available documentation so far, a number of interactions can be envisioned, which will be clarified during an upcoming inter-project meeting to be organized by the European Commission in Brussels at a time after the publication of the present report.

Table 5.1 Knowledge transfer to the STREST project.

STREST task	Possible knowledge transfer from other EU projects
3.	SHARE (OpenQuake hazard data)
3.1	GEISER (Mignan et al., in rev., a), SHARE (Musson et al., 2012; Delavaud et al., 2012)
3.2	SYNER-G (Weatherill et al., 2014), NERA (Song et al., 2013)
3.3	NERA (Causse et al., 2013)
3.4	GEISER (Douglas et al., 2013; Mignan et al., in rev., a)
3.5	MATRIX (Mignan et al., in rev., b; Komendantova et al., 2014)
3.6	GEISER (Douglas et al., 2013; Mignan et al., in rev., a)
4.1	MATRIX / REAKT (Iervolino et al., 2013a; b); SYNER-G (Modaressi et al., 2014)
4.3	MATRIX / REAKT (Iervolino et al., 2013a; b); SYNER-G (Khazai et al., 2014)
4.4	SYNER-G (Hancilar and Taucer, 2014)
5.1	SYNER-G (Franchin, 2013; 2014); MATRIX (Mignan et al., in rev., b)
CI-B1	SYNER-G (Esposito and Iervolino, 2014)
CI-B2	GEISER (Douglas et al., 2013; Mignan et al., in rev., a)
CI-B3	SYNER-G (Kakderi et al., 2014)

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