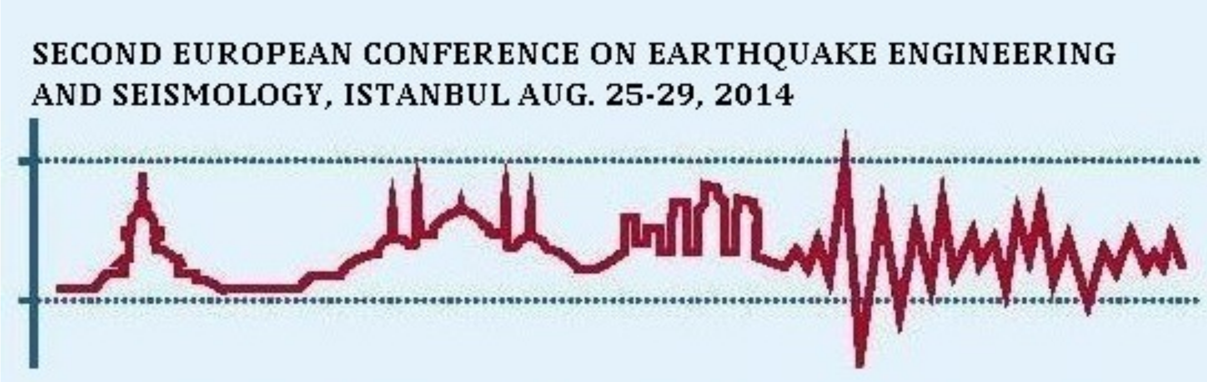

TOWARDS REAL-TIME SEISMIC RISK MITIGATION FOR CRITICAL FACILITIES: LESSONS LEARNED FROM CASE STUDIES IN REAKT

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Work package 7 (WP7, Strategic Applications and Capacity Building) of the EC-funded project REAKT (Strategies and Tools for Real Time EArthquake RisK ReducTion, FP7, www.reaktproject.eu, contract no. 282862) is devoted to the development of feasibility studies and, in some cases, implementation efforts of real-time earthquake risk mitigation methods to strategic test sites. Methods include operational earthquake forecasting (OEF, investigated in WP3), earthquake early warning (EEW, dealt with in WP4), and real-time structural health monitoring (SHM, the subject of WP5). Implementation takes advantage of optimised decision-making strategies developed in WP6. WP7 represents therefore a key element of the whole research project, as the strategic applications provide the opportunity to implement and test scientific and technical products achieved by the different research units, and to develop a better understanding of what the end-users expect by applying EEW, SHM and OEF to reduce earthquake related risk at the selected test sites. This is achieved through close cooperation between academic researcher and end-users since the beginning of the project and constitutes one of the most innovative aspects of REAKT. Several strategic applications have been selected, as listed in Table 1 (see also Cua et al., 2012). The application / end-user group includes civil protection authorities, railways, hospitals, schools, industrial complexes, nuclear plants, lifeline systems, national seismic networks, and critical structures. The scale of target applications encompasses a wide range, from two high-school complexes in Naples, to individual critical structures, such as the bridge connecting Rion and Antirion nearby Patras, and the Fatih Sultan

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Mehmet bridge in Istanbul, to large complexes, such as the Sines industrial area in Portugal and the Thessaloniki harbour area, to distributed lifeline and transportation networks and nuclear plants. WP7 is organised in twelve research units, called *Tasks*, as briefly described in the following.

Task 7.2 deals with a feasibility study on the use of EEW and OEF information at nuclear power plants. The study includes a comprehensive performance evaluation of the latest EEW VS codes (Behr et al., 2013) in use in Switzerland and California. The alerts are displayed at swissnuclear using an *ad-hoc* customisation of the CISN ShakeAlert UserDisplay.

Task 7.3 concerns the use of EEW information at the Sines industrial complex. Relevant products to be produced by this research unit are: a) a GIS-based seismic risk simulator for Sines; b) a model for seismic risk analysis accounting for the possible presence of an EEW system; c) a cost-benefit analysis on the use of EEW methodologies at Sines.

Task 7.4a is devoted to a feasibility study regarding the use of EEW for risk reduction to the Baiano line of the Circumvesuviana railway system. Within this research task, the feasibility of using hybrid EEW for the Baiano line based on the recording of the Irpinia regional seismic network (ISNet) and performance-based EEW approaches (Iervolino et al., 2011) is being evaluated.

Task 7.4b is focused on tailoring EEW alerts to two high-schools located in the Campania region, in southern Italy. Amongst the most important achievements of this task are: a) a comprehensive vulnerability assessment of the two schoolhouses; b) the development of automatic control systems to be activated in case of emergency; c) educational activities and training involving both teachers and students; d) the installation of strong-motion stations and SOSEWIN (Fleming et al., 2009) nodes at the school buildings.

Task 7.5 investigates the potential implementation of PRESTo (Satriano et al., 2011) EEW algorithm on the Italian national strong-motion network (RAN). This research task involves: a) producing EEW scenarios for a selected suite of moderate-to-large recorded and synthetic events in Italy and, b) recommending hardware and software specifications for the implementation of the EEW system based on the RAN network.

Task 7.6 is implementing a real-time earthquake monitoring system for automatic shutdown of the IGDAS natural gas network in Istanbul. This application involves: a) the installation of more than 100 strong-motion acceleration sensors at the locations of the district regulators in the Istanbul region and, b) the integration of IGDAS and its control centre (monitored with SOSEWIN) into the Istanbul earthquake rapid response and EEW system (Sesetyan et al., 2011).

Task 7.7a deals with risk assessment and initial implementation efforts of EEW methods to protect the Thessaloniki Port. This research task comprises: a) the installation of ten SOSEWIN nodes at different critical locations within the Port area; b) the development of a local hazard map; c) a risk assessment study for buildings of different typology and seismic resistance; d) the implementation of VS and PRESTo EEW systems.

Task 7.7b is concerned with producing real-time risk estimates for the AHEPA hospital complex in Thessaloniki, with particular reference to two adjacent 8-storey reinforced concrete buildings equipped within the project with SOSEWIN monitoring nodes. Critical results achieved in this research task are: a) a system identification study; b) the comparison between experimental and simulated structural response; c) the development of emergency management plans based on the fragility curves developed for the target building and real-time shaking information; d) the implementation of EEWs, considering both VS and PRESTo algorithms.

Task 7.8 is devoted to initial probabilistic hazard mapping and EEW implementation efforts in Iceland. The main achievements of this research units will include: a) a near-real-time relative relocation of events in the South Iceland Seismic Zone (SISZ) and mapping of active faults and current seismicity near present and planned hydropower plant construction sites; b) the automatic daily generation of maps displaying time-dependent earthquake probabilities for western Iceland and the SISZ; c) implementation of the VS EEW algorithm based on real-time seismic network in the SISZ, managed by IMO.

Task 7.9 deals with a feasibility study on whether an earthquake rapid response system can be successfully operated in the territories of the Eastern Caribbean and to select appropriate fragility curves for critical infrastructures in the region using existing assessment tools. Amongst the most relevant scientific achievements of this research unit are: a) the computation of scenario synthetic seismograms for the identified sensitive objectives; b) the evaluation of different networks configurations and alert algorithms to compare theoretical and real warning times; c) the determination of optimal alarm thresholds.

Task 7.10 focuses on the implementation and evaluation of the EEW VS algorithm at the seismological laboratory of UPAT to deliver real-time information about expected shaking at the Rion-Antirion bridge to the GEFYRA operation centre and Patras civil protection offices. This task relies on receiving data in real-time from different broadband and strong-motion stations in Greece, augmented by 6 strong-motions accelerographs installed within REAKT.

Task 7.11 aims at improving of the SHM system of the FSM bridge in Istanbul (already equipped with a real-time 36-channel SHM system) by: a) installing an additional SOSEWIN network and, b) developing a real-time data processing and analysis software.

Selectively presented in this contribution are the key goals and finding of the entire work package. As the project approaches its final phase, emphasis is placed on the most significant technical and scientific results achieved, along with practical indications of interest derived by the academic / end-user interactions. We focus in particular on a) analysing the applications envisaged by the end-users given the various types of hazard information; b) presenting the actions that might be undertaken in response to heightened hazard; c) discussing potential algorithmic and technological improvements towards routine implementation of real-time seismic methodologies at critical facilities.

Table 1. REAKT WP7 applications at a glance.

Real-time seismic risk reduction method	Application	Scientific partner	Final objective
EEW only	Sines Industrial Complex, Portugal	IST	Feasibility study
	Circumvesuviana Railway, Italy	AMRA	Feasibility study
	Italian national strong-motion network	AMRA	Feasibility study
	IGDAS natural gas distribution network, Istanbul, Turkey	KOERI / GFZ	Implementation
	Port of Thessaloniki, Greece	AUTH / GFZ	Implementation
	Strategic facilities in the territories of the Eastern Caribbean	EUCENTRE / UWI / CCEO	Feasibility study
EEW and SHM	Schools in Campania, Italy	AMRA / GFZ	Implementation
	AHEPA hospital in Thessaloniki, Greece	AUTH / GFZ	Implementation
	Fatih Sultan Mehmet (FSM) bridge, Istanbul, Turkey	KOERI / GFZ	Implementation
EEW and OEF	Swiss nuclear power plants	SED@ETHZ	Feasibility
	Power plants in Iceland	IMO	Implementation
	Rion Antirion bridge, Patras, Greece	UPAT	Implementation

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