STREST

D 1.1

DELIVERABLE

PROJECT INFORMATION

Project Title:	**Harmonized approach to stress tests for critical infrastructures against natural hazards**
Acronym:	**STREST**
Project N°:	603389
Call N°:	FP7-ENV-2013-two-stage
Project start:	01 October 2013
Duration:	36 months

DELIVERABLE INFORMATION

Deliverable Title:	**Kick-off meeting report**
Date of issue:	25 November 2013
Work Package:	WP1 - Project Coordination and Management
Deliverable/Task Leader:	ETH Zurich
Reviewer:	JRC

REVISION: Version 3

SEVENTH FRAMEWORK PROGRAMME

Project Coordinator:	Prof. Domenico Giardini
Institution:	ETH Zürich
e-mail:	giardini@sed.ethz.ch
fax:	+ 41 446331065
telephone:	+ 41 446332610

Abstract

The kick-off meeting of the STREST project took place on 21-22 October 2013 at ETH Zurich, Switzerland. Thirty-three persons from the twelve partner institutions and from three of the six partner industries participated. The present report provides an overview of the STREST project and a summary of the 13 presentations given over the 2-day meeting. Based on a summary of the discussions (meeting minutes), the report concludes with a list of actions and recommendations to facilitate a smooth and efficient project start.

Keywords: Presentations, Discussions, Actions, Recommendations

Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 603389

Deliverable Contributors

ETH Zurich Arnaud Mignan

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 STREST PROJECT AT A GLANCE

Critical Infrastructures (CIs) provide essential goods and services for modern society; they are highly integrated and have growing mutual dependencies. Recent natural events have shown that cascading failures of CIs have the potential for multi-infrastructure collapse and widespread of societal and economic consequences. Moving toward a safer and more resilient society requires improved and standardized tools for hazard and risk assessment of low probability-high consequence (LP-HC) events, and their systematic application to whole classes of CIs, targeting integrated risk mitigation strategies. Among the most important assessment tools are the stress tests, designed to test the vulnerability and resilience of individual CIs and infrastructure systems. Following the results of the stress tests recently performed by the EC for the European Nuclear Power Plants, it is urgent to carry out appropriate stress tests for all other classes of CIs.

The objectives of the STREST project are to:

- Establish a common and consistent taxonomy of CIs;
- Develop a rigorous, consistent modelling approach to hazard, vulnerability, risk and resilience assessment of LP-HC events;
- Design a stress test framework and specific applications to address the vulnerability, resilience and interdependencies of CIs;
- Enable the implementation of European policies for the systematic implementation of stress tests.

STREST focuses on earthquakes, tsunamis, geotechnical effects and floods, and on three principal CI classes: (a) individual, single-site, high risk infrastructures, (b) distributed and/or geographically extended infrastructures with potentially high economic and environmental impact, and (c) distributed, multiple-site infrastructures with low individual impact but large collective impact or dependencies. Fig 1.1 shows a word cloud generated from the STREST Description of Work (DoW). This infographic provides a statistical view of the main concepts considered in the project.

Fig. 1.1 STREST word cloud

The STREST project is a consortium of twelve partner institutions from eight countries. Fig 1.2 shows a map of the locations of the different partners. Table 1.1 gives the list of partner institutions.

Fig. 1.2 STREST project partners

Table 1.1 STREST project partners

Acronym	Name	Country
ETH Zurich	Eidgenoessische Technische Hochschule Zurich	Switzerland
EPFL	École Polytechnique Fédérale de Lausanne	Switzerland
BUH	Basler & Hofmann AG, Ingenieure Und Planer	Switzerland
EUCENTRE	Centro Europeo di Formazione e Ricerca in Ingegneria Sismica	Italy
AMRA	AMRA - Analisi e Monitoraggio del Rischio Ambientale SCARL	Italy
INGV	Istituto Nazionale di Geofisica e Vulcanologia	Italy
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek - TNO	Netherlands
UJF	Université Joseph Fourier Grenoble 1	France
AUTH	Aristotelio Panepistimio Thessalonikis	Greece
BU	Bogazici Universitesi	Turkey
UL	Univerza v Ljubljani	Slovenia
JRC	JRC -Joint Research Centre- European Commission	Belgium

STREST works with key European CIs, to test and apply the developed stress test methodologies to specific CIs, chosen to typify general classes of CIs. Six test sites have been chosen (Fig 1.3):

- CI-A1: Oil refinery and petrochemical plant, Milazzo, Italy (data obtained by AMRA from ENI/Kuwait)
- CI-A2: Large dams, Valais, Switzerland (in collaboration with EPFL and the Office of Dams in the Swiss Federal Office of Energy)
- CI-B1: Major hydrocarbon pipelines, Baku-Tbilisi-Ceyhan (BTC), Turkey (in collaboration with BU and BOTAS Int. Ltd.)
- CI-B2: Gas storage and distribution network, Netherlands (in collaboration with TNO and Gasunie)
- CI-B3: Port infrastructure, Thessaloniki, Greece (in collaboration with AUTH and the Port Authority of Thessaloniki, THPA SA)
- CI-C1: Industrial district, Emilia region, Italy (in collaboration with EUCENTRE and the Confindustria of Piacenza)

Fig. 1.3 The six CI types considered in STREST

Results expected by the end of the STREST project are:

- Methods to harmonize the treatment of uncertainties and the mechanics of hazard assessment, with focus on the quantification of epistemic uncertainties and its effects on LP-HC hazard, the integration of regional versus site-specific hazards and near-source effects;
- Consistent quantification of the occurrence of LP-HC events (extremes, cascading effects) and schemes to introduce them in hazard and risk evaluations;
- Definition of appropriate measures to express aggregated probabilities of exceeding limit values across an extended footprint, taking into account the spatial correlation characteristics;
- Consistent taxonomy of different classes of CIs, to classify them in terms of common characteristics of vulnerability, possible consequences and resilience;
- Probabilistic models for vulnerability and consequence assessment, designed to enable transferring from hazard to risk and evaluating the consequences of system failures extending much beyond direct damages to equipment and structures, involving cascading effects;

1.2 STREST KICK-OFF MEETING AGENDA

The kick-off meeting of the STREST project took place on 21-22 October 2013 at ETH Zurich, Switzerland (Fig 1.4). The detailed agenda is given in Table 1.2. A summary of the presentations is given in section 2.

Table 1.2 STREST kick-off meeting agenda

Monday 21st October (afternoon): Selected critical infrastructures and interaction with industry (WP6)	
12:30 - 13:30	*Welcome lunch*
13:30 - 14:00	Opening, Outline of the STREST project (D. Giardini, ETH Zurich)
14:00 - 14:15	Introduction to the applications (K. Pitilakis, AUTH)
14:15 - 14:45	CI-A1 ENI/Kuwait oil refinery & petrochemical plant, Milazzo, Italy (E. Salzano, AMRA)
14:45 - 15:15	CI-A2 Large dams in the Valais, Switzerland (A. Schleiss, EPFL)
15:15 - 15:45	CI-B1 Major hydrocarbon pipelines, Turkey (M. Erdik, BU & I. Gurcan & M. Cilsal, BOTAS Int. Ltd.)
15:45 - 16:15	*Coffee break*
16:15 - 16:45	CI-B2 Gasunie gas storage & distribution network, Netherlands (M. Spruijt, TNO & R. Rombout, Gasunie)
16:45 - 17:15	CI-B3 Port infrastructure of Thessaloniki, Greece (K. Pitilakis, AUTH & E. Michailidis, THPA SA)
17:15 - 17:45	CI-C1 Industrial district affected by the 2012 Emilia earthquake, Italy (H. Crowley & R. Nascimbene, EUCENTRE)
17:45 - 18:15	General discussion, decisions on the working plan and contingency plans (chaired by K. Pitilakis, AUTH)
19:00 - 21:00	*Social dinner*
Tuesday 22nd October (morning): Work Plan	
8:30 - 9:00	WP2 - SoA (P. Zwicky, BUH)
9:00 - 9:45	WP3 - Hazard (F. Cotton, UJF)
9:45 - 10:30	WP4 - Risk (I. Iervolino, AMRA)
10:30 - 10:45	*Coffee break*
10:45 - 11:30	WP5 - Stress tests (B. Stojadinovic, ETH Zurich)
11:30 - 12:00	WP7 - Dissemination (F. Taucer, JRC)
12:00 - 13:00	*Lunch*

Fig. 1.4 The STREST kick-off meeting at ETH Zurich

1.3 STREST KICK-OFF MEETING LIST OF PARTICIPANTS

Thirty-three persons from the twelve partner institutions and from three of the six partner industries participated to the STREST kick-off meeting. The participants are listed in Table 1.3.

Table 1.3 STREST kick-off meeting list of participants

Partner	Name	Email address
1. ETH Zurich	1. Giardini, Domenico	domenico.giardini@erdw.ethz.ch
	2. Mignan, Arnaud	arnaud.mignan@sed.ethz.ch
	3. Stojadinovic, Bozidar	stojadinovic@ibk.baug.ethz.ch
	4. Sun, Li	sun@ibk.baug.ethz.ch
2. EPFL	5. Schleiss, Anton (21st only)	anton.schleiss@epfl.ch
	6. Franca, Mario	mario.franca@epfl.ch
3. BUH	7. Zwicky, Peter	Peter.Zwicky@baslerhofmann.ch
	8. Billmaier, Maximilian	maximilian.billmaier@baslerhofmann.ch
4. EUCENTRE	9. Crowley, Helen	helen.crowley@eucentre.it
	10. Nascimbene, Roberto	roberto.nascimbene@eucentre.it
	11. Weatherill, Graeme	graeme.weatherill@eucentre.it
	12. Pagani, Marco (22nd only)	marco.pagani@eucentre.it
5. AMRA	13. Iervolino, Iunio	iunio.iervolino@unina.it
	14. Salzano, Ernesto	salzano@irc.cnr.it
	15. Chioccarelli, Eugenio	eugenio.chioccarelli@unina.it
6. INGV	16. Selva, Jacopo	jacopo.selva@bo.ingv.it
	17. Lorito, Stefano	stefano.lorito@ingv.it
7. TNO	18. Spruijt, Mark	mark.spruijt@tno.nl
	19. Courage, Wim	wim.courage@tno.nl
8. UJF	20. Cotton, Fabrice	fabrice.cotton@ujf-grenoble.fr
	21. Gueguen, Philippe	pgueg@obs.ujf-grenoble.fr
9. AUTH	22. Pitilakis, Kyriazis	kpitilak@civil.auth.gr
	23. Fotopoulou, Stavroula (22nd only)	sfotopou@civil.auth.gr
10. BU	24. Erdik, Mustafa	erdikm@gmail.com
11. UL	25. Fajfar, Peter	Peter.Fajfar@fgg.uni-lj.si
	26. Dolsek, Matjaz	Matjaz.Dolsek@fgg.uni-lj.si
12. JRC	27. Taucer, Fabio	fabio.taucer@jrc.ec.europa.eu

	28. Krausmann, Elisabeth	elisabeth.krausmann@jrc.ec.europa.eu
	29. Galbusera, Luca	luca.galbusera@jrc.ec.europa.eu
Industry	**Name**	**Email address**
THPA SA	30. Michailidis, Emmanouil	emichailidis@thpa.gr
BTL	31. Gurcan, Ismet	ismet.gurcan@botasint.com
	32. Cilsal, Murat	murad.cilsal@botasint.com
Gasunie	33. Rombout, René (21st only)	r.rombout@gasunie.nl

2 Presentations

2.1 OUTLINE OF THE STREST PROJECT (D. GIARDINI, 8 SLIDES)

2.1.1 Summary

"*We need a new understanding of what risk is*" - D. Giardini, ETH Zurich

D. Giardini, coordinator of the STREST project, presented an overview of the project based on the DoW. Topics included: Budget table, list of partners, governance structure, work package (WP) description, test sites ("exploratory applications"), timescale and milestones and some recommendations. Recommendations were the following: "Follow the plan; follow the schedule (close in 3 years), follow the Consortium Agreement (CA), innovate, review (QA), enlarge industry participation, cooperate with other projects, communicate and outreach, have an impact in Brussels and EU, bridge with Horizon2020".

2.1.2 List of references

None.

2.2 INTRODUCTION TO THE APPLICATIONS (K. PITILAKIS, 14 SLIDES)

2.2.1 Summary

"*The STREST test sites were chosen because we know that the data is available*" -

K. Pitilakis, AUTH

K. Pitilakis, leader of WP6, provided an introduction to "Exploratory applications of new stress test concepts to critical infrastructures". He first presented an overview of WP6 with a description of the work efforts by participant, of the objectives of the WP and of the different CI types (as defined in the DoW). A short description of the different test sites followed (see Fig 1.3). Finally, organization of the work was discussed with focus on interactions with other WPs, timing schedule and issues to tackle during the WP6 session. Issues included data availability, knowledge of past risk studies (for knowledge transfer and avoiding duplication of work), bridging with other WPs and contingency plans.

2.2.2 List of references

None.

2.3 CI-A1 ENI/KUWAIT OIL REFINERY & PETROCHEMICAL PLANT, MILAZZO, ITALY (E. SALZANO, 21 SLIDES)

2.3.1 Summary

E. Salzano made a presentation, which can be divided in three parts: (i) a personal view on NaTech risk, (ii) a detailed description of the ENI/Kuwait Milazzo oil refinery and petrochemical plant and (iii) some general recommendations to stress tests. In the first part, a brief introduction to technological events was given (Seveso accident type) and to interactions between natural hazards and technological accidents (i.e., NaTech events).

Focus was made on the different types of cascading effects such as unavailability of utilities (e.g., electric power, water cooling), unavailability of safety barriers (e.g., firefighting water) and overloading of emergency rescue services. Examples included the Tupras oil refinery accident following the 1999 Kocaeli earthquake in Turkey, offshore accidents following the 2005 hurricane Katrina, the collapse of chemical plants following the 2008 Sichuan earthquake and the Ichihara-Chiba refinery accident following the 2011 Tohoku earthquake/tsunami. These examples illustrated that a multi-disciplinary analysis is required (natural hazards, equipment hazard, equipment vulnerability, consequence analysis, risk assessment, early warning, domino effects).

The second part described the Milazzo refinery, which has a capacity of 8 million tons/y, and which can be affected by earthquakes, volcanoes and tsunamis. The spatial extension and spatial complexity of the infrastructure were addressed. Different areas were described (Fig 2.1): Area I (gas storage units), Area II (refining units), Area IIIa and IIIb (storage units) and Area V (buried storage units). The following recommendations were given in the last part of the presentation: (i) a "bow-tie" approach may be used for a systematic analysis of NaTech scenarios; (ii) a shift must be made from damage state (DS) analysis to risk state (RS) analysis.

Fig. 2.1 The different areas of the Milazzo site

2.3.2 List of references

Campedel, Cozzani, Garcia-Agreda, Salzano, 2008, Extending the Quantitative Assessment of Industrial Risks to Earthquake Effects, Risk Analysis, 28, 1231-1246

Cozzani, Gubinelli, Salzano, 2006, Escalation thresholds in the assessment of domino accidental events, Journal of Hazardous Materials, 28; 1-21

Cozzani, Tugnoli, Salzano, 2007, Prevention of domino effect: from active and passive strategies to inherently safe design, Journal of Hazardous Materials, 139, 209-19

Cozzani, Salzano, Tugnoli, 2009, The development of an inherent safety approach to the prevention of domino accidents, Accident Analysis and Prevention, 41, 6, 1216-1227

Fabbrocino, Iervolino, Orlando, Salzano, 2005, Quantitative Risk Analysis of oil storage facilities in seismic areas, Journal of Hazardous Materials, 123, 61-69

Krausmann, Cozzani, Salzano, Renni, 2011, Industrial accidents triggered by natural hazards: an emerging risk issue, Natural Hazards and Earth System Sciences, 11, 921–929

Lanzano, Salzano, Santucci De Magistris, Fabbrocino, 2013, Seismic vulnerability of natural gas pipelines, Reliability Engineering & System Safety, 117, 73–80

Lanzano, Salzano, Santucci De Magistris, Fabbrocino, in press 2013, Seismic vulnerability of gas and liquid buried pipelines, Journal of Loss Prevention in the Process Industries, doi: 10.1016/j.jlp.2013.03.010

Milazzo, Ancione, Basco, Lister, Salzano, Maschio, 2013, Potential damage to industrial storage tanks due to volcanic ash fallout, Natural Hazards, 66, 939–953

Milazzo, Ancione, Salzano, Maschio, Milazzo, in press 2013, Risks associated with volcanic ash fallout from Mt.Etna with reference to industrial filtration systems, Reliability Engineering & System Safety, doi: 10.1016/j.ress.2013.05.008

Salzano, Garcia Agreda, Di Carluccio, Fabbrocino, 2009, Risk assessment and early warning systems for industrial facilities in seismic zones, Reliability Engineering & Systems Safety, 94, 1577-1584

2.4 CI-A2 LARGE DAMS IN THE VALAIS, SWITZERLAND (A. SCHLEISS, 51 SLIDES)

2.4.1 Summary

A. Schleiss made a presentation on the large dams in Valais-Wallis, structured in three parts: Structural safety, monitoring and maintenance, and emergency concepts. This presentation was based on the work of G. Darbre, Head of the Swiss Dam Safety Agency of the Swiss Federal Office of Energy. Dams are strategic infrastructures in Switzerland with 217 dams under federal surveillance and hundreds more under the surveillance of cantons.

There are different types of dams: Gravity dams, embankment dams, arch dams and buttress dams. The main purpose of Swiss dams is hydropower. Other purposes include water supply, irrigation, recreation area, biotopes, flood control and sediment retention. Structural safety is assured by modelling of mechanical loadings and structural analysis by finite elements (Fig 2.2). For design, Q_{1000} floods are considered while 1.5 Q_{1000} floods are considered for safety assessment. Monitoring is done by visual checks, measurements (regular performance check, explanation of unexpected performance) and operating tests.

An example of abnormal behaviour was then given. In 1978, pendulum displacements of the 1957 Zeuzier dam (156 m high) changed dramatically due to the construction of a nearby tunnel (Rawil, 1.4 km away). As a consequence, activities in the tunnel were stopped.

The emergency concept is defined by a strategy for identification of threats and for protection measures and by a public warning system (planning, alarm equipment, organizational measures). Inundation maps are modelled by flood wave modelling. Based on the modelled footprints, evacuation maps are defined.

Finally A. Schleiss presented the main characteristics of a series of dams: Grande Dixence (285 m high, 400 Mm^3, since 1961), Mauvoisin (250 m high, 210 M m^3, since 1957, modified in 1990), Emosson (180 m high, 225 Mm^3, since 1974), Gries (60 m high, 18 Mm^3, since 1965), Zeuzier (156 m high, 50 Mm^3, since 1957), Moiry (148 m, 77 Mm^3, since 1958), Ferden (67 m high, 1.72 Mm^3, since 1975), Les Toules (86 m, 20 Mm^3, since 1963), Z' Mutt (74 m high, 0.77 Mm^3, since 1970).

For the case studies of the individual risk, two dams will be selected - most probably a concrete and an embankment dam. Flood and earthquakes will be considered as the main hazards but also the impact of large sliding masses into the reservoirs (rockslides, glacier break down), which may be triggered also by earthquakes.

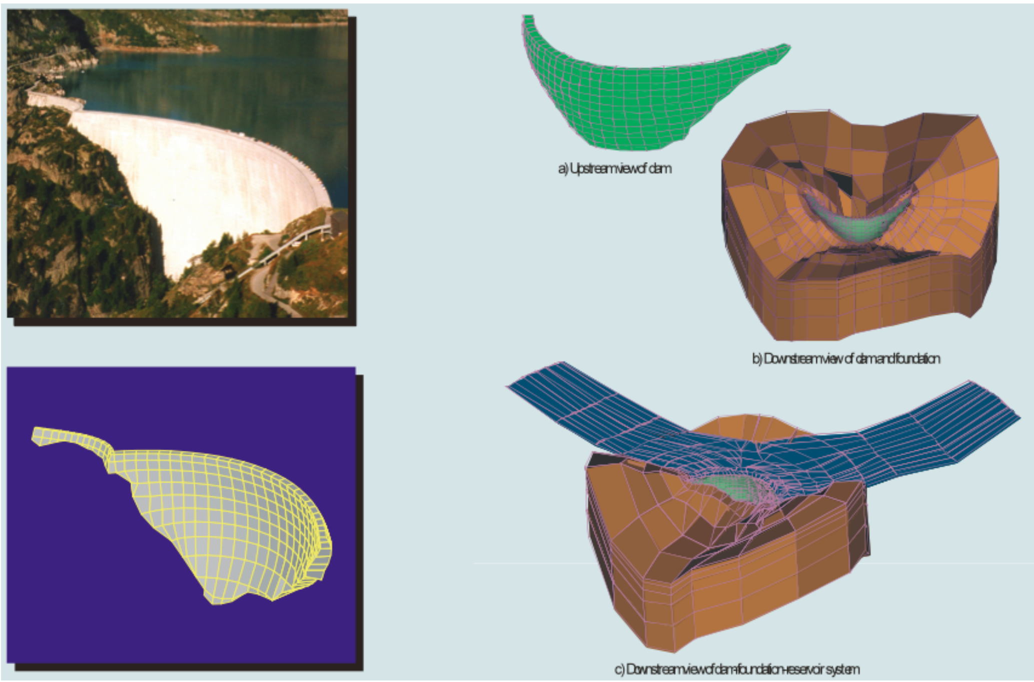

Fig. 2.2 Swiss dam structural analysis by finite elements

2.4.2 List of references

Darbre, G.R., 1998. Probabilistic assessment of current requirements on uncontrolled overtopping of dams during floods. Closing Report. Seminar on « Risk and safety of technical system ». 1998.

Darbre, G.R., 1998. Dam Risk Analysis. Swiss federal office for water management. 1998.

Darbre, G.R., 2000. Probabilistic safety assessment of dams. Vol. I , Q . 76 – R . 13, Compte rendu du XXe Congrès des CIGB, Beijing 2000, 185-196.
Darbre, G.R., 2011. Dam Safety in Switzerland. Dams in Switzerland – Source for Worldwide Swiss Dam Engineering, Ed. Swiss Committee on Dams, 11-14
Schleiss, A.J.; Pougatsch H. Les barrages – du projet de la mise en service. Traité de genie cicil, Volume 17, Presses polytechniques et universitaires romandes, ISBN 978-2-88074-831-9.

2.5 CI-B1 MAJOR HYDROCARBON PIPELINES, TURKEY (M. ERDIK, 38 SLIDES | I. GURCAN & M. CILSAL, 7.35 MIN. MOVIE)

2.5.1 Summary

M. Erdik presented the Baku-Tbilisi-Ceyhan (BTC) and South Caucasus (SCP) pipelines and integrated them in the tectonic context of Turkey. The BTC pipeline transports crude oil from offshore oil fields in the Caspian Sea to the Mediterranean. The pipeline travels from the terminal near Baku through Azerbaijan, Georgia and Turkey to the Ceyhan marine terminal (7 crude oil storage tanks). The pipeline, which is buried along its entire length, is 1768 km long. The BTC pipeline facilities include: 8 pump stations, 2 intermediate pigging stations, one pressure reduction station and 101 small block valves.

BIL is the operator of the BTC pipeline Turkish section. The SCP transports gas from Shah Deniz field from the Caspian Sea to Turkey. This 42-inch diameter pipeline follows the route of the BTC pipeline. The route passes through three active faults in Azerbaijan, four in Georgia and seven in Turkey. Of the 42 fault zones identified in Turkey along the route, five are confirmed as Holocene active (Erzurum, North Anatolian, Deliler, Cokak and Kiziloluk faults). The widest river crossing is the Ceyhan River in Turkey, which is 5.2 m deep and over 500 m wide.

The fault catalogue of Turkey is available from the EMME Active Faults project (and shared in the SHARE project fault database). Other hazard information in Turkey includes maps of past earthquakes, of strain rates (Global Earthquake Model, GEM) and of instrumental values of shaking (Probabilistic Seismic Hazard Assessment, PSHA). Site-specific data along the BTC pipeline is also available.

Pipelines are mostly affected by permanent ground displacement (limited impact of vibratory ground motion). The principal causes of permanent ground displacement are faulting, tectonic uplift and subsidence, liquefaction and landslides. Crossing of active faults has been considered in the design of the pipelines. The design showed good performance following the 1999 Kocaeli earthquake, with a pipeline remaining in service after having been subjected to a 3 m fault offset. The case of the Trans-Alaskan Pipeline following the 2002 Denali earthquake was also mentioned.

Modelling of fault crossing buried pipelines and non-linear response analysis can be done in various ways, including analytical and semi-analytical models, numerical models and studies on parametric behaviour. Cascading effects including hazardous material leakage, explosion and fire must also be considered. Moreover, for systematic performance and risk assessment of such extended pipelines, a simulation framework based on the Monte Carlo method is needed.

The presentation was followed by a promotional movie from BIL, showing the main characteristics of the operations and infrastructures as well as future plans.

Fig. 2.3 Baku-Tbilisi-Ceyhan (BTC) and South Caucasus (SCP) pipelines

2.5.2 List of references

None.

2.6 CI-B2 GASUNIE GAS STORAGE & DISTRIBUTION NETWORK, NETHERLANDS (M. SPRUIJT, 9 SLIDES | R. ROMBOUT, 12 SLIDES | W. COURAGE, 28 SLIDES)

2.6.1 Summary

"*We need to assess the terrorist attacks of Mother Nature*" - M. Spruijt, TNO

M. Spruijt presented a quick history of industrial safety and a summary of the TNO expertise for the STREST project. The TNO expertise includes: Advanced statistics (e.g., Bayesian Networks), damage modelling (civil, urban constructions, industrial installations), accidental release modelling, "off standard Quantitative Risk Assessment (RA)" using RA methodology for natural hazard scenario analysis, cascading effects scenario analysis, layers of protection analysis (redundancy) and resilience.

A second presentation was given by R. Rombout, Asset Manager at Gasunie, on the characteristics of the Gasunie gas storage and distribution network. Gas is produced at the Groningen natural gas fields, discovered in 1958 and located in the Northeast of the Netherlands. The Slochteren gas field contains approx. 3,000 billion m^3, with approx. 100 other gas fields existing in the region. Most of the production is made by NAM, it is marketed by GasTerra and transported by Gasunie. The network is 12,000 km long. It includes 11 compressor stations, 11 blending stations, 84 metering stations, 13 export stations, 1,300 gas delivery stations, one LNG installation and one nitrogen installation. The Gasunie design differs from other countries (Fig 2.4): No design classification for earthquakes, buildings belonging to the network system are constructed out of masonry and single vertical design for the support of pipes. Moreover, there are site-amplifying effects of 2.5. Other hazards include flooding, soil conditions change and collapsing of tall structures (wind turbines, HV power lines). The Dutch Supervisory Board for Mining requested Gasunie to carry out an impact analysis in early 2013. The aim was to verify the robustness of the gas grid against personal and process safety, assurance of supply and operational readiness. R. Rombout then showed a ranking of actions to reduce risks. As highest priority, supports of control room flooring, ceiling, panels, cabinets and air-conditioning units should be modified; pressure safeguarding should be replaced per IEC norm; single, vertical and temporary pipe supports should be modified; the removing of older non piggable lines should be considered. Other actions of medium and lower priority were described.

A third presentation was given by W. Courage to describe the techniques and models, which may be used in the context of STREST. Examples were then shown for illustration. Methods included: Belief Networks, structured expert judgement, logic tree tools and structural reliability methods among others. Examples of applications included: Tunnel Bleve, accidental dangerous good release and investigation of its propagation depending on wind conditions, pipe structural safety - soil interaction, and flood risk calculations with a presentation of flood maps in The Hague.

Fig. 2.4 A detail of the Gasunie network

2.6.2 List of references

None.

2.7 CI-B3 PORT INFRASTRUCTURE OF THESSALONIKI, GREECE (K. PITILAKIS & E. MICHAILIDIS, 50 SLIDES)

2.7.1 Summary

K. Pitilakis presented the port infrastructure of Thessaloniki with a description of the different parts of the infrastructure, the elements at risk, and finally hazard and risk results from previous projects (e.g., RISK-UE, SRM-LIFE, SYNER-G, REAKT, THALIS). The Thessaloniki's Port great area includes a chemical industry, transportation infrastructures (roads, highways, railways) and the port itself. Noteworthy, the port is at proximity of the rest of the city. The size of the served area is about 80 km^2, the size of the port area is 1,500,000 m^2 and the storage area is 600,000 m^2. The trade cargo counts 16,000,000 tons with a capacity of 370,000 TEUs, 3,000 ships and 220,000 passengers. There are 6 piers, for a total length of 6,200 m (Fig 2.5). The sea depth is up to 12 m.

Elements at risk inside the port and in the surrounding area are numerous and include: waterfront structures*, cargo transfer and handling equipment*, electric power system*, potable and wastewater*, fuel system*, telecommunication system*, railway tracks and roadway system*, buildings and CIs*, industrial facilities (chemical, oil). For STREST, a large data set is available including most of the infrastructure types (indicated by a *) as well as a defined typology-taxonomy of infrastructures. Fragility curves are available from various publications for different infrastructures (e.g., quay walls, cargo handling equipment). Additional data and methods are available from the SYNER-G project (Pitilakis et al., 2014). At the present time, fragility curves for hazards other than earthquake are missing (e.g., tsunami, flood).

Numerous seismic hazard studies and related information are available for the region of Thessaloniki. They include: microzonation studies, geological, geophysical, geotechnical data (e.g., from boreholes) and maps (e.g., liquefaction susceptibility), PSHA (Papaioannou, 2004; SHARE project). Regarding tsunami hazard, bathymetric maps are available. Information on inter- and intra-dependencies are also available (electric power network → port facilities, road network → port facilities, port facilities → road network).

Fig. 2.5 Harbor of Thessaloniki

2.7.2 List of references

Ichii K, (2003, Application of performance-based seismic design concept for caisson-type quay walls. PhD Dissertation, Kyoto University.

Ichii K, 2004, Fragility curves for gravity-type quay walls based on effective stress analyses. In 13th World Conference on Earthquake Engineering, Vancouver, BC Canada.

Kakderi K, Pitilakis K, 2010, Seismic analysis and fragility curves of gravity waterfront structures. In Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honour of Professor I. M. Idriss, San Diego, CA, Paper No. 6.04a.

Kakderi K, 2011, Seismic vulnerability assessment and seismic risk management of complex transportation networks. Application to port facilities. Ph.D. dissertation, Aristotle University of Thessaloniki, Greece.

Ko Y-Y, Yang H-H, Chen CH, 2010, Seismic fragility analysis for sheet pile wharves – Case study of the Hualien harbor in Taiwan. In Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor I.M. Idriss, San Diego, California, Paper No. 6.05a.

Na UJ, Shinozuka M, 2009, Simulation-based seismic loss estimation of seaport transportation system. Reliability Engineering and System Safety 94(3): 722-731.

Na UJ, Chaudhuri SR, Shinozuka M, 2008, Probabilistic assessment for seismic performance of port structures. Soil Dynamics and Earthquake Engineering, 28(2): 147–158.

Na UJ, Chaudhuri SR, Shinozuka M, 2009, Effects of spatial variation of soil properties on seismic performance of port structures. Soil Dynamics and Earthquake Engineering, 29(3): 537– 545

National Institute of Building Sciences (NIBS), 2004, HAZUS-MH: Users's Manual and Technical Manuals. Report prepared for the Federal Emergency Management Agency, Washington, D.C.

Papaioannou Ch. 2004, Technical Report: Probabilistic Analysis of Seismic Hazard in Thessaloniki, Research Program SRM-LIFE, Coord. K.Pitilakis, Thessaloniki.

Pitilakis K, Crowley H, Kaynia A, 2014, SYNER-G: Typology definition and fragility functions for physical elements at risk. Buildings, lifelines, transportation networks and critical facilities. Springer Ed., ISBN 978-94-007-7871-9.

2.8 CI-C1 INDUSTRIAL DISTRICT AFFECTED BY THE 2012 EMILIA EARTHQUAKE, ITALY (H. CROWLEY & R. NASCIMBENE, 43 SLIDES)

2.8.1 Summary

R. Nascimbene and H. Crowley presented the industrial district affected by the 2012 Emilia earthquake, first with an in-depth description of the damage and second with a list of available data (hazard and vulnerability). EUCENTRE has collected detailed damage data for 7 industrial complexes using the AEDES template (Italian post-earthquake damage collection), for a total of around 20 buildings.

Typical damage observed after the first earthquake was: Structural damage to connections and elements (columns and foundations), non-structural damage to panels and interaction between structural and non-structural elements. Observations are summarized in 9 photographs in Fig 2.6. The traditional pre-cast building typologies in Italy were then described. Pre-96 buildings have inadequate connections and low horizontal strength. Post-96 buildings have standard steel elements for connections but still only designed to low levels of lateral force.

Fragility curves are available in the literature (Bolognini et al., 2008; Casotto et al., in prep.) as well as hazard studies (Camassi et al., 2012; Caputo et al., 2012; Castelli et al., 2012; Faccioli, 2013; Ganas et al., 2012; Stucchi et al., 2012). Confindustria Piacenza and EUCENTRE are collecting data on 10 industrial complexes (more than 100,000 m^2) in the Piacenza region. Available information includes: structural details such as connection types, geometry, materials and design data, use of building (exhibitions and production buildings), contents (mechanical components, biomedical components, electrical components).

Moreover, the Seismic Risk Prevention Area, Tuscany Region has provided EUCENTRE with a database of over 600 industrial buildings. Data already available are geometries. Additional data should include: type of activity (production, commercial, warehouse, offices, mixed), period of use, occupancy, value (low-medium-high) and socio-economic damage (low-medium-high based on production/stored goods).

Fig. 2.6 Damage following the first 2012 Emilia earthquake

For the STREST project, data collection will continue (M1-12), fragility curves will be developed for industrial buildings (M1-12) as well as vulnerability functions in terms of repair cost and business interruption (due to direct damage) and possibly the modelling of contingent business interruption, as a function of the data and models available (M12-24). It was decided that the Emilia event should provide an important case study from which a number of lessons can be learnt for future stress tests for similar types of industrial districts. Instead, the STREST methodology is likely to be applied in a different region, possibly Tuscany.

The first task to be carried out immediately will be a 1-2 page summary of the scope of this industrial case study, including the needs from WP3 in terms of intensity measures and probabilities of exceedance, the needs of WP4 in terms of fragility and vulnerability models and a first list of outcomes that should be achieved by the stress tests (as input to WP5).

2.8.2 List of references

Bolognini, D., Borzi, B., Pinho, R. [2008] "Simplified Pushover-Based Vulnerability Analysis of Traditional Italian RC precast structures," Proceedings of the 14th World Conference on Earthquake Engineering, Beijing, China.

Camassi, R., Rovida, A., Locati, M., Castelli, V., Viganò, D. and Stucchi, M. (2012) "The earthquakes of May 2012 within the seismic context of the area," (in Italian) *Progettazione Sismica*.

Caputo, R., Iordanidou, K., Minarelli, L., Papathanassiou, G., Eliana Poli, M., Rapti-Caputo, D., Sboras, S., Stefani, M. and Zanferrari, A. (2012) "Geological evidence of pre-2012 seismic events, Emilia-Romagna, Italy," Annals of Geophysics, 55, (4)

Casotto, C., Silva, V., Crowley, H., Nascimbene, R., Pinho, R. (2013) Seismic fragility of RC precast industrial structures, *in preparation*,

Castelli, V., Bernardini, F., Camassi, R., Caracciolo, C.H., Ercolani, E. and Postpischl (2012) "Looking for missing earthquake traces in the Ferrara-Modena plain: an update on historical seismicity," Annals of Geophysics, 55, (4)

Faccioli, E. (2013) "Recent evolution and challenges in the seismic hazard analysis of the Po Plain region, Northern Italy," Bulletin of Earthquake Engineering, 11:5-33.

Ganas, A., Roumelioti, Z., Chousianitis, K. (2012) "Static stress transfer from the May 20, 2012, M 6.1 Emilia-Romagna (northern Italy) earthquake using a co-seismic slip distribution model," Annals of Geophysics, 55, (4)

Stucchi, M., Meletti, C., Montaldo, V., Crowley, H., Calvi, G.M., Boschi, E. (2011) "Seismic hazard assessment (2003-2009) for the Italian building code," Bulletin of Seismological Society of America, 101 (4): 1185-1911.

2.9 WP2 - STATE-OF-THE-ART (P. ZWICKY, 16 SLIDES)

2.9.1 Summary

P. Zwicky, leader of WP2, presented the four tasks and linked deliverables of WP2, as defined in the DoW. The objectives of WP2 are to review, compare and analyse the methodologies and findings from (i) advanced Plant Safety Assessment studies for nuclear power plants (NPP) and post-Fukushima stress tests for NPPs, (ii) national standards for hazard and risk assessment and for stress tests for different classes of CIs, (iii) lessons learned from recent catastrophic events, and (iv) achievements and heritage of relevant on-going and completed EU projects.

The proposed work plan is defined as follows: (1) collect information from peer-reviewed literature and technical report review, (2) develop tables of content for the four state-of-the-art (SoA) reports, (3) organize a technical WP2 meeting at ETH Zurich in January 2014 to view available information and coordinate the reports drafting, (4) review and study the relevant data and extract lessons learned and conclusions and (5) prepare the four reports by M6 with drafts, consultation/comments and finalization.

For Task 2.1, information from the International Atomic Energy Agency (IAEA), national industry and regulators and EU commission will be investigated.

For Task 2.2, comparative analyses will be performed of present national standards for hazard and risk assessment and for stress tests for different classes of non-nuclear CIs as well as of current practices in and guidelines for CI risk assessment across EU countries.

In Task 2.3, the scope has first to be defined with a selection of CIs and hazards (e.g., earthquake, flood, tsunami) to be analyzed. Examples of preliminary information available are: industrial accident database analyses (JRC/Bologna University), NaTech studies following the 2011 Tohoku earthquake (JRC/Kyoto University), the 2008 Sichuan earthquake (JRC/INERIS) and the 1999 Kocaeli earthquake (JRC/Tulane University/Bogazici University), and NaTech pipeline analyses (JRC, CNR).

Task 2.4 is made of two steps: (1) a comprehensive review of relevant EU projects based on the EU database (Fig 2.7):

http://ec.europa.eu/research/ environment/index_en.cfm?pg=projects&area=hazards

and of associated projects to STREST (e.g., INFRARISK, ASTARTE, INTACT) and (2) focus on a sub-selection of projects for knowledge transfer to specific STREST tasks (e.g., MATRIX multi-hazard framework, SYNER-G fragility curves and typologies).

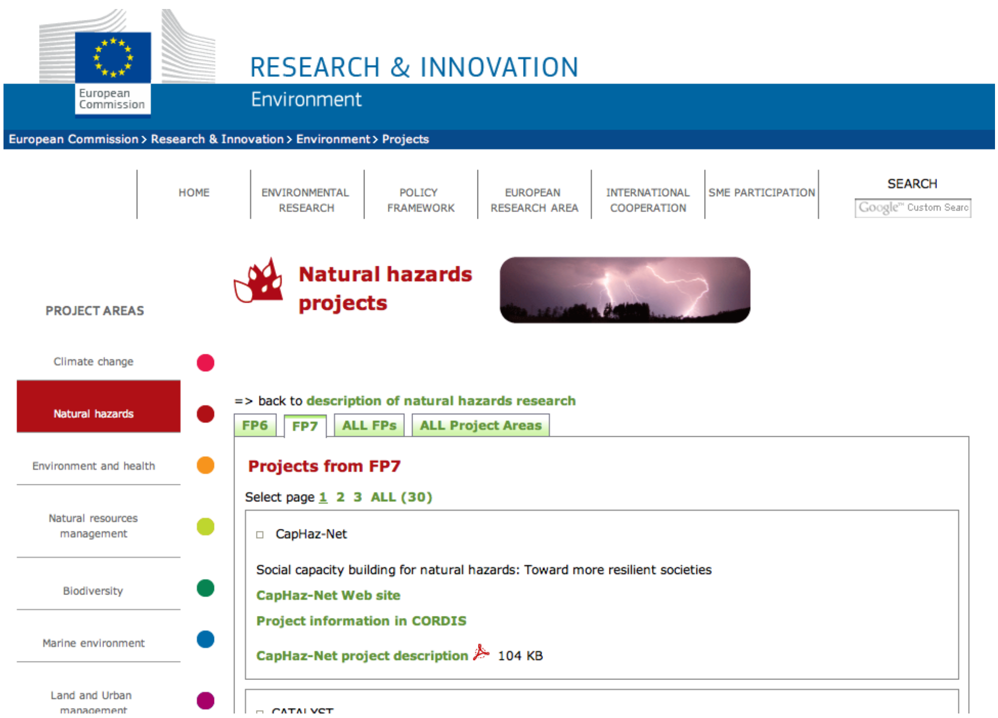

Fig. 2.7 The EU project data base portal

2.9.2 List of references

None.

2.10 WP3 - HAZARD (F. COTTON, 36 SLIDES)

2.10.1 Summary

F. Cotton, leader of WP3, presented a work structure for WP3 and described the different items to be considered. WP3 should be CI-focused and data-driven with a hierarchical structure: best estimate (centre), low-high values (body, based on alterative interpretations) and low-high ranges (range, beyond the data). Items to be considered are: low-probability high-consequence (LP-HC) events, multi-hazard and cascading events and exploration of epistemic uncertainties (with an adaptation of the knowledge from the nuclear industry).

The deliverables of the work package should provide standards, guidelines and should be didactic and focus on best examples. Interface between WP3 and other WPs should be based on a common metric, i.e., the same hazard intensities should be used for the generation of hazard footprints (WP3) and for the development of fragility curves (WP4). Moreover a SSHAC study level should be chosen for WP3 (Senior Seismic Hazard Analysis Committee, Fig 2.8).

While the nuclear industry requires level 3 or 4, the target of STREST should be level 2 (i.e., simpler, lower cost while keeping a certain degree of expert elicitation). Strengths and weaknesses of the different levels will be investigated. The goal of Deliverable 3.1 is to define guidelines relative to the treatment of epistemic (inter-model) uncertainties when LP-HC events are defined. Planned activities include SoA on the treatment of epistemic uncertainties in natural hazards, elaboration of guidelines for stress tests (LP-HC event focused) and application to at least one case study.

The port of Thessaloniki has been proposed as principal site as data on hazard uncertainty will be made available from the EUROSEISTEST project. Other envisioned activities are the development of different models for the determination of the maximum magnitude (geological - including dynamic fault segment cascading - versus geodetic measurements) and the testing of an induced seismicity hazard logic tree based on results from the GEISER project.

Deliverable 3.2 will assess the spatial variability and correlation of hazard intensities in order to evaluate aggregated probabilities of exceeding limit values across an extended footprint. The methods will be applied to pipelines in Turkey. Activities will include an analysis of signal coherency, single station sigma method, probabilistic fault displacement hazard analysis (PFDHA), studies on ground motion prediction equations (GMPE), further development, validation and application of the "Shake-field" approach developed in SYNER-G specifically for spatially distributed systems and extreme event scenarios.

Deliverable 3.3 will report on near-source hazard assessment and the definition of reference scenarios for stress tests. Possible test areas are Milazzo and Turkey (to be confirmed). Near-source directivity effects will be introduced to ordinary PSHA. Moreover, NGA-2 near-field GMPE may be integrated in Openquake.

Deliverable 3.4 will provide guidelines and case studies of site monitoring to reduce the uncertainties affecting site-specific earthquake hazard assessment. Activities will consist in comparing differences in mean hazard estimates, epistemic uncertainties and aleatory variability depending on the approach used for the site-specific component as well as in reviewing studies for well-instrumented sites (e.g., EUROSEISTEST). Impact of kappa uncertainty on hazard curves was shown for illustration. Moreover, strong motion data from the 230 station Istanbul Earthquake Rapid Response and Early Warning System will be used as well as geotechnical/geophysical data from Thessaloniki.

Deliverable 3.5 will report on cascading events and multi-hazard probabilistic scenarios. A top-down approach will be used, with (i) the review of SoA hazard assessment for earthquakes (SHARE), floods and tsunamis, (ii) the mapping of the relationship between the three hazards and 6 CI locations for generic multi-hazard scenarios and (ii) the investigation of at least 2 test sites for in-depth cascade modelling. Proposed sites are the port of Thessaloniki (earthquake-earthquake interactions, in relationship with M_{max} assessment in Task 3.1) and dams in Switzerland (earthquake -> landslide -> tsunami on artificial lake -> flood down the dam). Modelling will be based on the simulation method developed in the MATRIX project and on the computation of conditional probabilities of occurrence (e.g., Coulomb stress modelling).

Deliverable 3.6 will provide a new software package incorporating induced seismicity hazard in PSHA. This will be integrated in the OpenQuake code developed by the Global Earthquake Model (GEM). While implementation of induced seismicity-based GMPEs is envisioned, other actions remain unclear. An application would be appropriate in the case of the Gasunie gas storage and distribution network. Deliverable 3.7 will be an integration of all results from other WP3 tasks. It will combine the various results by CI site and harmonize the different findings for knowledge transfer to subsequent WPs. Close collaboration with the various task leaders will be required at the early stage of WP3. Finally, it will provide a comparative analysis (ranking of sites being LP-HC event prone) and sensitivity tests.

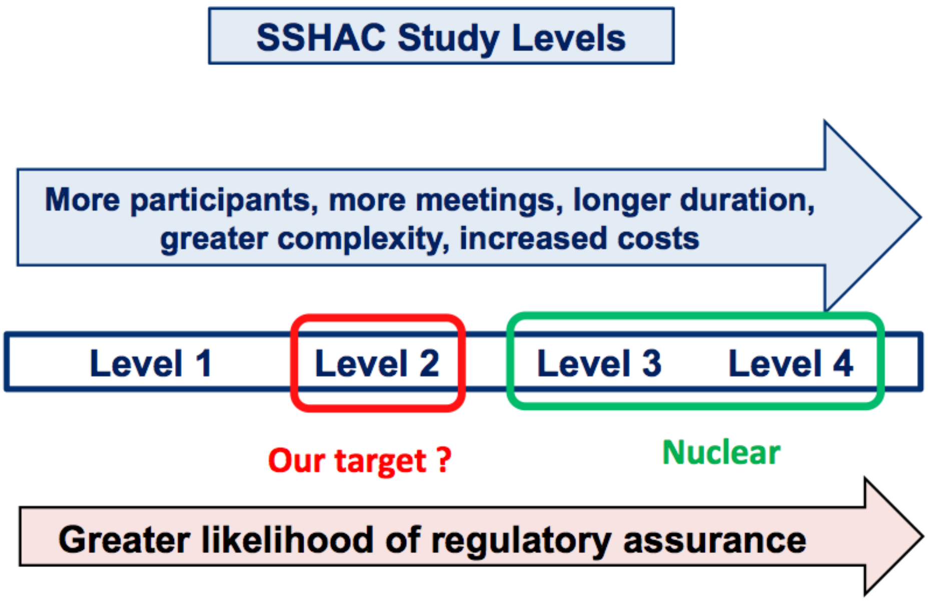

Fig. 2.8 SSHAC study levels. Courtesy of J. Bommer

2.10.2 List of references

None.

2.11 WP4 - RISK (I. IERVOLINO, 25 SLIDES)

2.11.1 Summary

I. Iervolino, leader of WP4, first presented the objectives and task descriptions for WP4 following the DoW, and then provided a list of planned activities aimed at defining vulnerability models for the performance and consequence assessment in stress tests.

The first step in WP4 will be to define a taxonomy for vulnerability of CIs with respect to stress tests. To this aim, it will also be checked whether fragility curves are already available for the selected applications and, if yes, if they're meaningful in terms of intensity measures and limit states required to assess consequences of failure in complex CIs. An example is the NaTech case of the Milazzo oil refinery (Fig 2.9), where an industrial accident, possibly triggered by structural failure, requires limit states in terms of leakage of hazardous materials. The main final aim of WP4 is to select and define the vulnerability models required to assess the performance of the CIs, which are the focus of WP6, with respect to the considered hazard.

Time-dependency effects on vulnerability (e.g., related to successive disruptive events occurring in sequences, such as earthquakes) and resilience, of CIs and communities, will also be investigated, even if in more general terms. In particular, the effect of seismic sequences on the quantitative definition of resilience for a CI, will be modelled.

Most participants of WP4 have a wide experience on vulnerability assessment also due to the participation to previous EC projects (SYNER-G, SHARE, REAKT, NERA, SERIES, RISK-UE, LESSLOSS, SAFER, SPEAR, SAFECAST, SAFECLADDING, MATRIX), granting the required background to make significant scientific progress on the topics of WP4.

Tasks will include: (1) Task 4.1: identification of quantitative and standardized models to carry out performance and loss assessment studies for the CIs at the core of WP6; (2 Task 4.2: Development of a framework accounting for interdependencies, in and between CIs, and their effect on loss propagation; (3) Task 4.3: time-variant issues in vulnerability and the effects of repeated disruptive events on the resilience-related recovery process; (4) Task 4.4: Definition of the taxonomy for the stress test of CIs; and (5) Task 4.5: Harmonization of quantitative definition of resilience of CIs and societal resilience.

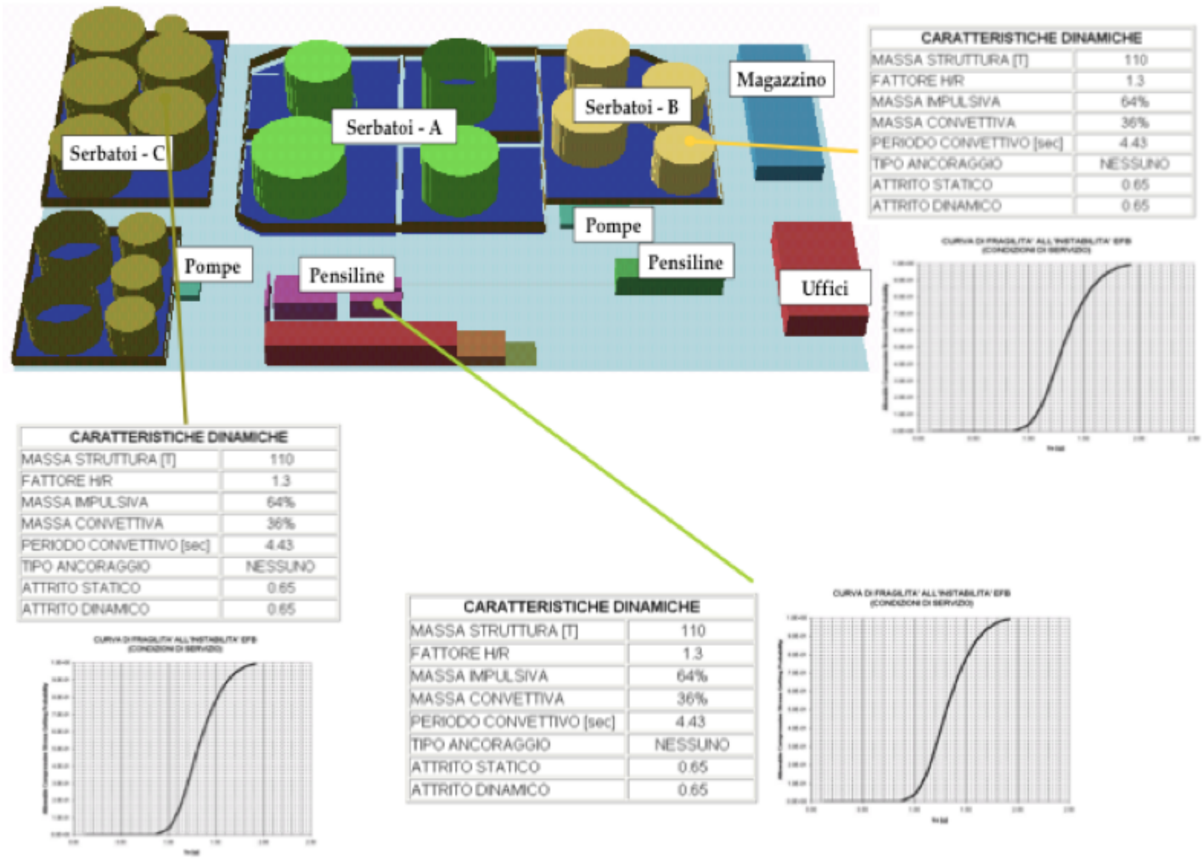

Fig. 2.9 Example of existing fragility curves for the Milazzo oil refinery

2.11.2 List of references

None.

2.12 WP5 - STRESS TESTS (B. STOJADINOVIC, 21 SLIDES)

2.12.1 Summary

"*Tails are the problem*" - B. Stojadinovic, ETH Zurich

B. Stojadinovic, leader of WP5, made a two-part presentation on the design of stress tests for CIs. The first part focused on the core methodology for risk assessment and stress tests (Deliverables 5.1 and 5.2) and the second one on life-cycle management and resilience (Deliverables 5.3 and 5.4).

Risk assessment was first defined. It can be deterministic or probabilistic and should provide a basis for risk averse decisions (i.e. stress tests). Stress tests are done to identify extremely unlikely events with unthinkable consequences, where existing statistics are not sufficient to cover these events. Stress tests should provide a basis for ambiguity averse decisions.

In WP5, the following terminology will be used (Paté-Cornell, 2012, Fig 2.10): (i) Perfect storms (combining hazard and vulnerability aspects) correspond to low-probability known events. This phenomenon mostly involves aleatory uncertainties (i.e, randomness of known events) and requires the statistical distribution of the different parameters involved; (ii) Black swans correspond to interdependent phenomena, whose existence is unknown. This phenomenon mostly involves epistemic uncertainties. Statistical distributions of parameters may be unknown too. The two types of phenomena require different approaches. A probabilistic method will be used to address perfect storms (event combination, tail models) while a deterministic approach will be used to address black swans ("reasoned imagination"). Stress test acceptance criteria will focus on performance objectives based on measures of the function (e.g., handled tonnage at a port) and/or consequences (e.g., substance release quantity and rate) (Nishijima et al., 2009).

The proposed method to do stress tests is a Bayesian framework. The outcomes of the stress tests are still to be clearly defined. Options include: Pass/no-pass (deterministic), probability of failure, conditional probability of failure, probability of consequences, conditional probability of consequences, change in the risk management approach (risk and ambiguity aversion combined).

In the second part of the presentation, life-cycle CI management was described. Hazards and vulnerabilities of a CI change over time (new knowledge added, anthropogenic hazard increased, engineered changes of the system, degradation, development of dependencies). As a consequence, a time-dependent component must be added to hazard and vulnerability models so that stress tests can be used to anticipate effects in the long-term. One can also optimize maintenance procedures to increase CI resilience.

Resilience is a process, corresponding to the continuous increase of resistance to hazards and to the continuous adaptation to changes. Resilience addresses in part how CIs affect societal functions and how societal decisions affect CIs. Outcomes of stress tests should be used to enhance the resilience of a community to natural hazards. This requires examining engineering, public policy, risk transfer and regulatory measures as well as the optimal combinations of these measures to sustainably enhance societal resilience. Life-cycle cost-benefit curves and risk acceptance curves should be used for this purpose.

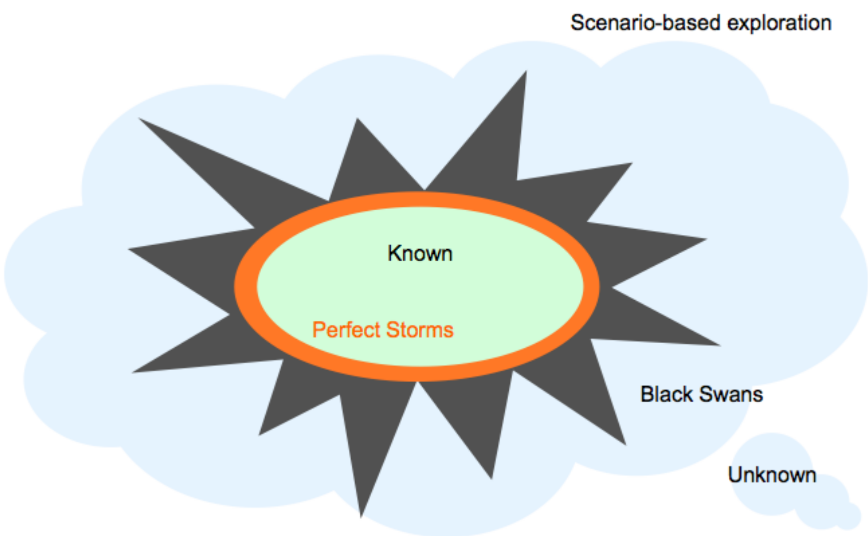

Fig. 2.10 Perfect storms versus black swans

2.12.2 List of references

Nishijima, K., M. A. Maes, J. Goyet and M. H. Faber, 2009, Constrained optimization of component reliabilities in complex systems. Structural Safety, 31, 168-178

Paté-Cornell, E., 2012, On "Black Swans" and "Perfect Storms": Risk Analysis and Management When Statistics Are Not Enough. Risk Analysis, 32, doi: 10.1111/j.1539-6924.2011.01787.x

2.13 WP7 - DISSEMINATION (F. TAUCER, 19 SLIDES)

2.13.1 Summary

F. Taucer, leader of WP7, presented the different aspects of dissemination associated to the STREST project. The objectives are to communicate to regulators and operators of non-nuclear CIs of the products developed during the project. These products are harmonized methodologies for risk assessment leading to the standardization and implementation in Europe of stress test methodologies. The aim is then to incorporate these stress test methodologies in the current management and long-term planning of non-nuclear CIs. Then the different tasks of WP7 were described, as defined in the DoW.

Task 7.1 will produce a set of six European Reference Reports (ERR) on: SoA and lessons learned (WP2), guidelines for harmonized hazard assessment for LP-HC events (WP3), guidelines for harmonized vulnerability and risk assessment for CIs (WP4), guidelines for stress test methodologies (WP5), strategies for enhancement of societal resilience (WP5) and End-of-project Policy Brief. A template of the ERR is shown in Fig 2.11.

Task 7.2 consists in the development of a web server and the preparation of dissemination material in the forms of leaflets and newsletters. The informational factsheet for the start of the project has already been completed. A short video targeting a large audience will also be produced, although details of the creation process and contents have yet to be defined. It should be verified if the EC could contribute. Additional actions include the development of STREST templates for deliverables (completed) and the production of educational material to increase awareness.

Other awareness and dissemination activities are part of Task 7.3, based on the participation to key international events (e.g., 15^{th} European Conference on Earthquake Engineering and Seismology and the 34^{th} General Assembly of European Seismological Commission, August 2014 in Turkey) and on the publication of scientific results in peer reviewed journals and magazines.

Task 7.4 will consist in the organization of two stakeholder workshops, a first one to collect and integrate user requirements and a concluding workshop to communicate the main results of the STREST project to European and International stakeholders.

Finally, Task 7.5 will consist in developing a detailed dissemination and exploitation plan of the project results, addressing the outcomes of WP7 on the enhancement of societal resilience through infrastructure stress tests.

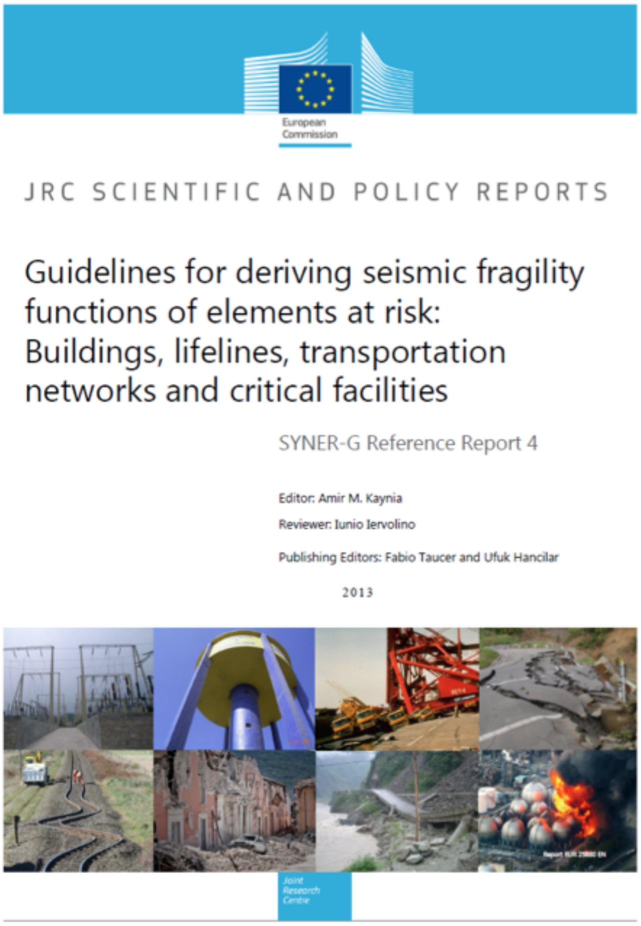

Fig. 2.11 Example of European Reference Report (ERR) for SYNER-G

2.13.2 List of references

None.

3 Actions and recommendations

This section corresponds to the minutes of the kick-off meeting (excluding the presentations already summarized in section 2), providing the next steps and some general recommendations, following the discussions between participants.

3.1 NEXT STEPS

3.1.1 List of responsible persons

By 31 October 2013, a list of responsible persons per Deliverable should be approved. WP Leaders are responsible for assigning names to their respective Deliverables. The draft is given in Table 3.1. Names are already proposed but are not final. Green rows indicate Deliverables already finalized and ready for submission. Orange cells indicate a change of responsible institution compared to the one given in the DoW - Once agreed, ETH Zurich will inform the STREST project officer of the changes. Noteworthy, each Deliverable/Task Leader should also obtain a list of all participants to their task and their respective roles.

Table 3.1 Responsible persons per Deliverable (DRAFT)

#	Title	Lead Partner	Person Responsible	Due
D1.1	Kick-off meeting report	ETH Zurich	A. Mignan	M1
D2.1	Hazard assessment & stress tests for NPPs	BUH	P. Zwicky	M6
D2.2	SoA hazard assessment & stress tests for non-nuclear CIs	BUH	M. Billmaler	M6
D2.3	Lessons learned from recent catastrophic events	JRC	E. Krausmann	M6
D2.4	Lessons learned from on-going & completed EU projects	ETH Zurich	A. Mignan	M6
D3.1	Effects of epistemic uncertainties on the definition of LP-HC events	INGV	J. Selva	M18
D3.2	Definition of extreme hazard scenarios for geographically-extended facilities	BU	M. Erdik	M18
D3.3	Near-source hazard assessment & definition of reference scenarios for stress tests	UJF	I. Iervolino	M18
D3.4	Guidelines & case studies of site monitoring to reduce the uncertainties affecting site-specific earthquake hazard assessment	UJF	P.-Y. Bard	M18
D3.5	Cascading events & multi-	ETH Zurich	A. Mignan	M18

	hazard probabilistic hazard scenarios			
D3.6	New software package incorporating induced seismicity hazard in PSHA	EUCENTRE	G. Weatherill	M18
D3.7	Comparative analysis & sensitivity tests of multi-hazard assessment of LP-HC events for the six selected application areas	ETH Zurich	A. Mignan	M24
D4.1	Guidelines for performance & consequences assessment of single-site, high-risk, non-nuclear CIs exposed to multiple natural hazards	AMRA	E. Salzano	M24
D4.2	Guidelines for performance & consequences assessment of geographically distributed, non-nuclear CIs exposed to multiple natural hazards	AUTH	K. Pitilakis	M24
D4.3	Guidelines for performance & consequences assessment of multiple-site, low-risk, high-impact, non-nuclear CIs exposed to multiple natural hazards	AMRA - changed to EUCENTRE	R. Nascimbene	M24
D4.4	Taxonomy of CIs based on their vulnerability characteristics and exposure to natural hazard initiating events	AMRA - changed to EUCENTRE	H. Crowley	M30
D4.5	Development of a coherent definition of societal resilience & its attributes	EUCENTRE - changed to ETH Zurich	B. Stojadinovic	M30
D5.1	Engineering risk assessment methodology for stress tests of non-nuclear CIs	ETH Zurich	B. Stojadinovic	M34
D5.2	Bayesian network framework for conducting stress tests of non-nuclear CIs	ETH Zurich	B. Stojadinovic	M34
D5.3	Tools & strategies to incorporate stress tests into the long-term planning and life cycle management of non-nuclear CIs	ETH Zurich	B. Stojadinovic	M34
D5.4	Strategies for stress test implementation at community level and strategies to enhance societal resilience using stress tests	ETH Zurich	B. Stojadinovic	M34
D6.1	Integrated report detailing analyses, results & proposed hierarchical set of stress tests for the six CIs covered in STREST	AUTH	K. Pitilakis	M32
D7.1	Implementation of the web	JRC - changed	A. Mignan	M3

	component concerned with general information on the project	to ETH Zurich		
D7.2	Project information factsheet leaflet	JRC - changed to ETH Zurich	A. Mignan	M3
D7.3	Project newsletters	JRC	F. Taucer	M30
D7.4	Report on user requirements from potential stakeholders	JRC	F. Taucer	M12
D7.5	Exploitation plan	JRC	F. Taucer	M30
D7.6	Publication of the STREST European Reference Reports & policy briefs	JRC	F. Taucer	M34
D7.7	Final workshop report with conclusions & recommendations	JRC	F. Taucer	M36
D7.8	High-quality brochure, describing the main project products & the key results from test application	JRC - changed to EUCENTRE	H. Crowley	M36

3.1.2 CI-centred WP interactions

WP interactions should be facilitated by a shared focus and common metrics, centred on the different requirements of the six test sites. Table 3.2 illustrates the points to be clarified at the early stage of the project. For each test site, it is first necessary to determine for which part of the CI a full inventory is available. Only a subsection of the full CI should be investigated due to time and resource constraints. If some data are missing, obtaining them should be a priority. The list of studied natural hazards (earthquake, flood and/or tsunami, other?) should be clearly defined for each CI. Processes participating to the generation of LP-HC events (uncertainty tails, site amplifications, cascading effects) at the hazard (WP3) and vulnerability levels (WP4) should be listed. A sub-list should then be defined to study specific aspects, again due to time and resource constraints. Finally, only one or two performance indicators should be defined per site.

It has been proposed to additionally write a 1-page summary report for WP3 and WP4 detailing expected outputs for each test site and also for each test site (WP6) a report detailing the required inputs (WP6) from other WPs. This action has yet to be clarified but its aim is to check that a common input/output interface is in place at the early stage of the project.

Table 3.2 Test sites characteristics per WP (DRAFT)

Test site	Subsection to be analyzed	Hazards	WP3 tasks	WP3-4 hazard intensity	WP4 tasks*	WP4-5 performance indicators
Milazzo		Earthquake Tsunami	3.3 3.7	Low frequency shaking?	All?	
Valais	1-2 dams (Les Toules?)	Earthquake Landslide Tsunami Flood	3.5 3.7		All?	
Turkey	BTC (full length?)	Earthquake	3.2 3.3? 3.7	Fault breaking	All?	
Thessaloniki	Port area infrastructures & some interconnected facilities in broader area (highways, electric power substations & potentially chemical industries)	Earthquake Tsunami	3.1 3.2 3.4 3.5 3.7	Ground shaking (PGA, PGV, PSA), Ground failure due to liquefaction (PGD) Inundation depth, flow velocity, impact hydrodynamic force	All	Port: Loss of capacity (cargo/container movements or handled) Other: to be defined
Netherlands	Groningen field area?	Induced earthquake	3.1 3.6 3.7		All?	
Emilia region	Emilia event as important case study (lessons learned). STREST methodology likely to be applied in other region (Tuscany?)	Earthquake	3.2 3.3 3.7	Spatially cross-correlated, site amplified spectral accelerations up to about 4 seconds	4.1 4.4 4.7	Structural, non-structural & content damage Economic losses

* IMPORTANT: Task 4.1 (core procedures) and Task 4.4 (taxonomy) apply to all sites. Need to clarify if Task 4.2 (cascading effects), Task 4.3 (time-dependency) and Task 4.5 (societal resilience) apply to all sites?.

3.1.3 File-sharing repository

Until STREST obtains a web presence (website due M3), ETH Zurich will investigate the different options to host a temporary file-sharing repository. A FTP folder is envisioned. The first information to be shared will relate to the kick-off meeting (e.g., presentations).

3.2 GENERAL RECOMMENDATIONS

3.2.1 Expertise harmonization

It has been recognized that the principal expertise of the STREST consortium is in seismic hazard and risk (as seen also in Fig 1.1). While flood (EPFL) and tsunami (INGV) expertises are also available, it remains unclear for which test sites fragility curves for floods and tsunamis are already available or need to be defined. Moreover expertise in business interruption (BI) is apparently missing in the consortium. These aspects have yet to be investigated.

While STREST aims at providing new methodologies, standard hazard data are also required as background information or to "fill in the gaps". For earthquakes, the SHARE fault database may be used as baseline. Ground shaking footprints may be generated using OpenQuake. There is no existing standard in tsunami modelling.

A harmonization of the treatment of uncertainties is also required. While epistemic uncertainties at the hazard level are the focus of Task 3.1, epistemic uncertainties are also present at the vulnerability level (implicit?). Also it remains unclear how uncertainties propagate in the processes modelled in other tasks. The different approaches should agree with the terminology defined in WP5, i.e., perfect storms represent aleatory uncertainties while black swans represent epistemic uncertainties.

Noteworthy, harmonization also means a common language with common definitions and common acronyms. A list of "STREST terms" might be added to the file-sharing repository for occasional updates.

3.2.2 Intra-WP redistribution of work load

Due to limited time and resources, the different work packages should remain focused and CI-centred. Stand-alone works should be avoided as well as detailed studies with limited impact on stress tests. If too many person-months are allocated to such types of task, some should be reallocated to help resolving critical issues, such as getting all the necessary input data for the six CIs.

References

Bolognini, D., Borzi, B., Pinho, R. [2008] “Simplified Pushover-Based Vulnerability Analysis of Traditional Italian RC precast structures,” Proceedings of the 14th World Conference on Earthquake Engineering, Beijing, China.

Camassi, R., Rovida, A., Locati, M., Castelli, V., Viganò, D. and Stucchi, M. (2012) “The earthquakes of May 2012 within the seismic context of the area,” (in Italian) *Progettazione Sismica*.

Campedel, Cozzani, Garcia-Agreda, Salzano, 2008, Extending the Quantitative Assessment of Industrial Risks to Earthquake Effects, Risk Analysis, 28, 1231-1246

Caputo, R., Iordanidou, K., Minarelli, L., Papathanassiou, G., Eliana Poli, M., Rapti-Caputo, D., Sboras, S., Stefani, M. and Zanferrari, A. (2012) “Geological evidence of pre-2012 seismic events, Emilia-Romagna, Italy,” Annals of Geophysics, 55, (4)

Casotto, C., Silva, V., Crowley, H., Nascimbene, R., Pinho, R. (2013) Seismic fragility of RC precast industrial structures, *in preparation*,

Castelli, V., Bernardini, F., Camassi, R., Caracciolo, C.H., Ercolani, E. and Postpischl (2012) “Looking for missing earthquake traces in the Ferrara-Modena plain: an update on historical seismicity,” Annals of Geophysics, 55, (4)

Cozzani, Gubinelli, Salzano, 2006, Escalation thresholds in the assessment of domino accidental events, Journal of Hazardous Materials, 28; 1-21

Cozzani, Tugnoli, Salzano, 2007, Prevention of domino effect: from active and passive strategies to inherently safe design, Journal of Hazardous Materials, 139, 209-19

Cozzani, Salzano, Tugnoli, 2009, The development of an inherent safety approach to the prevention of domino accidents, Accident Analysis and Prevention, 41, 6, 1216-1227

Darbre, G.R., 1998. Probabilistic assessment of current requirements on uncontrolled overtopping of dams during floods. Closing Report. Seminar on « Risk and safety of technical system ». 1998.

Darbre, G.R., 1998. Dam Risk Analysis. Swiss federal office for water management. 1998.

Darbre, G.R., 2000. Probabilistic safety assessment of dams. Vol. I , Q . 76 – R . 13, Compte rendu du XXe Congrès des CIGB, Beijing 2000, 185-196.

Darbre, G.R., 2011. Dam Safety in Switzerland. Dams in Switzerland – Source for Worldwide Swiss Dam Engineering, Ed. Swiss Committee on Dams, 11-14.

Fabbrocino, Iervolino, Orlando, Salzano, 2005, Quantitative Risk Analysis of oil storage facilities in seismic areas, Journal of Hazardous Materials, 123, 61-69

Faccioli, E. (2013) “Recent evolution and challenges in the seismic hazard analysis of the Po Plain region, Northern Italy,” Bulletin of Earthquake Engineering, 11:5-33.

Ganas, A., Roumelioti, Z., Chousianitis, K. (2012) “Static stress transfer from the May 20, 2012, M 6.1 Emilia-Romagna (northern Italy) earthquake using a co-seismic slip distribution model,” Annals of Geophysics, 55, (4)

Ichii K, (2003, Application of performance-based seismic design concept for caisson-type quay walls. PhD Dissertation, Kyoto University.

Ichii K, 2004, Fragility curves for gravity-type quay walls based on effective stress analyses. In 13th World Conference on Earthquake Engineering, Vancouver, BC Canada.

Kakderi K, Pitilakis K, 2010, Seismic analysis and fragility curves of gravity waterfront structures. In Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honour of Professor I. M. Idriss, San Diego, CA, Paper No. 6.04a.

Kakderi K, 2011, Seismic vulnerability assessment and seismic risk management of complex transportation networks. Application to port facilities. Ph.D. dissertation, Aristotle University of Thessaloniki, Greece.

Ko Y-Y, Yang H-H, Chen CH, 2010, Seismic fragility analysis for sheet pile wharves – Case study of the Hualien harbor in Taiwan. In Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor I.M. Idriss, San Diego, California, Paper No. 6.05a.

Krausmann, Cozzani, Salzano, Renni, 2011, Industrial accidents triggered by natural hazards: an emerging risk issue, Natural Hazards and Earth System Sciences, 11, 921–929

Kyriazis, P., H. Crolwey and A. Kainya, 2014, SYNER-G: Typology Definition and Fragility Functions for Physical Elements at Risk. Buildings, Lifelines, Transportation Networks and Critical Facilities. Springer Ed., ISBN 978-94-007-7871-9

Lanzano, Salzano, Santucci De Magistris, Fabbrocino, 2013, Seismic vulnerability of natural gas pipelines, Reliability Engineering & System Safety, 117, 73–80

Lanzano, Salzano, Santucci De Magistris, Fabbrocino, in press 2013, Seismic vulnerability of gas and liquid buried pipelines, Journal of Loss Prevention in the Process Industries, doi: 10.1016/j.jlp.2013.03.010

Milazzo, Ancione, Basco, Lister, Salzano, Maschio, 2013, Potential damage to industrial storage tanks due to volcanic ash fallout, Natural Hazards, 66, 939–953

Milazzo, Ancione, Salzano, Maschio, Milazzo, in press 2013, Risks associated with volcanic ash fallout from Mt.Etna with reference to industrial filtration systems, Reliability Engineering & System Safety, doi: 10.1016/j.ress.2013.05.008

Na UJ, Shinozuka M, 2009, Simulation-based seismic loss estimation of seaport transportation system. Reliability Engineering and System Safety 94(3): 722-731.

Na UJ, Chaudhuri SR, Shinozuka M, 2008, Probabilistic assessment for seismic performance of port structures. Soil Dynamics and Earthquake Engineering, 28(2): 147–158.

Na UJ, Chaudhuri SR, Shinozuka M, 2009, Effects of spatial variation of soil properties on seismic performance of port structures. Soil Dynamics and Earthquake Engineering, 29(3): 537– 545

National Institute of Building Sciences (NIBS), 2004, HAZUS-MH: Users's Manual and Technical Manuals. Report prepared for the Federal Emergency Management Agency, Washington, D.C.

Nishijima, K., M. A. Maes, J. Goyet and M. H. Faber, 2009, Constrained optimization of component reliabilities in complex systems. Structural Safety, 31, 168-178

Papaioannou Ch. 2004, Technical Report: Probabilistic Analysis of Seismic Hazard in Thessaloniki, Research Program SRM-LIFE, Coord. K.Pitilakis, Thessaloniki.

Pitilakis K, Crowley H, Kaynia A, 2014, SYNER-G: Typology definition and fragility functions for physical elements at risk. Buildings, lifelines, transportation networks and critical facilities. Springer Ed., ISBN 978-94-007-7871-9.

Salzano, Garcia Agreda, Di Carluccio, Fabbrocino, 2009, Risk assessment and early warning systems for industrial facilities in seismic zones, Reliability Engineering & Systems Safety, 94, 1577-1584

Schleiss, A.J.; Pougatsch H. Les barrages – du projet de la mise en service. Traité de genie cicil, Volume 17, Presses polytechniques et universitaires romandes, ISBN 978-2-88074-831-9.

Stucchi, M., Meletti, C., Montaldo, V., Crowley, H., Calvi, G.M., Boschi, E. (2011) "Seismic hazard assessment (2003-2009) for the Italian building code," Bulletin of Seismological Society of America, 101 (4): 1185-1911.