# FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate Change)



# Novel indicators for identifying critical <a href="INFRA">INFRA</a>structure at <a href="RISK">RISK</a> from Natural Hazards

#### **Deliverable D9.6**

## **Final Conference Summary Report and Broadcast Video**



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WP	9
<b>Submission Date</b>	05/11/2016
Primary Reviewer	M. Segarra/DRAGADOS
Dissemination Level	PU

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960.

#### **Project Information**

Project Duration:1/10/2013 - 30/09/2016Project Coordinator:Professor Eugene O' Brien<br/>eugene.obrien@rod.ie





Work Programme: 2013 Cooperation Theme 6:

Environment (Including Climate Change).

Call Topic: Env.2013.6.4-4 Towards Stress Testing of Critical Infrastructure

Against Natural Hazards-FP7-ENV-2013-two stage.

**Project Website:** www.infrarisk-fp7.eu

#### Partners:

ETH

Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich Eidgenössische Technische Hochschule Zürich, Switzerland.

DRAGADOS

Dragados SA, Spain.

GDG GWIN & IDOUTERTY GEO SOLUTIONS

Gavin and Doherty Geosolutions Ltd., Ireland.

probabilistic solutions consult and training

 $\label{lem:consult} \mbox{Probabilistic Solutions Consult and Training BV, Netherlands}.$ 

CSIC

Agencia Estatal Consejo Superior de Investigaciones Científicas,

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**UCL** 

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PSJ, Netherlands.



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#### **Document Information**

Version	Date	Description	Primary Author
Rev00	05/11/2016	Final Conference Summary	M.J. Jiménez,
		Report and Broadcast Video	M. García-Fernández (CSIC)
Rev01	10/11/2016	Final Conference Summary	M. Segarra (DRAGADOS)
		Report and Broadcast Video	
Rev02-Final	10/11/2016	Final Conference Summary	M.J. Jiménez (CSIC)
		Report and Broadcast Video	

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#### **Executive Summary**

The final public event of the EU-FP7 funded project INFRARISK —Novel indicators for identifying INFRAstructure at RISK from Natural Hazards— was the Final Dissemination Conference.

The INFRARISK project was due to end on 30th of September 2016 and the Final Dissemination Conference was organized on 29th of September in Madrid. During the one-day event new research was presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

The conference addressed the main INFRARISK topics on the stress testing framework, the road and rail example case studies, the INFRARISK Decision Support Tool (IDST), and the INFRARISK GIS Knowledge Base. After the results were presented to the 70 participants attending the conference, the final session incorporated a panel discussion moderated by the coordinator of INFRARISK. The five panelists were experts from both industry and academia together with the coordinators of similar EU-projects.

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#### 1.0 INTRODUCTION

The final public event of the EU-FP7 funded project INFRARISK– Novel indicators for identifying INFRAstructure at RISK from Natural Hazards– was the Final Dissemination Conference.

The INFRARISK project was due to end on 30th of September 2016 and the Final Dissemination Conference was organized on 29th of September in Madrid.

During the one-day event new research was presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

The conference addressed the main INFRARISK topics on the stress testing framework, the road and rail example case studies, the INFRARISK Decision Support Tool (IDST), and the INFRARISK GIS Knowledge Base. After the results were presented to the 70 participants attending the conference, the final session incorporated a panel discussion moderated by the coordinator of INFRARISK. The five panelists were experts from both industry and academia together with the coordinators of similar EU-projects.

This document describes the one-day conference closing the project. It summarizes the activities related to the organization of the event, the event itself, the communication actions to promote the event, and the products related to the Final Dissemination Conference event.

#### 2.0 THE FINAL DISSEMINATION CONFERENCE

The event marked the end of the three years long project. It started with a short presentation by **M. Segarra** welcoming participants to the INFRARISK Final Dissemination Conference at **DRAGADOS** premises in Madrid and consisted of three main parts.

- Session 1 consisted in two keynote speeches on the objectives of the final conference and a
  general overview of the project by the coordinator followed by a speech on the protection of
  critical infrastructure from the perspective of infrastructure management.
- Session 2 included the presentations on the results of the main aspects of the project by the partners with contributions on:
  - the approach to risk assessment and the INFRARISK stress testing framework as developed in the project
  - o the different objectives and challenges on the hazard identification related to earthquakes, flooding, and landslides and the assessment of asset vulnerability
  - the INFRARISK Case Studies focusing on TEN-T Road and Rail networks (Italy and Croatia)
  - the development of two INFRARISK software tools: the INFRARISK Decision Support Tool (IDST) and the INFRARISK GIS Knowledge Base (KB).
  - Session 3 was the closing session of the Conference and consisted in a panel discussion which had two parts. First, each of the panelists delivered a short introduction and then the open discussion started.

The conference was open to a large audience and a large number of stakeholders and public authorities which were reached out to with an invitation to attend the conference. Special attention was paid to inviting practitioners, operators and managers in construction companies at national and international levels to provide them with information about the work done within INFRARISK.

A first announcement of the Final Dissemination Conference was sent on April 2016 to a mailing list of contacts as provided by partners in INFRARISK. These contacts included construction and management companies and enterprises related to road and rail infrastructure in partner countries as well as coordinators of similar European projects. The first announcement was also disseminated through construction platforms and networks: European Construction Technology Platform (ECTP), European Network of Construction Companies for Research and Development (ENCORD), Conference of European Directors of Roads (CEDR), Forum of European National Highway Research Laboratories (FEHRL), *Plataforma Española Tecnológica de Construcción* (PTEC) Asociación de Empresas Constructoras y Concesionarias de Infraestructuras (SEOPAN). See Appendix A for the text of first announcement.

The final announcement which included the detailed programme of the Final Dissemination Conference was sent through e-mail to more than 1000 contacts of companies and enterprises all over Europe (see Appendix B).

Around 70 participants attended the conference at DRAGADOS premises in Madrid. The complete list of registered participants is incorporated in Appendix C in this report.

Videos produced within INFRARISK ("The project in 3 min.", "Natural hazards", "Critical Infrastructures", "Stress tests", "INFRARISK Training activities announcement") were showcased in the conference room as an introduction to the project during the registration time from 9:30-10:00 while participants were occupying their seats in the room and also during the coffee and lunch breaks of the conference.

During the conference, interviews were collected from different INFRARISK partners for the production of the final audiovisual materials consisting on a video "Project Outcomes" promoting the results of the project and the final dissemination conference which is available on the INFRARISK website.

The conference was live webcasted (INFRARISK website: infrarisk-fp7.eu) and videos covering the whole event were produced which have been uploaded to the project website. The links to the videos are specified in section 6 in this report.

A selection of photos taken during the Final dissemination Conference is available at INFRARISK web site:

#### http://www.infrarisk-fp7.eu/content/infrarisk-final-dissemination-conferencehttp

Press call and press releases were delivered to announce the Final Conference event and the outcomes of the project and get more visibility:

http://www.infrarisk-fp7.eu/content/conference-streaming

#### http://www.infrarisk-fp7.eu/content/call-press

During the conference, a team of Spanish TV channel TVE24 interviewed the coordinator (E. O'Brien, ROD) and the dissemination manager (M.J. Jiménez, CSIC) of INFRARISK. The focus was both the project outcomes and the Final Conference. TVE24 reported on the important goals of project, its outcomes and the Final Dissemination Conference event in the program "Europa 2016".

The video can be watched at:

#### https://www.youtube.com/watch?v=CkDIjLepG1E

and was broadcasted on the 30<sup>th</sup> September, just the day after the Final Conference.

Appendix E includes a detailed report on the Communication actions to raise awareness on INFRARISK and the Final Dissemination Conference event.

#### 3.0 FINAL DISSEMINATION CONFERENCE: PROGRAMME

The conference was organized in three sessions according to the following programme:

09:30 - 10:00	Registration
10:00 - 11:00	SESSION 1
10:00 - 10:10	Welcome M. Segarra (DRAGADOS)
10:10 - 10:30	Overview of the project & Objectives of final dissemination conference E. O'Brien (ROD) Coordinator of INFRARISK
10:30 - 11:00	Protection of critical transport infrastructure - a network management perspective
	B. Bell (Univ. of Surrey)
11:00 - 11:30	Coffee break
11:30 - 13:30	SESSION 2
11:30 - 12:00	INFRARISK Stress Testing Framework and Risk Assessment Methodology B. Adey (ETHZ) & P. van Gelder (PSCT)
12:00 - 12:30	Hazard Identification & Asset Vulnerability Assessment D. D'Ayala (UCL) & M. García-Fernández (CSIC)
12:30 - 13:00	INFRARISK Case Study: TEN-T Road and Rail networks (Italy and Croatia)  J. Clarke (ROD) & R. Corbally (ROD)
13:00 - 13:30	INFRARISK Decision Support Tool (IDST) and INFRARISK GIS Knowledge Base
	Z. Sabeur (IT innovation) & D. Roman (SINTEF)
13:30 - 14:30	Lunch Break
14:30 - 16:30	SESSION 3: PANEL DISCUSSION
14:30 - 16:30	Brief introductions & Discussion
	E. O'Brien (INFRARISK)
	P. Petiet (INTACT) A. O'Connor (RAIN)
	A. Ansal (European Association of Earthquake Engineering)
	J. Lóbez (Crisis Management, Ministry Public Works Spain)
	J. Rodríguez (PTEC- Spanish Construction Technology Platform)
16:30 - 16:40	Closing

#### 4.0 SESSION 1

The first session of the Conference was moderated by **M. García-Fernández**, researcher at the partner institution **CSIC**.

The first presentation was delivered by **E. O'Brien (ROD)**, the project coordinator, giving an overview of the project and the objectives of the Final Dissemination Conference.

Following the introductory presentation, **B. Bell**—**University of Surrey**—shared the view on how an infrastructure manager sees the protection of critical transport infrastructures from natural hazard events. After presenting a general framework of the problem, he stressed the most important points in his view that would be most critical in dealing with the risk of natural hazards on transport infrastructure.



E. O'Brien on an overview of the project and objectives of the Conference



B. Bell on a network management perspective

#### 5.0 SESSION 2

Session 2 of the conference was moderated by **M. Segarra (DRAGADOS)** and was aimed at presenting the results of the project. It included the presentations of INFRARISK partners on the main methodologies and outputs of the project.

A first talk by **B. Adey (ETHZ)** and **P. van Gelder (PSCT)** presented the approach to risk assessment and the INFRARISK stress testing framework as developed in the project. The process to assess infrastructure related risks due to natural hazards with stress tests which is applicable independent of the hazard to be considered, the infrastructure objects to be taken into account and the types of consequences to be considered. The general stress test framework is described as such in which stress tests are just a special instance of a risk assessment where, instead of marginalizing over all the possible stress scenarios, one specific stress scenario is chosen for which its potential effects are gauged.

**D. D'Ayala (UCL)** and **M. García-Fernández (CSIC)** delivered a presentation on the different objectives and challenges of the hazard identification related to earthquakes, flooding, and landslides and the assessment of asset vulnerability. The approach to seismic hazard assessment for low probability seismic inputs affecting critical transport infrastructures was described together with the methodology for assessing single and multi- risk expected vulnerability of elements in the infrastructure and the path from asset damage to the assessment of network damage.





B. Adey & P. van Gelder reporting on the INFRARISK stress testing framework and risk assessment methodology

Next, J. Clarke (ROD) and R. Corbally (ROD) reported on the INFRARISK Case Study: TEN-T Road and Rail networks (Italy and Croatia). For the Italian case study (a road network located in the province of Bologna), the impacts of seismic hazard scenarios and the landslide cascading hazard effects were shown and the consequences on the network repair costs and the travel disruption to network users were described. The impacts of flood hazard scenarios on a national rail network in Croatia were also shown as evaluated through a qualitative risk assessment method (ORT) to demonstrate the use of

such a methodology to determine the rail sections along the network where the risk is most substantial. A quantitative risk assessment was subsequently demonstrated for the network whereby the network vulnerability was assessed according to the potential for bridge scour, track inundation and track blockages due to rainfall-triggered landslides.





D. D'Ayala & M. García-Fernández

J. Clarke & R. Corbally

The session 2 round of presentations was closed by **Z. Sabeur (IT innovation)** and **D. Roman (SINTEF)**. They both showed the development of two INFRARISK software tools: the INFRARISK Decision Support Tool (IDST) and the INFRARISK GIS Knowledge Base (KB). The IDST is an advanced information system that enables civil engineers, infrastructure maintenance agencies and crisis managers to assess the potential risks due to natural hazards (earthquakes and floods and their cascading landslide effects). The KB allows users to upload, transform and query data relating to infrastructure components and natural disaster events.



D. Roman & Z. Sabeur



**INFRARISK IDST portal** 

#### 6.0 SESSION 3

The closing session of the Conference was a panel discussion which had two parts. In the first part each of the panelists delivered a short introduction. The five panelists were experts in both industry and academia and coordinators of similar EU-projects. The discussion was moderated by E. O'Brien (coordinator of INFRARISK). Five panelists were invited; P. Petiet (EU-project INTACT), A. O'Connor (EU-project RAIN), J. Lóbez (Crisis Management, Ministry of Transport and Public Works, Spain), J. Rodríguez (PTEC-Spanish Construction Technology Platform, Spain), A. Ansal (EAEE-European Association of Earthquake Engineering). All of them are experts from industry or academia, and two of them are coordinating similar EU-projects which made a well-balanced panel in relation to the INFRARISK project and the Final Dissemination Conference.



Panel discussion: P. Petiet short introduction to EU-project INTACT

Following the introductions, the second part of the session included the discussion which was opened to the audience by the moderator. There was a lively discussion regarding what were considered key aspects such as how to take up advances to mitigate destruction or loss of infrastructures and how to make understandable the fact that higher first costs makes lower whole life costs.

The weight to be put on sustainability as compared to that put on resilience was also discussed. Much attention should be paid to resilience since most infrastructures in Europe are overused and overstressed and high consequences and impacts can be expected if the smallest distraction from steady state would happen.

The collection of data was considered to be another key issue. Collecting the necessary data was recognized as a huge challenge because very little data from infrastructures if any would be, in

general, delivered publicly. End-users should be encouraged to get involved and to use the results and outcomes of this kind of projects.



Panel discussion: J. Lóbez short introduction on Crisis Management System in Spain

Another important issue which came to the discussion was standardization. In general, it was felt that some kind of standardization of the techniques developed in similar EU projects funded in FP7 (INTACT, INFRARISK, STRESS, RAIN) dealing with the effects of Natural Hazards on European Critical Infrastructure might as well be needed.

#### 7.0 FINAL CONFERENCE LIVE WEB-CAST VIDEOS

The whole conference was live webcasted (INFRARISK website: infrarisk-fp7.eu) and videos covering the whole event were produced which have been uploaded to the project website. The links to the videos are the following:

Live streaming introductory video:

https://www.youtube.com/watch?v=wpyZ-A5zzCg&feature=youtu.be

Welcome address by M. Segarra, DRAGADOS:

http://www.infrarisk-fp7.eu/sites/default/files/docs/SEGARRA.pdf

Overview of the project & Objectives of Final Dissemination Conference by E. O'Brien:

https://www.youtube.com/watch?v=bE5 95AszPw&feature=youtu.be

Protection of critical transport infrastructure - a network management perspective by B. Bell:

https://www.youtube.com/watch?v=qPlzUByopdA&feature=youtu.be

INFRARISK Stress Testing Framework and Risk Assessment Methodology by B. Adey & P. van Gelder:

https://www.youtube.com/watch?v=Y1pSo7tY AU&feature=youtu.be

Hazard Identification & Asset Vulnerability Assessment by D. D'Ayala & M. García-Fernández:

https://www.youtube.com/watch?v=fHb9t5q2C6I&feature=youtu.be

INFRARISK Case Study: TEN-T Road and Rail networks (Italy and Croatia) by J. Clarke & R. Corbally:

https://www.youtube.com/watch?v=L8SmqbMj8BQ&feature=youtu.be

INFRARISK Decision Support Tool (IDST) and INFRARISK GIS Knowledge Base by Z. Sabeur & D. Roman:

https://www.youtube.com/watch?v=nK2li3t8NU4&feature=youtu.be

Session 3. Brief Introductions and Panel Discussion:

https://www.youtube.com/watch?v=pl6akn02i10&feature=youtu.be

#### 8.0 CONCLUSION

The Final Dissemination Conference achieved its objectives of presenting the final results of the project, including a discussion panel on the perspectives of future development in the protection of European CIs, to a wide audience of stakeholders, professionals and public authorities, most of them not participating in previous meetings of the project.

The live webcasting of the conference allowed enlarging the audience at national and international level.

# **APPENDIX A: 1<sup>St</sup> Announcement of Final Conference**























## **RCAB**

# Final Dissemination Conference, Madrid, 29<sup>th</sup> September 2016

**INFRARISK**, an EU-funded project (2013-2016), brings together 11 members with a well-balanced and strong partnership amongst universities, research institutions, SMEs, and a Large Enterprise, to develop a strategy to ensure that levels of infrastructure related risk due to natural hazards are acceptable. Stress tests are implemented through an operational framework that supports the work of managers, operators, stakeholders and policy makers, providing insight into the impact of extreme natural hazard events and enabling the vulnerability of their infrastructure networks to be assessed.

#### **About the Conference**

The final conference aims to communicate the results and outputs of the INFRARISK project. New research will be presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

The conference will address the following INFRAIRSK topics:

- Stress testing framework
- Road and rail example case studies
- INFRARISK Decision Support Tool (IDST)
- INFRARISK GIS Knowledge Base

**Date:** Thursday, 29<sup>th</sup> September 2016 09:00-16:00

**Venue:** DRAGADOS, Madrid, Avda. Camino Santiago 50, 28050-Madrid, Spain (the venue is at close distance from Airport/Madrid-Barajas)

**Who should attend?** Stakeholders including policy makers, owners, operators, managers, regulators, practitioners, research scientists, engineers, and civil protection bodies.

**Registration:** Please send your full name along with the name of your institution/company/project via E-mail to <a href="mailto:info@infrarisk-fp7.eu">info@infrarisk-fp7.eu</a>.

**No Fee:** There is no participation fee associated with the conference.

Contact: For any questions regarding the conference please contact M.J. Jimenez: mi.jimenez@csic.es

A detailed agenda for the event will be provided in May

More information: www.infrarisk-fp7.eu



## **APPENDIX B: Final Announcement of Final Conference**















(1) SINTEF



**RCAB** 



# Final Dissemination Conference, Madrid, 29th September 2016

**INFRARISK**, an EU-funded project (2013-2016), brings together 11 members with a well-balanced and strong partnership amongst universities, research institutions, SMEs, and a Large Enterprise, to develop a strategy to ensure that levels of infrastructure related risk due to natural hazards are acceptable. Stress tests are implemented through an operational framework that supports the work of managers, operators, stakeholders and policy makers, providing insight into the impact of extreme natural hazard events and enabling the vulnerability of their infrastructure networks to be assessed.

#### **About the Conference**

The final conference aims to communicate the results and outputs of the INFRARISK project. New research will be presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

The conference will address the following INFRARISK topics:

- Stress testing framework
- Road and rail example case studies
- INFRARISK Decision Support Tool (IDST)
- INFRARISK GIS Knowledge Base

#### **Date**

Thursday, 29<sup>th</sup> September 2016 09:30-16:30

#### Venue

DRAGADOS, Madrid, Avda. Camino Santiago 50, 28050-Madrid, Spain (the venue is at close distance from Airport/Madrid-Barajas )

#### Registration

Participation is open to all persons interested in this conference.

We encourage you to register for the conference early as the number of participants is limited by the number of seats in the conference room.

Please send your full name along with the name of your institution/company/project and your contact details via E-mail to info@infrarisk-fp7.eu.

#### No Fee

There is no participation fee associated with the conference.

#### **Programme**

09:30-10:00	Registration
10:00-11:00	SESSION 1
10:00-10:10	Welcome
10:10-10:30	Overview of INFRARISK project
10:30-11:00	Protection of critical transport infrastructure - a network management perspective
11:00-11:30	Coffee break
11:30-13:30	SESSION 2
11:30-12:00	INFRARISK Stress Testing Framework and Risk Assessment Methodology
12:00-12:30	Hazard Identification & Asset Vulnerability Assessment
12:30-13:00	INFRARISK Case Study: TEN-T Road and Rail networks (Italy and Croatia)
13:00-13:30	INFRARISK Decision Support Tool (IDST)
13:30-14:30	Lunch Break
14:30-16:30	SESSION 3: PANEL DISCUSSION (with the participation of similar EU projects)
14:30-14:50	Brief introductions of related EU projects
14:50-16:30	Discussion
16:30-16:40	Closing

#### Who should attend?

Stakeholders including policy makers, owners, operators, managers, regulators, practitioners, research scientists, engineers, and civil protection bodies.

#### **Contact**

For any questions regarding the conference please contact M.J. Jimenez: mj.jimenez@csic.es



www.infrarisk-fp7.eu



## **APPENDIX C: List of registered participants**

CO	NS	OR	TI	Ш	M

Maria José JIMÉNEZ	CSIC	SPAIN
Mariano GARCÍA-FERNÁNDEZ	CSIC	SPAIN
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D . DD41/	561	

Peter PRAK PSJ NETHERLANDS
Karlo MARTINOVIC GDG IRELAND
Francesca MEDDA UCL UK

Bryan ADEY

Juan Carlos LAM

ETHZ

SWITZERLAND

Jürgen HACKL

ETHZ

SWITZERLAND

Magnus HEITZLER

ETHZ

SWITZERLAND

Pieter van GELDER

SWITZERLAND

NETHERLANDS

Teresa SALCEDA **DRAGADOS SPAIN** Dumitru ROMAN **SINTEF NORWAY** Robert CORBALLY Roughan & O'Donovan (ROD) **IRELAND** Julie CLARKE Roughan & O'Donovan (ROD) **IRELAND** Eugene O'BRIEN Roughan & O'Donovan (ROD) **IRELAND** Miguel SEGARRA **DRAGADOS SPAIN** Zed SABEUR IT innovation UK

#### **PANELISTS**

Atilla ANSAL European Assoc. Earthquake Engineering EAEE TURKEY
Jóse LÓBEZ Ministry Public Works SPAIN
Jésus RODRÍGUEZ PTEC SPAIN

Peter PETIET TNO NETHERLANDS
Alan O'CONNOR TRINITY COLLEGE IRELAND
Brian BELL Univ. Surrey IRELAND

#### **PARTICIPANTS**

Andrea ALCALDE GUTIÉRREZ Vias y Construcciones S.A. **SPAIN** Andoni ALKORTA **INTERBIAK SPAIN** Marta ÁLVAREZ MORENO ACCIONA Infraestructuras S.A. **SPAIN** Pedro AVELLANOSA SANTOS **SPAIN GEOCISA David BURGOS BARRERO** Vias y Construcciones S.A. **SPAIN** Ricardo CASTELO DE LA TORRE ACCIONA Infraestructuras S.A. **SPAIN** Albert COMTE **SPAIN CEDEX** Silvia DÍAZ ALCOLEA **GEOCISA SPAIN** Jose Manuel DURÁN CUEVAS **CDTI SPAIN** Jesus Mª ESTRADA VILLEGAS **GRUPO TRAGSA SEPI SPAIN** Jesús A. FERNÁNDEZ CORCHERO **PROINTEC SPAIN** Francisco J. MORALES-GAMIZ **CEMOSA SPAIN** Clara GALARZA GIORGIO **DRACE INFRAESTRUCTURAS SPAIN** Manuel GÓMEZ DE MEMBRILLERA **OFITECO SPAIN** Johana GONZÁLEZ **OFITECO SPAIN** 

Grigore HAVARNEANU	INTERNATIONAL UNION OF RAILWAYS	FRANCE
Onno HAZELAAR (A.H.M.)	Pro Rail	NETHERLANDS
Ramon HERNANDEZ ESTEVEZ	PROINTEC	SPAIN
Joaquin de HITA ALONSO	TECNICAS REUNIDAS	SPAIN
Jose María HONTORIA	SACYR	SPAIN
Noemi JIMÉNEZ-REDONDO	CEMOSA	SPAIN
Jürgen KRIEGER	Federal Highway Research Institute (BASt)	GERMANY
Susana LAGÜELA LÓPEZ	University of Vigo	SPAIN
José LÓBEZ	MFOM	SPAIN
Mónica LÓPEZ	Development Bank of Latin America	MADRID
Yasen MARKOV	Ministry of Transport	BULGARIA
Elena MARTÍN	DRAGADOS	SPAIN
Cristina MARTINEZ GARCÍA	SACYR	SPAIN
Carlos MARTIN-PORTUGUES	ACCIONA Infraestructuras S.A.	SPAIN
Pablo MOCHÓN	SACYR	SPAIN
Juan Jesús MUÑOZ	GEOCISA	SPAIN
María NAVARRO CAMALLONGA	PROINTEC	SPAIN
David ORTIZ	SACYR	SPAIN
Ana ORTS PONS	PROINTEC	SPAIN
Laura PARRA RUIZ	CEDEX	SPAIN
José Mª PEREIRA PÉREZ	DRACE INFRAESTRUCTURAS	SPAIN
Miguel PÉREZ-GALDÓS	ACCIONA Infraestruc. S.A.	SPAIN
Christian PÉREZ-JIMÉNEZ	TECNALIA/RESILIENCE INFRASTRUCTURES	SPAIN
Montse POZA VALLEJO	DRAGADOS	SPAIN
Eva PRIETO	DRACE INFRAESTRUCTURAS	SPAIN
Marta de REGOYOS SAINZ	ACCIONA Infraestructuras S.A.	SPAIN
Julián Jorge RODRÍGUEZ	Vias y Construcciones S.A.	SPAIN
Vicenta RUBERT ALTAVA	Dirección General de Vivienda y Rehabilitación	SPAIN
Jesús SANTAMARÍA	MINISTRY PUBLIC WORKS	SPAIN
Francisco SANTIAGO MESA	DRAGADOS	SPAIN
Matthias SCHLÖGL	AIT Austrian Institute of Technology GmbH	AUSTRIA
Miguel SEISDEDOS	IRIDIUM	SPAIN
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Raquel ZAPARDIEL SÁEZ	Dirección General de Vivienda y Rehabilitación	SPAIN
Antonio GOMEZ GALVEZ	CDTI	SPAIN
Álvaro RODÍGUEZ GARCÍA	TÉCNICAS REUNIDAS	SPAIN
Pablo José LÓPEZ VILARES	CCS	SPAIN

#### **APPENDIX D: Presentations**





# INFRARISK Novel indicators for identifying critical INFRAstructure at RISK from natural hazards

# **Final Dissemination Conference**

Miguel Segarra

**DRAGADOS** 

Madrid, Spain

29 October, 2016





# Some Ideas

- 1. Protecting citizens from natural hazards.
- 2. Minimize risks and vulnerabilities of European infrastructure networks.
- 3. Horizon 2020 Societal Challenge 4: Smart, Green and Integrated Transport.
  - 1. Resource efficient transport that respects the environment.
  - 2. Better mobility, less congestion, more safety and security.





# Some Ideas

- 1. Rare low frequency high consequence natural hazards events (black swans) can have catastrophic impacts on critical infrastructures and trigger cascading effects.
- 2. Capitalise on knowledge acquired so far in various sectors having already developed stress test methodologies and from the lessons learned after Fukushima and adapt it for critical (non nuclear) infrastructure types that may be threatened by key natural hazards in Europe.
- 3. Reinforced European safety assessment capacity. Improved and more reliable stress tests of critical infrastructures. Support for decision making and prioritisation in the field of mitigation options and support to preparedness. Better surveillance capacity.





#### Some Ideas

- 1.Better assessment allows us to be prepared in terms of:
  - 1. Increasing the resilience of the network.
  - 2. Providing system redundancy in the event a hazards realizes.
  - 3. Prioritize the investment for hardening the network before the impact of extreme weather.
  - 4. Update crisis and emergency plans in advance, making them more efficient.

## FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate change)





Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

www.infrarisk-fp7.eu

#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960





# Overview of the Project & Objectives of the Final Dissemination Conference

Eugene OBrien
Roughan & O'Donovan
Dublin, Ireland



**Final Dissemination Conference** 

29th September 2016, DRAGADOS, Madrid, Spain





## **Objectives of the Final Conference**

- General Overview of the Project
  - Why INFRARISK?
- Disseminate the key aspects of the research
  - Stress testing, Hazard Assessment & Structural Vulnerability
- Demonstrate the validity of the methodologies and tools developed
  - Case study description & Decision Support Software Tool
- Highlight Research Activities of similar EU projects
  - RAIN, INTACT and STREST





## **Overview - Project Details**

## Funding Vehicle

EU 7<sup>th</sup> Framework Programme

## Work Programme

2013 Cooperation Theme 6 – Environment (incl. Climate Change)

## Call Topic

Env.2013.6.4-4 Towards stress tests for critical infrastructure against natural hazards

## Duration & Budget

October 2013 – September 2016 approx. €2,8 million







## **Overview - Background to the Concept**

- Preparedness and resilience/vulnerability of society
- Natural hazards are increasing:
  - ➤ Increased land occupation
  - > Eastwards expansion of the EU
  - > Ageing infrastructure
  - ➤ Climate Change
  - > Human activity
  - ➤ Pan European Networks





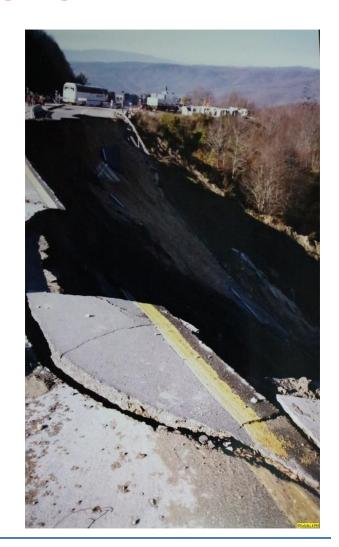






#### **Overview - EU Concerns**

- In 2014, there were 324 disasters globally
- 141 million people were affected
- Almost 8000 fatalities
- Economic damage of US\$ 99 billion









#### **Overview - EU Concerns**

## The Izmit earthquake in Turkey:

- Railway running parallel to the fault was seriously disrupted
- Roads were damaged by landslides
- 60 km of trans European network disrupted due to viaduct collapse
- 17 000 people killed
- 0,5 million lost their homes
- Reconstruction cost of €15 billion













### **Overview - EU Concerns**

## **Central European Floods of 2002**

 250 roads and 256 bridges damaged in Germany and Czech Republic

#### **UK Floods of 2013/14**

Damage of up to €1 billion









#### **Overview - Resilient Infrastructure**

- We need to be able to assess resilience
- 96% of current spending is on response only 4% on prevention and preparedness!

Improving flood defences for 1-in-100-year flood would

cost €1,75 billion









#### **Overview - Resilient Infrastructure**

- We need to be able to assess resilience
- 96% of current spending is on response only 4% on prevention and preparedness!
- Improving flood defences for 1-in-100-year flood would

cost €1,75 billion

But would save €7 billion!









## **Challenges for Resilient Infrastructure**

- Increased Traffic (1,5% to 2% per year in tonne-km)
- Ageing Infrastructure (30% of railway bridges > 100 years old)
- Budget cuts!







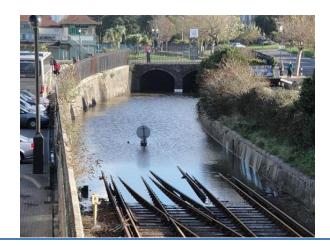






#### **Overview - Focus of INFRARISK**

- Stress testing methodology
- Low probability, high consequence natural hazard events
  - Earthquakes, floods and landslides (including cascading effects)
- European road and rail infrastructure (TEN-T)
- Risk quantification
  - Physical damage, transport delays, economic loss













## **Overview - Outputs**

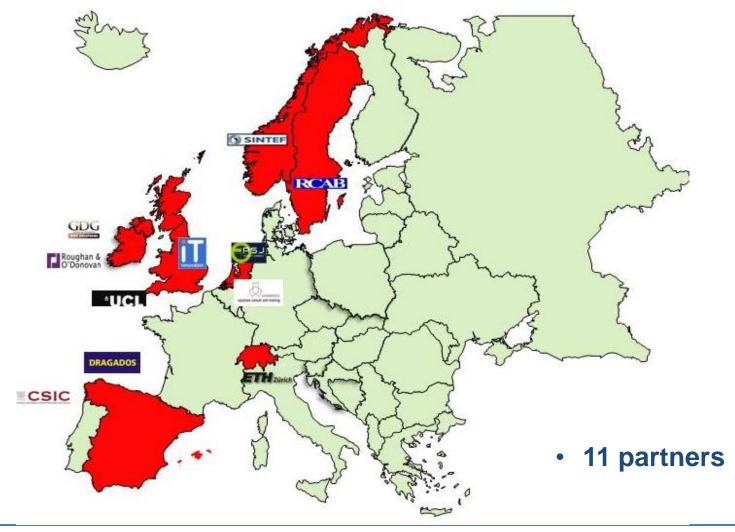
- A harmonised multi-risk assessment framework
- INFRARISK Decision Support (Software) Tool
- Training Modules for Infrastructure Managers



















#### **SME** partners

- Roughan O'Donovan
- **GDG**
- **PSCT**
- **PSJ**
- **Ritchey Consulting**











#### **Research Institutes &**

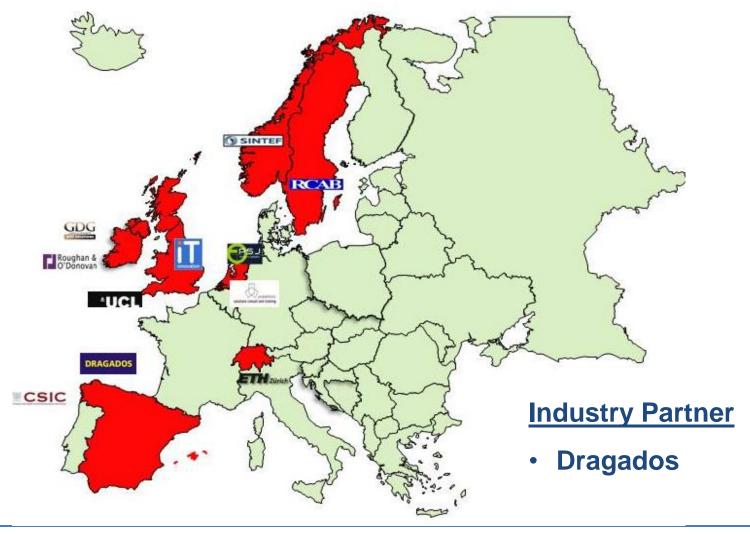
#### **Universities**

- **ETH Zürich**
- UCL
- CSIC
- **Univ Southampton**
- SINTEF







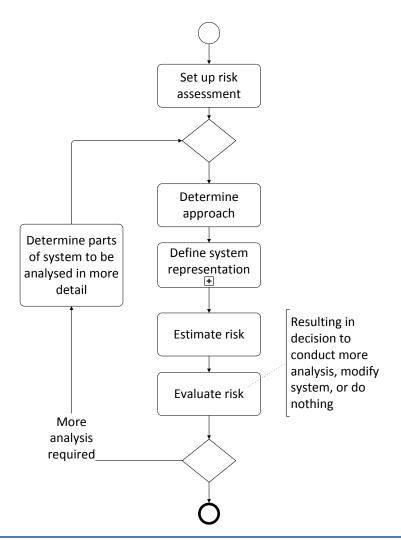








#### **Overview – Stress Test Framework**













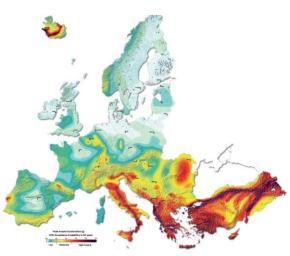


## **Overview - Hazards**



Alfieri et al. 2013





Giardini et al. 2013















### **Overview - Infrastructure Elements**







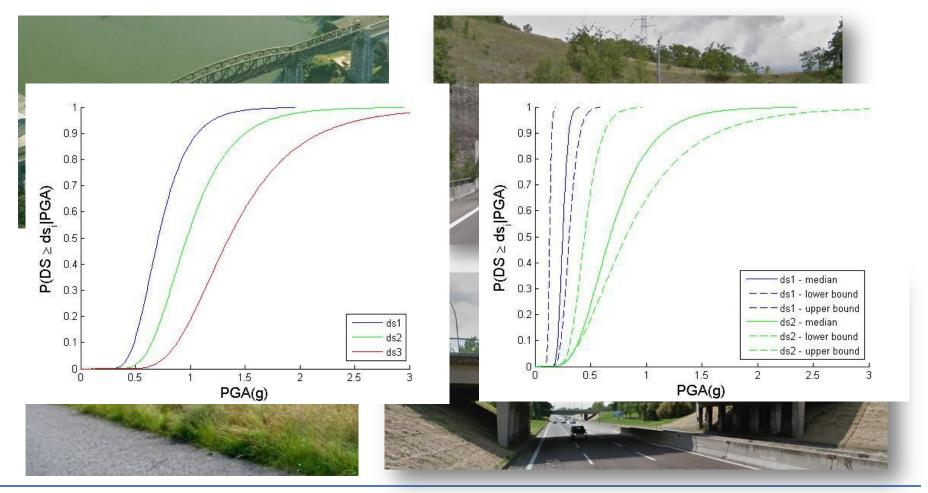








### **Overview - Infrastructure Elements**

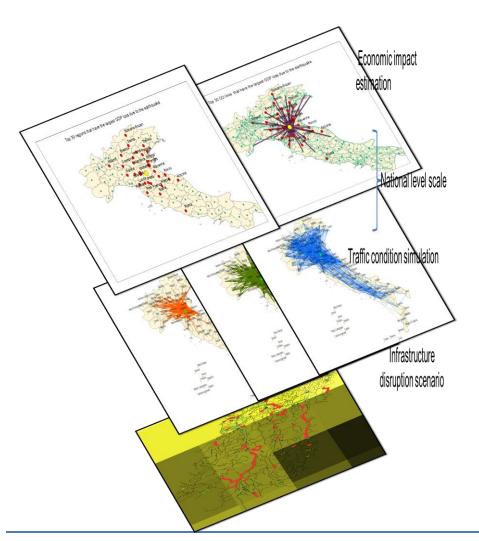


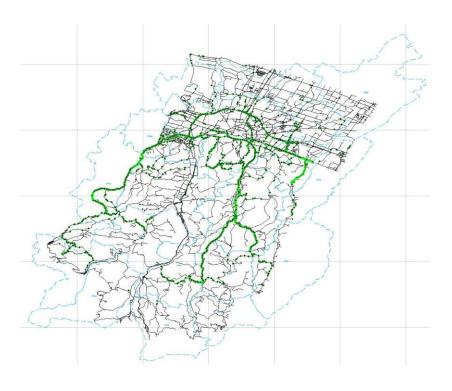






## **Overview - Traffic Modelling**

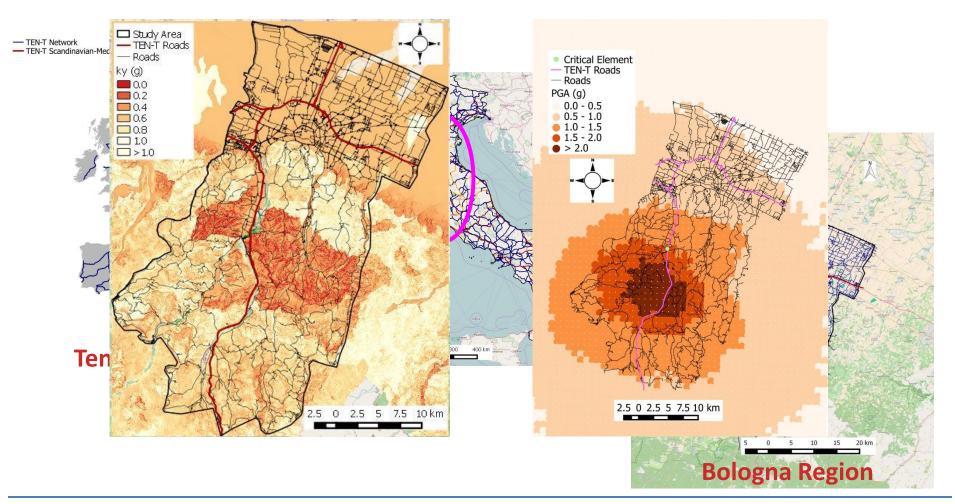








#### **Overview - Case Studies I**

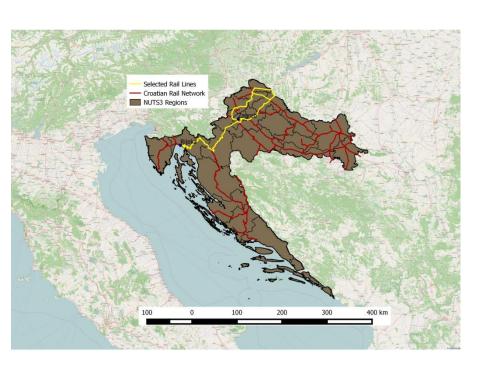


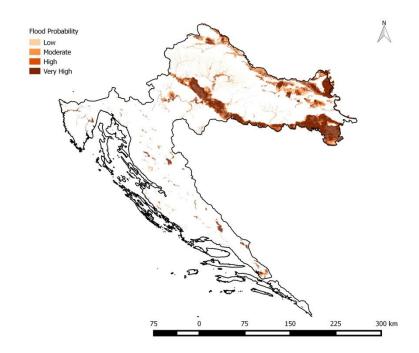






### **Overview - Case Studies II**

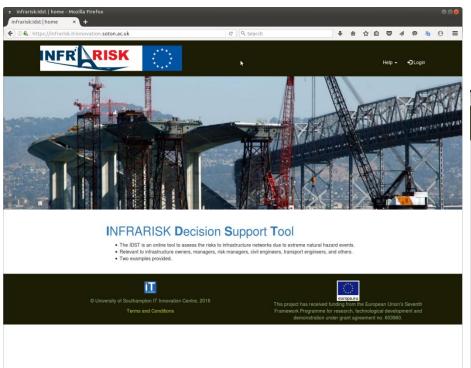


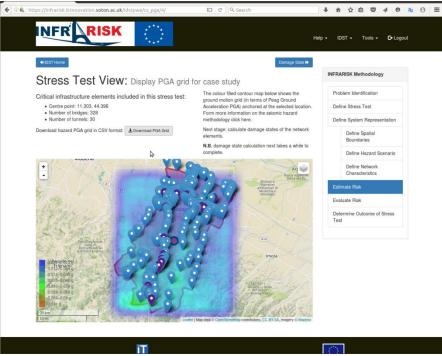






## **Overview - Decision Support Tool**

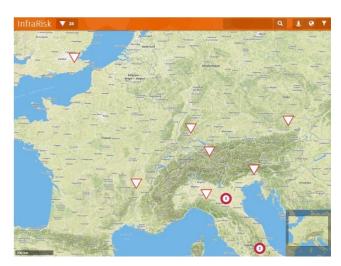








## **Overview - Knowledge Base of Elements**













## **Overview - Training Course**

- 1. Introduction
- 2. Stress Testing Procedure and Overarching Risk Assessment methodology



- 3. Infrarisk Decision Support Tool (IDST)
- 4. The Objective Ranking Tool (ORT) and its application to the Croatian Rail Case Study







## **Overview - Related Projects**

RAIN (Coordinator – Trinity College Dublin)



Risk Analysis of Infrastructure Networks in response to Extreme Weather

INTACT (Coordinator – TNO)



On the Impact of Extreme Weather in Critical Infrastructure

• STREST (Coordinator – ETHZ) STREST



Harmonized approach to stress tests for critical infrastructures against natural hazards





#### **Conference Structure**

10.30-11.00: Protecting Critical Infrastructure (Brian Bell)

11.00-11.30: Break

11.30-12.00: Stress Testing Methodology & Framework (Bryan Adey, Pieter Van Gelder)

12.00-12.30: Hazard Identification and Asset Vulnerability (Dina D'Ayala)

12.30-13.00: Italian Road and Croatian Rail Case studies (Julie Clarke, Robert Corbally)

13.00-13.30: Decision Support Tool & Database (Zoheir Sabeur, Titi Roman)

13.30-14.30: Lunch

14.30-14.50: RAIN and INTACT (Alan O' Connor, Peter Petiet)

14.50-16.30: Panel Discussion









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#### **Acknowledgement**

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# Protection of critical transport infrastructure – a network management perspective

**Brian Bell** 

Advisory Board Chair & University of Surrey Neath & Guildford, UK



**Final Dissemination Conference** 

Friday 29th September 2016, Dragados, Madrid, Spain





#### **Contents**

- 1. Novel indicators for identifying critical infrastructure at risk from natural hazards
- Novel indicators for identifying critical (transport) infrastructure at risk from natural hazards
- 3. Novel indicators for identifying critical infrastructure at risk from natural hazards
- 4. Novel indicators for identifying critical infrastructure at risk from natural hazards







#### Infrastructure

## What do we mean by infrastructure?

- •Simply anything man made that is necessary to sustain society as we now know it today.
  - Utilities
    - Water, electricity, gas, sewerage, telephone, district heating
  - Transport
    - •Roads, railways, airports, ports, commercial waterways
  - Buildings
    - Housing, shops, offices, factories







## **GB** Transport Infrastructure

Network Rail (Great Britain)	16,000km of railway with 40,000 bridges, 17,000 retaining walls, 700 tunnels and 2,500 stations
London Underground (London)	400km of railway with 270 stations and 180km of tunnels
Highways England	7,754km of trunk road and motorway with 17,000 structures including 8,800 bridges
Local roads (Great Britain)	380,000km of roads with around 80,000 bridges
Canal & River Trust (Great Britain)	3,540km of canal with 1,654 locks, 54 tunnels, 3,115 bridges, 417 aqueducts and 91 reservoirs







## Transport infrastructure networks are complex and bring together diverse disciplines and components

- •Civil
  - •Earthworks (embankments & cuttings), structures (bridges tunnels & retaining walls), road pavements/railway tracks, drainage, gantries, docks, locks
- Building
  - Stations, airports, depots, signal boxes, sub stations
- Mechanical
  - Pumps
- Electrical
  - Signals, power supplies, lighting
- Telecommunication
  - •Fixed links (copper & fibre optic), mobile networks, radio systems







## **Critical Transport Infrastructure**

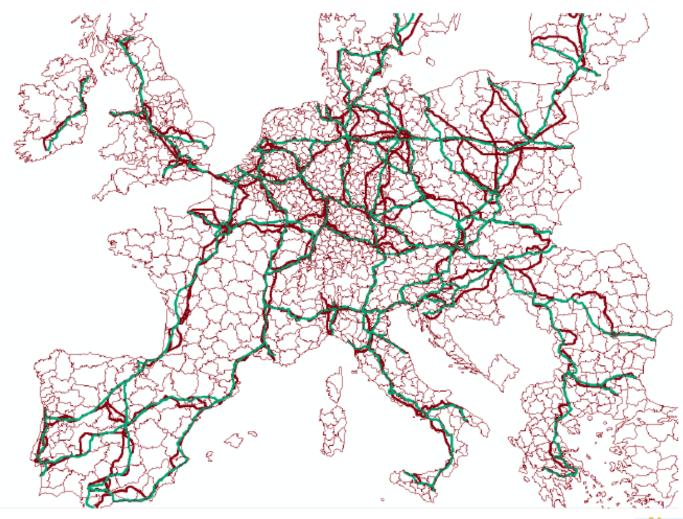
The INFRARISK project team has identified the TEN-T Trans European Road and Rail Networks as being critical to the economic and social health of Europe







### The TEN-T Network (Road shown blue, rail shown red)

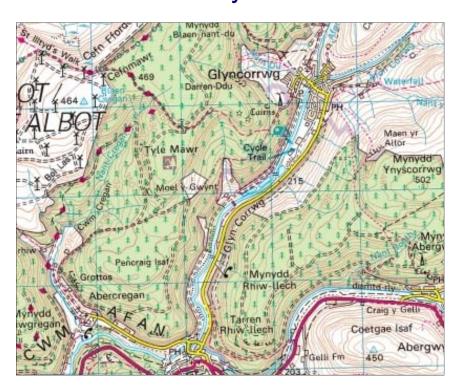








Nevertheless to infrastructure network managers and local communities almost all other road and rail routes are critical, as their loss will inhibit free movement and may isolate communities





So the developments achieved within INFRARISK need to be capable of deployment at different levels







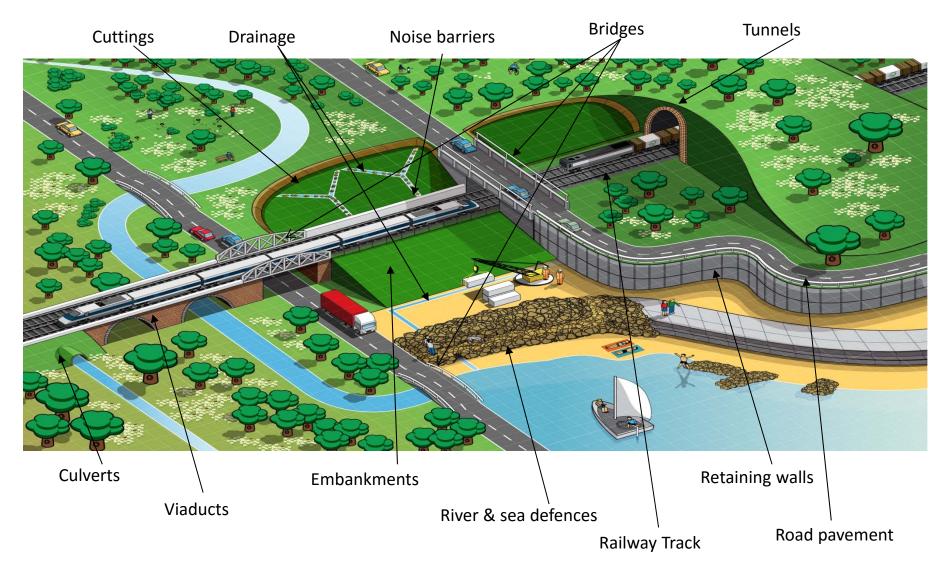
The safety and availability of land transport infrastructure depends principally on well maintained civil engineering assets:

 bridges, tunnels, earthworks (embankments and cuttings), retaining walls, road pavements, railway tracks and drainage systems as shown on the next slide















All of these assets are at risk from natural hazards such as earthquakes, landslides, rainfall and flooding.

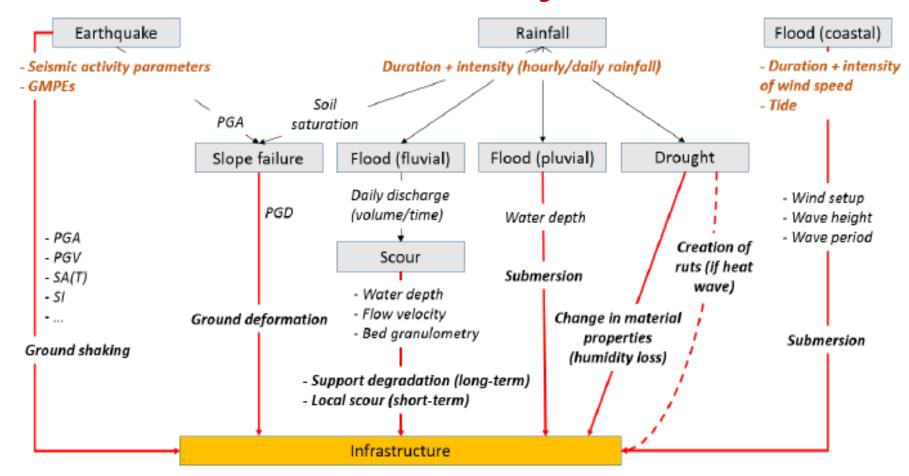
The INFRARISK project has chosen to concentrate on earthquakes and flooding, including earthquake induced landslides and scouring as outlined on the next slide.







## Hazards considered by INFRARISK



So let's look at some of the effects of these hazards on transport infrastructure







## Earthquakes















### Rain induced slope failures









## Fluvial flooding







### Bridges damaged by scour



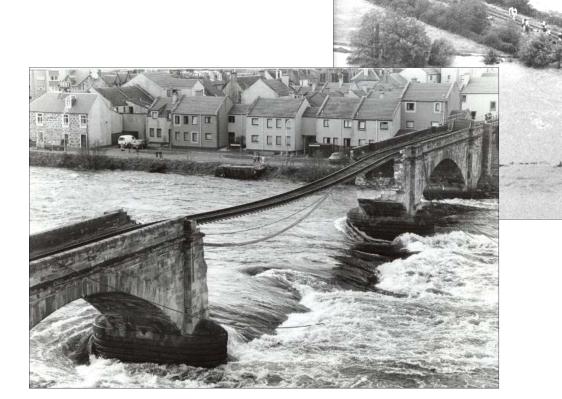








### Bridge collapses due to scour









## Pluvial flooding







### Drought & heat













### Coastal storms and flooding







#### **Indicators**

From a Network Management perspective

Maintaining safety is paramount

Maintaining a service to the public is the second most important priority

This means that transport infrastructure assets such as embankments, tunnels and major bridges are hyper critical and need to be treated as if they have an infinite life so they need to be protected against natural hazards alongside the normal maintenance interventions to inhibit deterioration.

Indicators of susceptibility can offer benefits for network management by suggesting priorities for action







#### What indicators currently exist for trigger events?

#### Earthquakes

None for an actual event but we have knowledge of earthquake prone areas

#### Pluvial flooding

 Principally weather forecasts, but these are only really accurate over one or two days and may not highlight very localised events which tend to be the main source of hazards to infrastructure

#### Fluvial flooding

- Knowledge of rain events in relevant catchment areas
- Distance from rain event to asset location
- Relative importance of tributary affected

#### Drought & heat

- Again, principally weather forecasts for the big picture
- Knowledge of micro-climates which could lead to localised hot spots

#### Coastal events

- Once again, weather forecasts. However those predicting severe storms are more likely to be accurate over longer time periods.
- Tide tables to judge the effect of storm surges







#### What indicators currently exist for infrastructure at risk?

- Natural slopes
  - Knowledge of local geology
  - Height above the infrastructure under consideration
  - History of landslides
- Earthworks (man made slopes)
  - Age of the earthwork
  - Examination reports and knowledge of local geology
  - Proximity of rivers and streams
  - History of failures in the area
- Structures
  - Knowledge of foundation depths
  - Cross section available for the passage of water
  - Examination reports recording current physical condition
  - Any records of previous floods survived

The INFRARISK project has developed new indicators that we will learn about today







## I just hope that they are a bit more sophisticated than this...



## Thank you for listening



## FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate change)





Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

www.infrarisk-fp7.eu

#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960





# A process to assess infrastructure related risks due to natural hazards with stress tests – Part 1

**Infrarisk Consortium** 

ETHZ – Bryan T. Adey, Jürgen Hackl, Juan Carlos Lam and

**Magnus Heitzler** 

**PSCT – Pieter van Gelder, Noel van Erp** 

# Problem





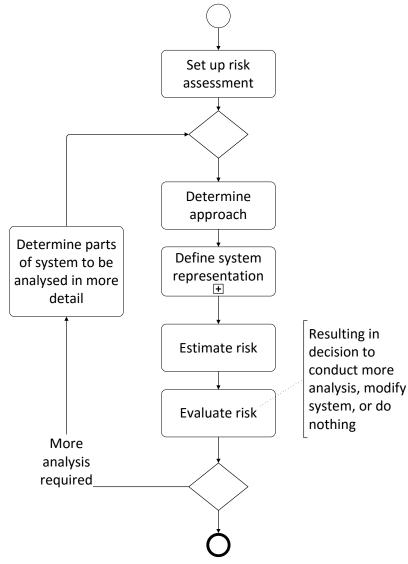




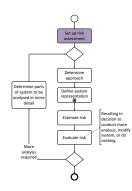
Infrarisk - Novel Indicators for Identifying Critical INFRAstructure at RISK from Natural Hazards

## **Process**

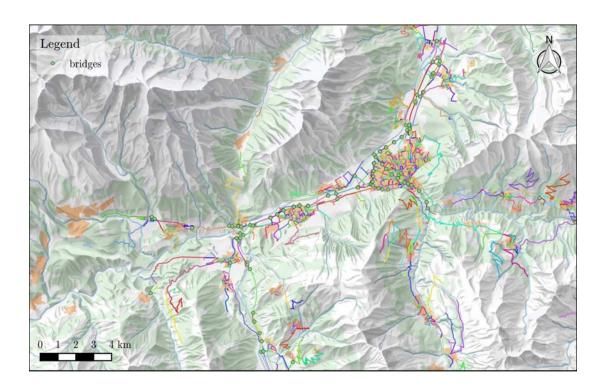
- A process to assess infrastructure related risks due to natural hazards was developed
- For use in a wide range of situations, e.g variations in
  - The types of infrastructure to be included in the assessment,
  - The types of hazards to be included in the assessment,
  - The expertise available,
  - The time available,
  - The need for detailed information, and
  - The computer support available.
- It encourages only obtaining as much information as required.



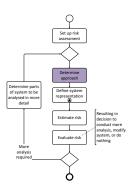
# Set up risk assessment



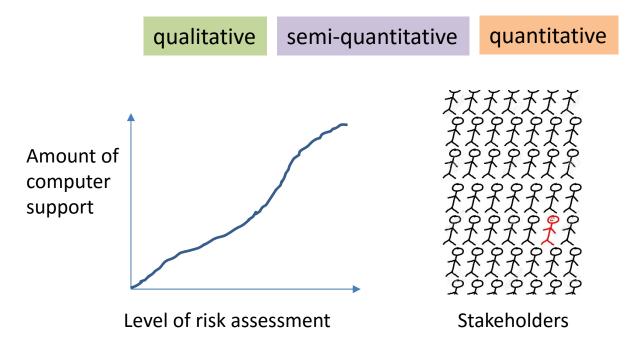
- determine what needs to be checked
- define acceptable levels of risk,
- affects the definition of the system representation, and the requirements to conduct the risk assessment



# Determine approach

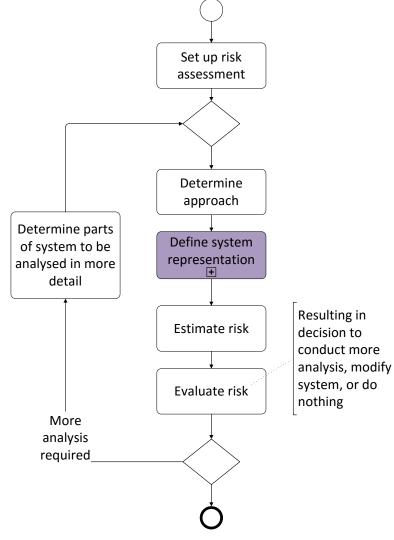


- determine how risk assessment will be conducted
- decide how to aggregate multiple risks

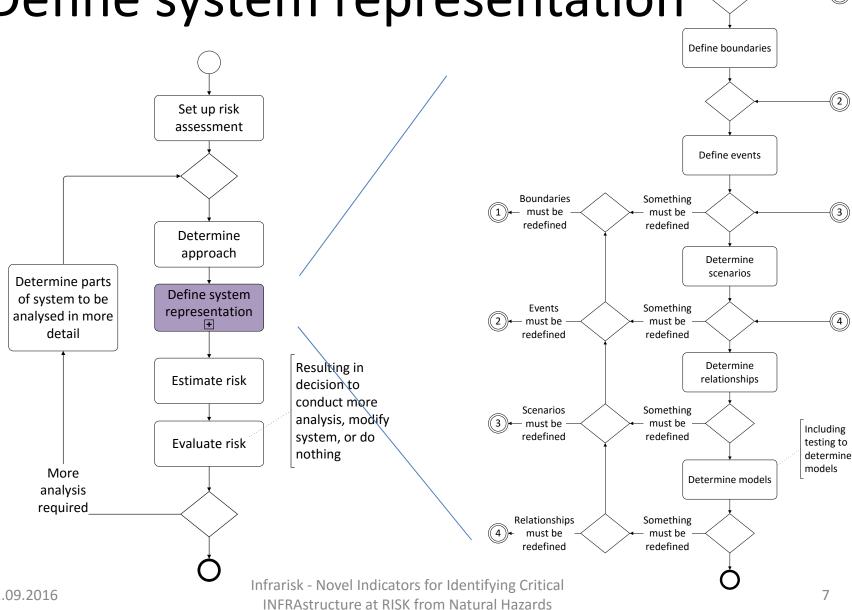


# Define system representation

- determining how the system will be modelled both spatially and temporally
- the system includes
  - the natural environment, e.g. amount of rain, amount of water in rivers,
  - the physical infrastructure, e.g. the behaviour of a bridge when subjected to high water levels, and
  - human behaviour, e.g. traffic patterns when a road bridge is no longer functioning.
- The model includes correlations between events and cascading events

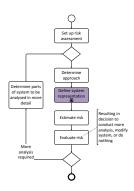


Define system representation



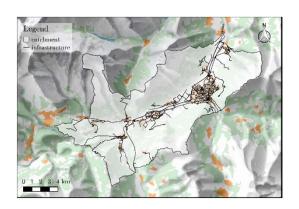
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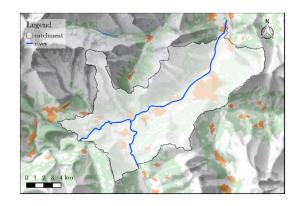
# Define boundaries

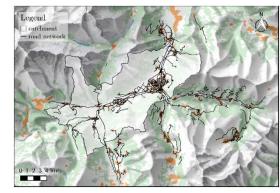


- define spatial boundaries
- define temporal boundaries
- they are different depending on the part of the system being analysed.

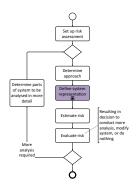








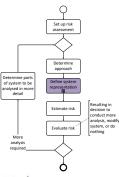
# Define events



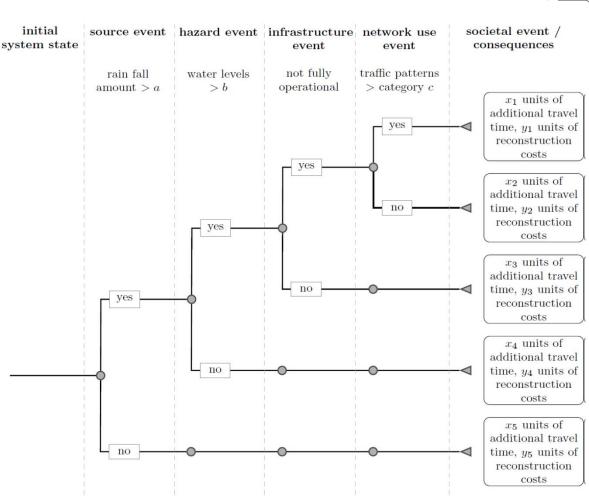
identify all events (cascading and non-cascading) to be analysed / modelled.

<b>Event type</b>	Examples of event and intensity measures
Source	For a rainfall source event, rainfall of pattern x with water per minute of over y mm <sup>2</sup> /s for more than 5 hours.
Hazard	For a flood hazard event, water levels reaching x m depth in locations a, b and c, and amounts of water per second coming in contact with bridge i over j m <sup>3</sup> /s.
Infra-structure	For a bridge collapse, damage resulting in full closure of the road, damage results in the closure of one lane of traffic, damage resulting in no closure of the road.
Network use	For example, due the freight corridor between Rotterdam and Genoa being closed 50% of goods is put onto trucks, 40% of goods is diverted over other train routes and 10% is not delivered.
Societal	Amounts an infrastructure manager spends on reconstruction amounts users spend in additional travel time

# Define scenarios



- link events together from the source to the societal events.
- determine the value of the intensity measures to provide clarity on how events are considered to be related
- do not estimate their probability of occurrence or put a value on the consequences



Infrarisk - Novel Indicators for Identifying Critical INFRAstructure at RISK from Natural Hazards

# Define relationships

Set up risk assessment

Determine parts of system to be analysed in more octal 

Estimate risk 

More analysis 
requires 

Tender of the conduct more octal 

Estimate risk 

Estimate risk 

Resulting in decision to conduct more octal 

Estimate risk 

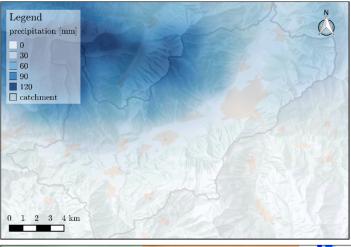
Tender octal 

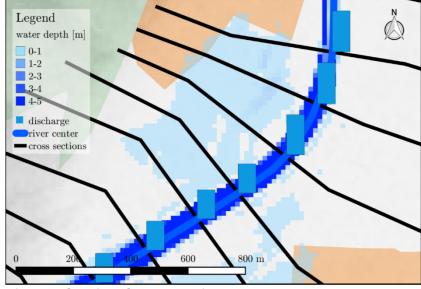
Estimate risk 

Tender octal 

Tender o

- Determine the relationships between the events
- involve testing to ensure that the relationships between events are defined correctly

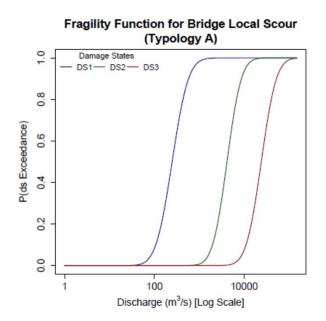


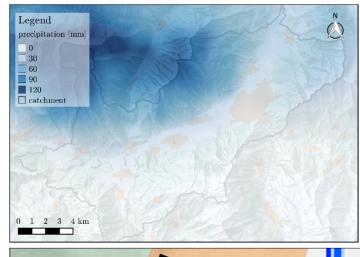


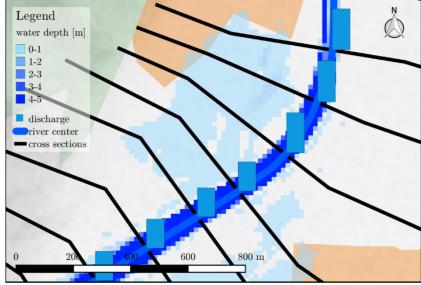
Infrarisk - Novel Indicators for Identifying Critical INFRAstructure at RISK from Natural Hazards

# Define models

 Determine the models of the relationships



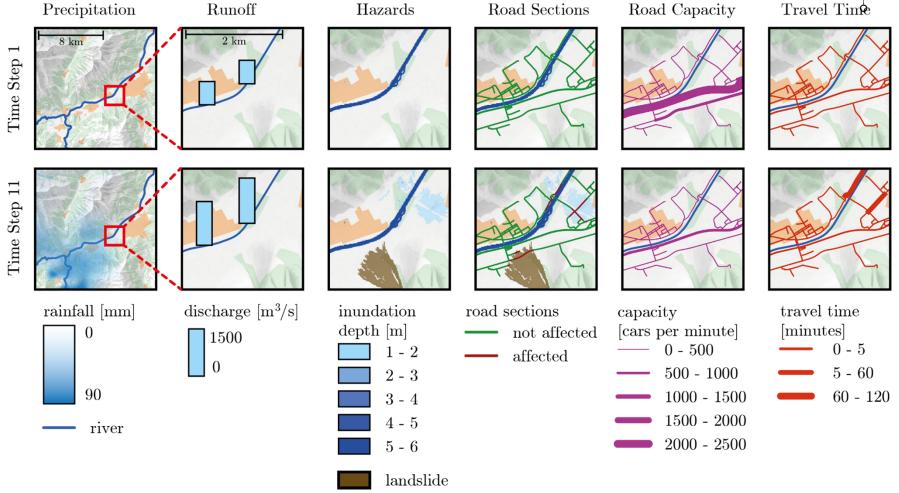




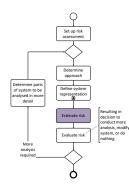
Infrarisk - Novel Indicators for Identifying Critical INFRAstructure at RISK from Natural Hazards

# Define models

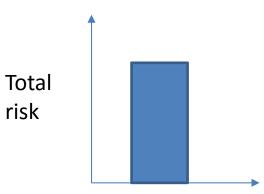


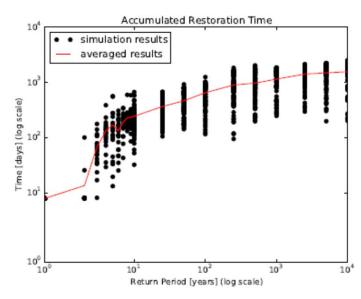


# Estimate risk

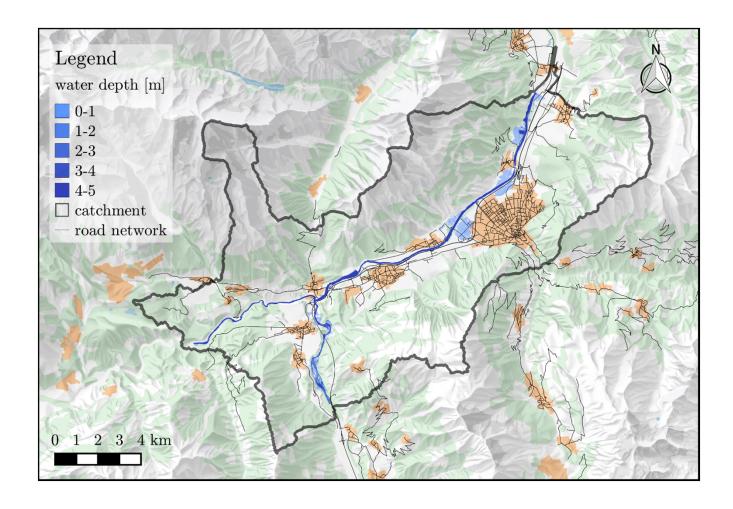


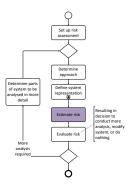
- estimate and aggregate
- pay attention to the certainty of the estimation of
  - the probabilities of occurrence and
  - consequences of each of the scenarios



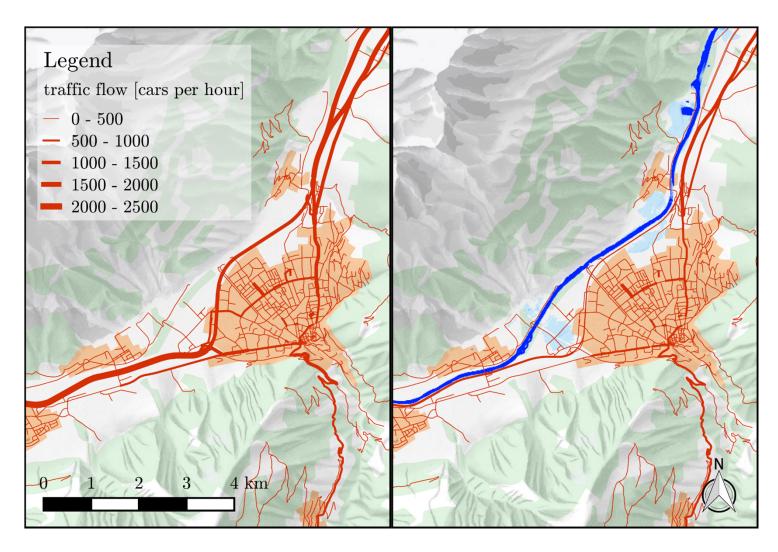


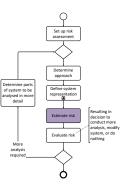
# Estimate risk



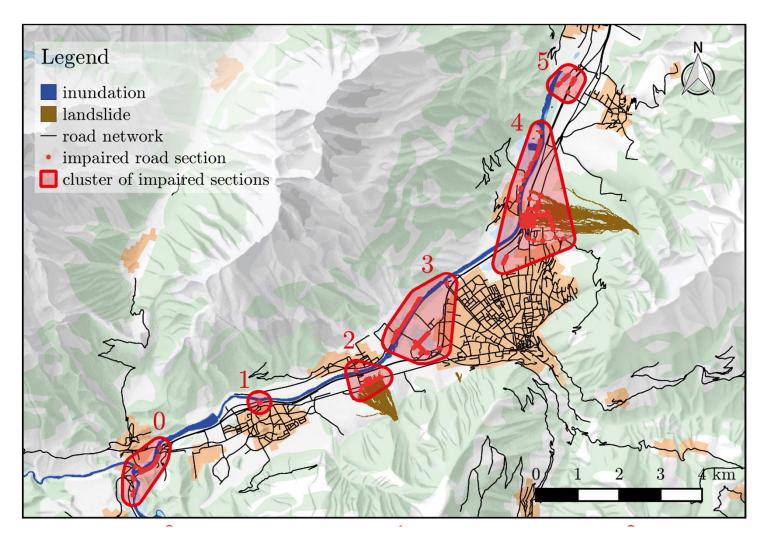


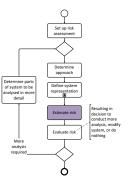
# Estimate risk



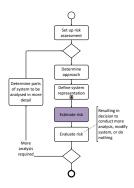


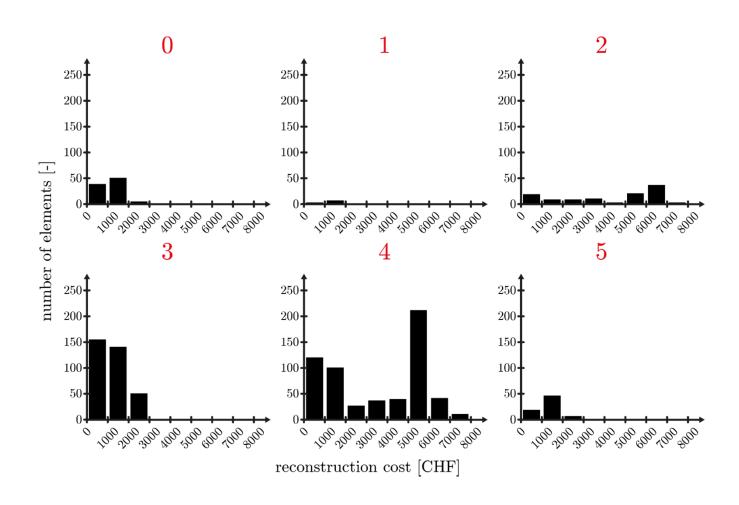
## Estimate risk





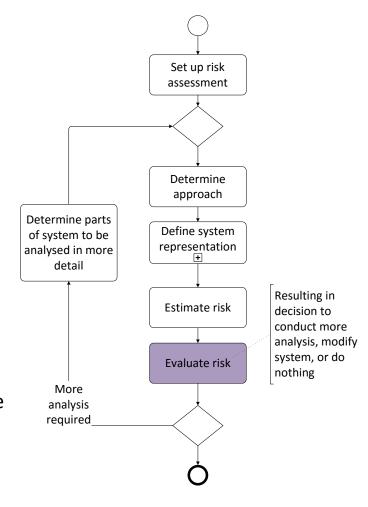
### Estimate risk





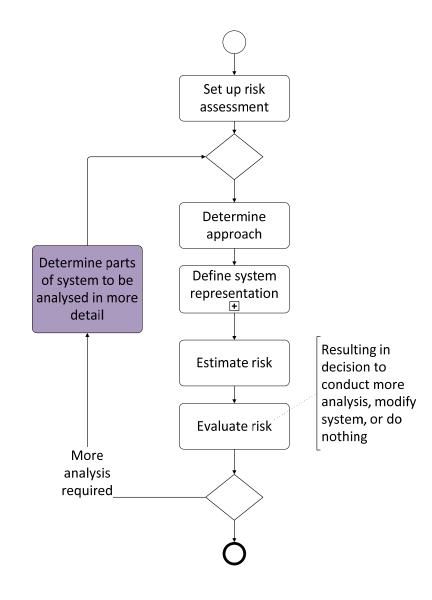
### Evaluate risk

- determine the meaning of the estimated risk to stakeholders
- decide as to whether the risk assessment has been satisfactorily done,
- ends with one of following decisions made:
  - Risk assessment performed satisfactorily and risk levels acceptable
  - Risk assessment performed satisfactorily and risk levels not acceptable
  - Risk assessment not conducted satisfactorily (more analysis is required)



# Determine parts...

- more detail, if any
- select parts likely to generate the most reduction in uncertainty
- do not only select parts where risk is likely to be reduced in a way that will result in a pass
- avoid preferential selection of parts, the uncertainty related to each part of the system need to be determined



### Conclusion

- A process to assess infrastructure related risks due to natural hazards was presented
- It can be used by all infrastructure managers in all of the wide range of situations in which they might be including variations in
  - The types of infrastructure to be included in the assessment,
  - The types of hazards to be included in the assessment,
  - The expertise available,
  - The time available,
  - The need for detailed information, and
  - The computer support available.
- More information on the process, and an example using a road network and flood and landslide hazards, can be found in Deliverable 4.2.



### FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate change)





Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

www.infrarisk-fp7.eu

#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960





# A process to assess infrastructure related risks due to natural hazards with stress tests – Part 2

**Infrarisk Consortium** 

**PSCT – Pieter van Gelder, Noel van Erp** 

ETHZ – Bryan T. Adey, Jürgen Hackl, Juan Carlos

Lam and Magnus Heitzler

Infrarisk Final Workshop

19<sup>th</sup> September 2016, Madrid, Spain





#### **Stress Testing Concept**

- Stress tests refer to the analysis of a particular system or subsystem under a specific set of adverse conditions to determine the potential losses.
- The outcome of stress tests can be used to inform decisions regarding the protection of existing or future-planned infrastructure, which can contribute to the resilience of critical transport networks.





#### **Stress Test Definition**

In a stress test we just construct the one outcome probability distribution for some given adverse scenario S, say,  $p(O_{i^{(s)}}|S,A^{(0)})$  where the  $O_{i}^{(s)}$  are the outcomes, for  $i^{(S)} = 1,..., n^{(S)}$  and  $A^{(0)}$  is the action to keep the status quo.





#### **Stress Test Definition**

- The stress output consists of, in probability theoretical terms, an outcome probability distribution which is conditional to the proposed stress scenario; i.e. a conditional outcome distribution.
- Typical stress outcome metrics are the costs of physical repairs to the network, delay times for network users, loss of connectivity etc.





### Missed stress test opportunity







#### Stress test framework follows the risk framework of WP4

#### We zoom in on the following steps:

- Generate a natural hazard stress scenario  $\rightarrow$  Spatial hazard map
- Spatial hazard map → Probability map via conditional fragility curves
- Probability Map → Damage state scenario selection via smart algorithms (MC, NS, PSA)
- Selected set of damage state scenarios → Estimation of outcome metric → Evaluation of the outcome metric





#### Selecting stress scenario's

- Stress scenarios can be based on
  - historical scenarios, employing shocks that occurred in the past,
  - hypothetical/synthetic scenarios, constructed to take account of plausible changes in circumstances that have no historical precedent.
  - extreme value theory, which applies statistical analysis to the tails of return distributions,
  - maximum loss approach, which estimates the combination of factors that would cause the largest loss to the system under consideration





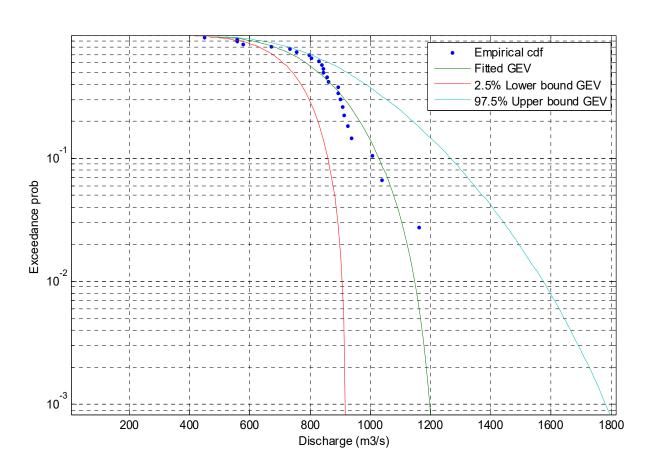
#### Selecting stress scenario's

- Structured brainstorming sessions, such as conducted in general morphological analyses (Ritchey, 1998), may be used to elicit stress scenario's
- One possible instrument by which to structure a brainstorming session is the use of Delphi panels and Similarity Judgment (Prak, 2009)





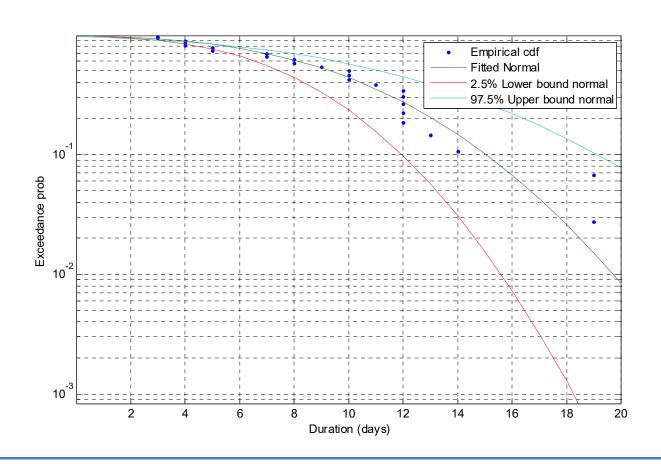
# Selecting stress scenario's: 1/T years flood hazard (intensity)







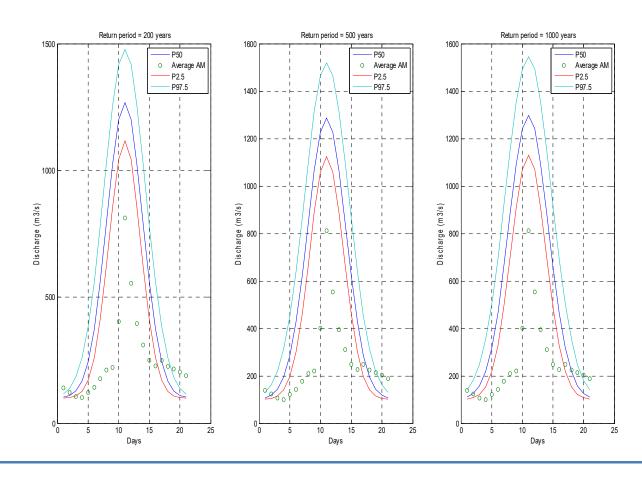
# Selecting stress scenario's 1/T years flood hazard (duration)







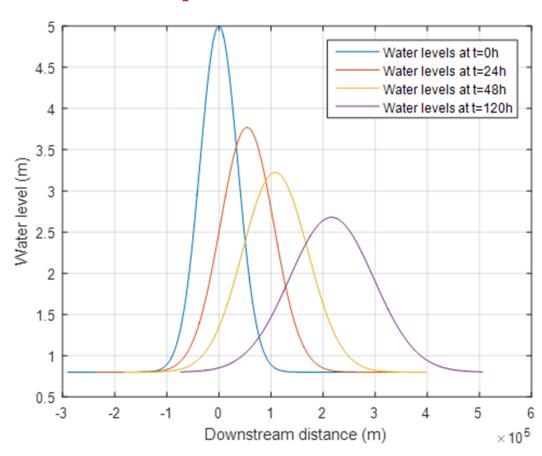
# Selecting stress scenario's (hydrographs)







### Propagation of flood stress scenario downstream 'Spatial hazard'

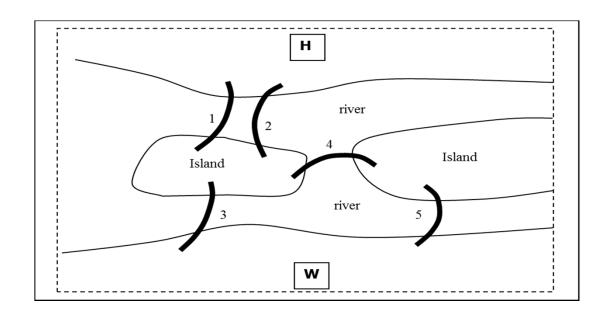






#### Infrastructural systems

 Infrastructural systems can be modeled as fault tree systems with a large number of (dependent) components







#### Spatial hazard map → Probability map

Say we have a probability map for damage states of objects arranged in a 11-by-11 grid, caused by the spatial hazard



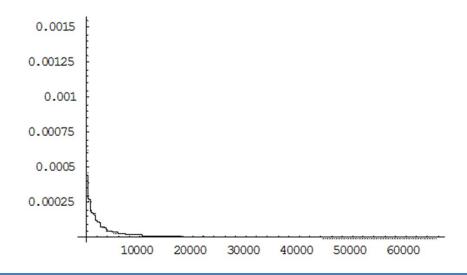
The damage state space which corresponds with this probability map is  $2^{121} = 2.66' \cdot 10^{36}$ .





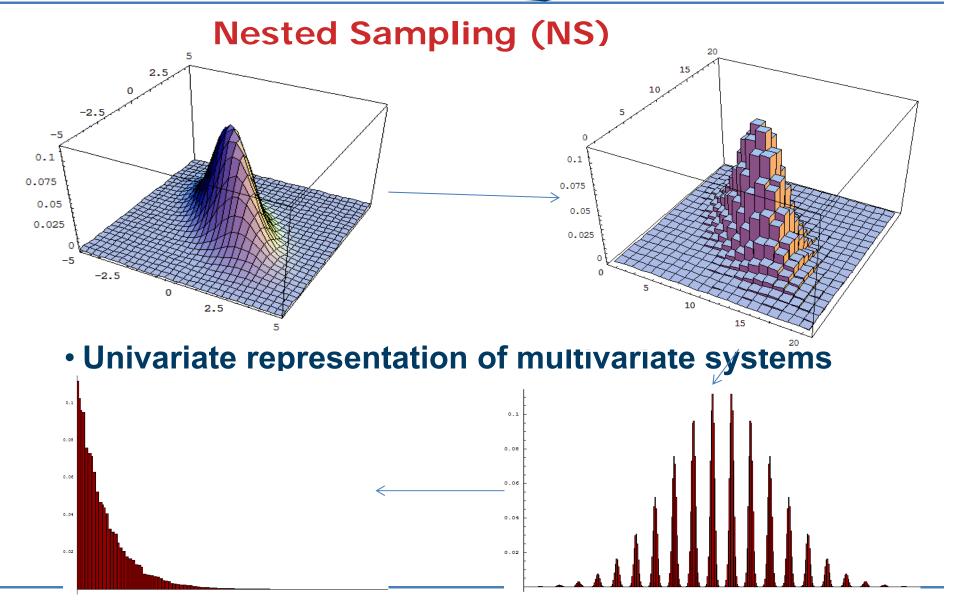
# Probability Map → Damage state scenario selection via smart algorithms (MC, NS, PSA)

 The 2.66 10<sup>3</sup>6 damage state vectors can be reduced to 65536 damage state vectors with a probability coverage of 1.0





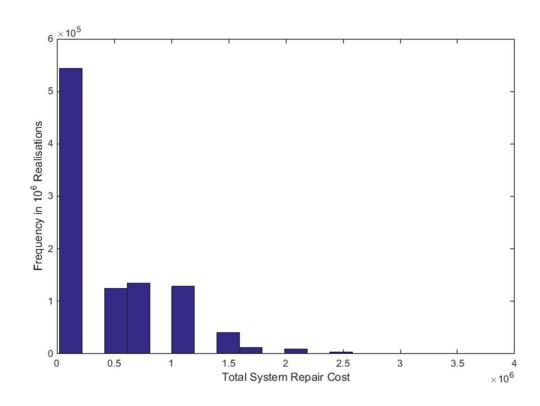








# Selected set of damage state scenarios → Estimation of outcome metric







# Decision making phase of a stress test outcome

- The level of risk that is considered acceptable will typically vary from situation to situation
- Stress test outcome distributions can be compared to eachother, following a Bayesian decision-theoretical framework





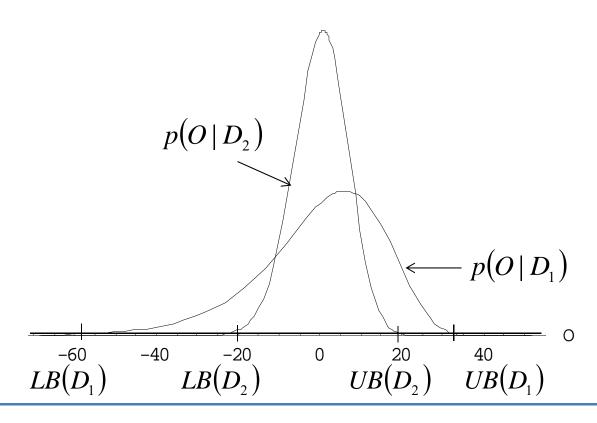
#### **Evaluation of the outcome metric**

Comparison of two conditionalized outcome probability distributions





# Decision making phase of a stress test outcome

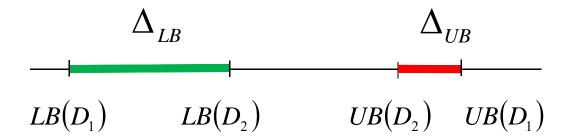






# Decision making phase of a stress test outcome

- Trade-off lower and upper bound 'gains':
  - $\Delta_{LB}$  dominates  $\Delta_{UB}$ .
  - $\Delta_{LB}$  favours  $D_2$  over  $D_1$ .
  - Choose  $D_2$ .







#### **Decision making phase of** a stress test outcome

• Or, equivalently, choose  $D_2$  because:

$$LB(D_2) - LB(D_1) > UB(D_1) - UB(D_2)$$

• Or, equivalently, choose  $D_2$  because:

$$LB(D_2) + UB(D_2) > LB(D_1) + UB(D_1)$$

 The comparison of bounds may be simplified into comparison of a single measure.

$$LB(D_1)$$

$$LB(D_2)$$

$$LB(D_1)$$
  $LB(D_2)$   $UB(D_2)$   $UB(D_1)$ 





# Decision making phase of a stress test outcome

• Choose the decision  $D_i$  which maximizes the sum of bounds:

$$LB(D_i) + E(D_i) + UB(D_i)$$
.

• As opposed to choosing the decision  $D_i$  which maximizes the expectation values:

$$E(D_i)$$
.





#### **Concluding remarks**

- General stress test framework is presented in which stress tests are just a special instance of a risk assessment, where instead of marginalizing over all the possible stress scenarios one specific stress scenario is chosen instead for which to gauge its potential effects.
- This stress test framework is simple enough on the conceptual side. On the practical side, however, when one wishes to implement this framework, things can quickly become non-trivial, for which 3 sampling algorithms have been developed.







Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

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#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960



# Hazard Identification & Asset (network) Vulnerability (Resilience) Assessment

UCL CEGE, UK

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CSIC, Spain

María-José JIMÉNEZ and Mariano GARCÍA-FERNÁNDEZ

Final Dissemination Conference 29 September 2016, Madrid, Spain







### **Objectives / Challenges**

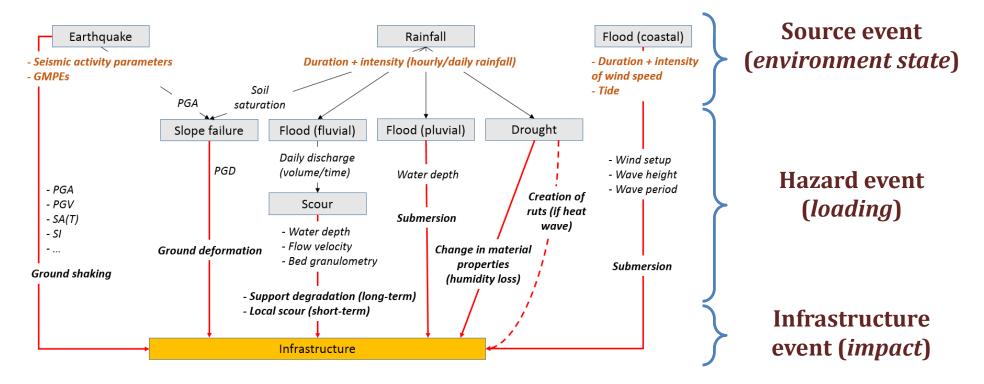
- Spatial extent of critical infrastructure → components may be exposed to a wide range of hazard types
- How to reconcile damage events from different hazard types?
- How to harmonize multi-risk assessment over the whole infrastructure?
- → Use of a Bayesian framework to assemble hazard-specific fragility curves
- Interdependency between infrastructure elements → high dimensionality of the space of solutions
- Functionality loss of elements is more important than direct repair costs
- Spatial consistency of hazard input (i.e. scenario-based approaches)
- → Application of Bayesian Networks in complement to simulation-based methods (e.g. FP7 SYNER-G project, OOFIMS tool)?





### Single and Multi-Risk Assessment

Interactions at the HAZARD level



- → Generation of cascading hazard events and joint independent hazard events
- → Spatial (geographical extent of infrastructure) and temporal (return periods of source events) modelling





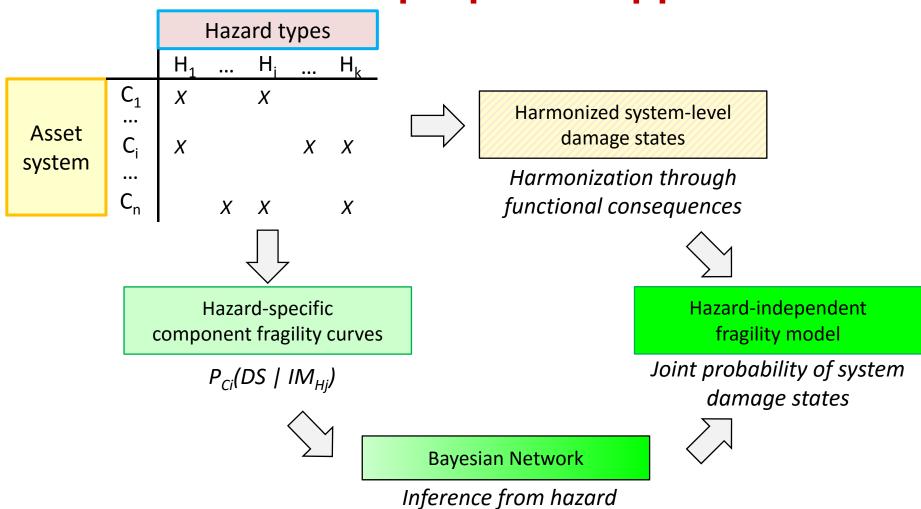
### Single and Multi-Risk Assessment

- Interactions at the EXPOSURE/VULNERABILITY level?
- Spatial extent of critical infrastructure → components may be exposed to a wide range of hazard types
- How to reconcile damage events from different hazard types?
- How to harmonize multi-risk assessment over the whole infrastructure?
- Development of a method to derive fragility models that are consistent between hazard types
- Use of a Bayesian framework to assemble hazard-specific fragility curves
- Application to roadway bridges, exposed to earthquakes (EQ), fluvial floods (FL) and ground failures (GF)





### Overview of the proposed approach

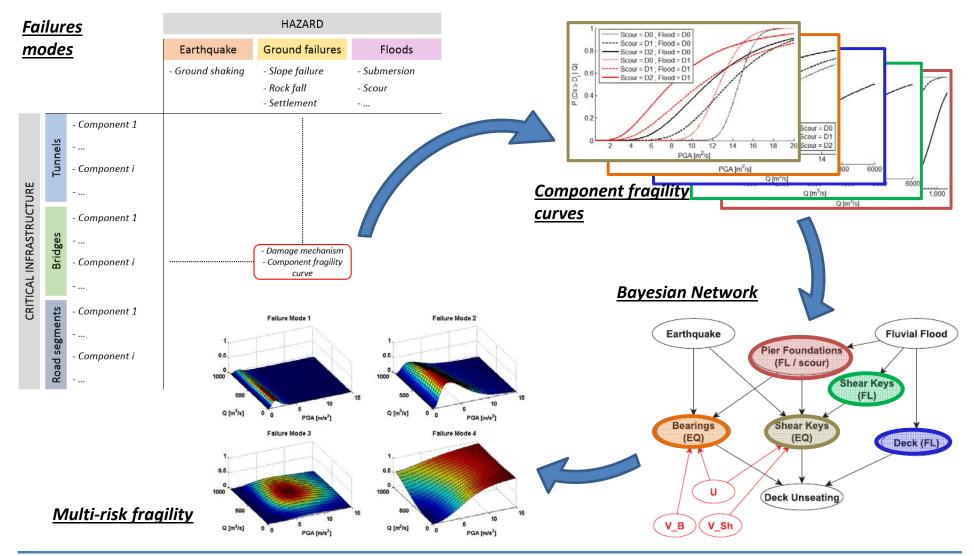


IM evidence





# Harmonized fragility functions







## Multi-hazard scenarios

- Multi-risk event taxonomy proposed by Lee & Steinberg (2008):
  - Single event;
  - Combined events: single event triggering multiple loading mechanisms;
  - Subsequent events: unrelated single events triggered by different sources and possibly separated in time;

- Proposed multi-risk scenarios:
  - *Single* event: flood (**FL**)
  - *Combined* events: earthquake-induced ground failure (**EQ** → **GF**)
  - Subsequent events: flood follow by an earthquake (FL + EQ → GF)
- → Multi-risk fragility framework should be consistent with all these cases





# Seismic Hazard Modelling

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(María-José JIMÉNEZ and Mariano GARCÍA-FERNÁNDEZ)

Final Dissemination Conference 29 September 2016, Madrid, Spain



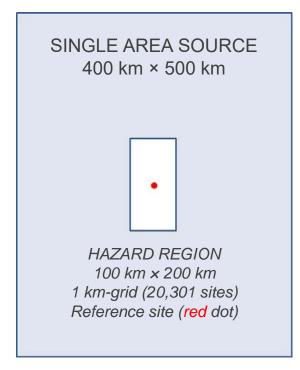


## Seismic Hazard Approach

- Development of a seismic hazard approach best suited to consider low probability ground motions affecting critical transport infrastructures networks.
- Probabilistic-based approach applying Monte Carlo simulation techniques (the most adapted when dealing with low-probability ground motions)
  - Allows for building **long-duration synthetic earthquake catalogues** (3×10<sup>6</sup> years) to derive low-probability ground motions
  - More powerful and flexible handling of uncertainties, and making straightforward the link with probabilistic risk analysis
  - Provides a distribution of maximum ground-motion amplitudes that follow a general extreme-value distribution
  - Facilitates the analysis of the occurrence of extremes, i.e., very low probability of exceedance, from unlikely combinations; which could be applied in the development of stress tests
- Development of extreme motion hazard deterministic scenarios







## Seismic Hazard Model

**Extreme ground-motion scenarios** for selected combinations of modelling inputs which include:

- (a) Seismic activity model (4)
- (b) Ground motion model (2)
- (c) Hazard level (3)
- (d) Fractile of extreme ground motions (3)
- Value at the **reference site** is the extreme ground motion corresponding to the selected hazard level (*i.e.*, annual probability of being exceeded) and fractile/percentile (p) of extreme values (*i.e.*, only 100-p% of extremes are larger)
- Assuming that the same parameters generating the extreme value at the centre apply to all grid points, extreme motion hazard deterministic scenarios (72 scenarios) are obtained for the whole hazard region

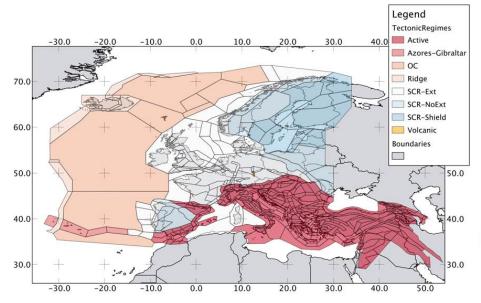




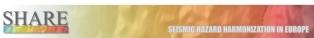
## **Seismic Activity Models**

#### Derived from area source model of European SHARE project

- ➤ **High activity** (from SHARE\_Active 203 sources, 31% area)
- ➤ Moderate activity (from SHARE\_SCR-Ext 80 sources, 40% area)
- ➤ Moderate-to-low activity (from SHARE\_SCR-NoExt 17 sources, 15% area)
- ➤ Low activity (from SHARE\_SCR-Shield 8 sources, 13% area)



SHARE
Area Source Model v6.1 (2013)









# **Seismic Activity Models**

Seismic Activity Model	N <sub>o</sub> /yr	β	weight	z(km) weight		M <sub>max</sub>	weight
	28571	1.950	0.10	2.5	0.10	7.00	0.50
and the second of	28571	2.303	0.60	10.0	0.40	7.20	0.20
High activity (SHARE_Active)	107143	2.000	0.10	18.0	0.50	7.40	0.20
	107143	2.303	0.10			8.00	0.10
	214286	2.303	0.10				
	143	2.150	0.15			6.50	0.50
Moderate activity	2857	2.303	0.85	uniform		6.70	0.20
(SHARE_SCR-Ext)				2 - 22		6.90	0.20
						7.10	0.10
	214	2.303	0.50			6.50	0.50
Moderate-to-low activity	2143	2.303	0.50		uniform	6.75	0.20
(SHARE_SCR-NoExt)					2 - 26	6.95	0.20
						7.20	0.10
	264	2.303	0.75			6.50	0.50
Low activity	514	2.303	0.25	uniform		6.70	0.20
(SHARE_SCR-Shield)					30-35	6.90	0.20
						7.10	0.10





#### **Ground Motion Models**

Two models based on those developed by Atkinson and Adams (2013) in the 2015 edition of the National Building Code of Canada, for  $V_{\rm S30}$ =760 m/s soils

- **➢ Generic Low Attenuation** (*derived from ENA*)
- **➢ Generic High Attenuation** (*derived from Wcrust*)

#### **Hazard level**

Three levels of **annual probability**, P1, of exceeding ground-motion values at the reference site:  $4 \times 10^{-4}$ ,  $2 \times 10^{-4}$ , and  $10^{-4}$  per year. They correspond to mean return periods of 2,500, 5,000, and 10,000 years ( $1/P1 = mean \ return \ period$ )

## Fractile of extreme ground-motions

Three options of **fractiles** of extreme ground-motion values at the reference site: **0.50**, **0.75** and **0.90**. They refer to percentile, p, of 50th, 75th, and 90<sup>th</sup> (i.e., only 100-p% of extremes are larger)





# **Spatial Variability**

Hypothesis: Spatial correlation (covariance) not direction dependent

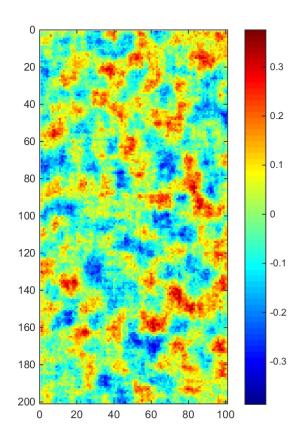
Approach: Running averaging window on a 2D normal random field

10,000 random fields

Selected 18 realizations:

< 2% distortion in reference site

=> 1296 scenarios

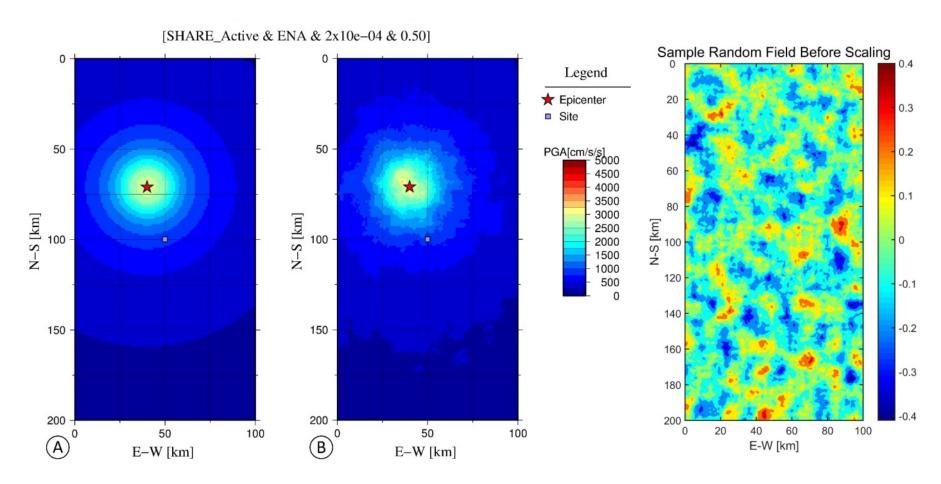






## Scenario example

## High activity & Generic Low Attenuation & 2×10<sup>-4</sup> & 0.50







# From Asset damage to network damage

Final Dissemination Conference 29 September 2016, Madrid, Spain







## The INFRARISK case-study





ltaly major roads



0 100 200 400 Kilometers

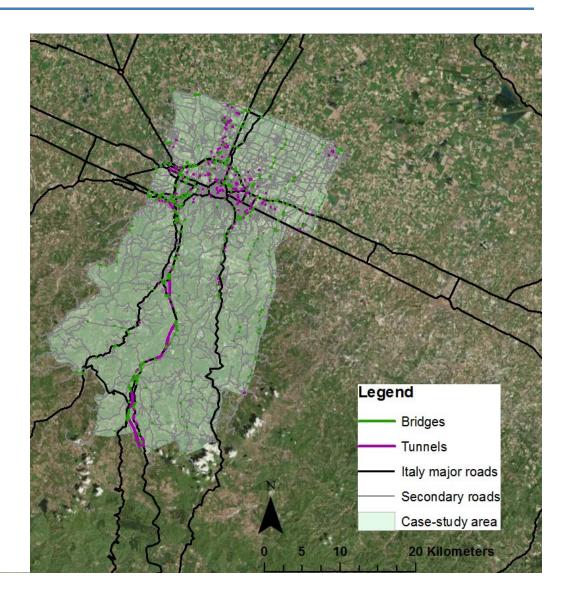






## The INFRARISK case-study Bologna area





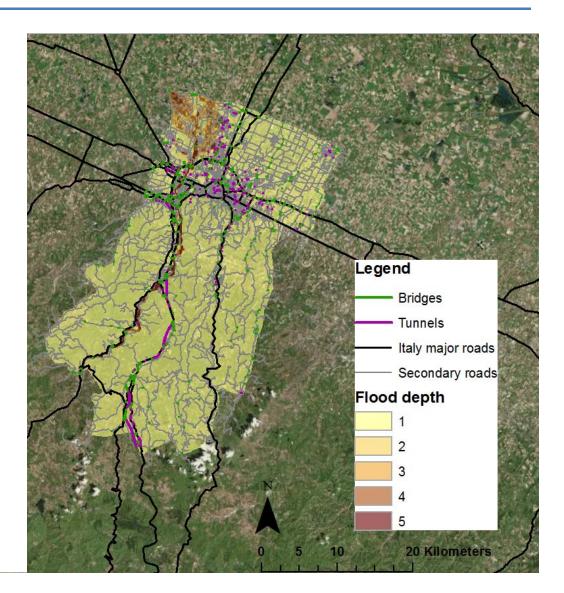






- Historic flood events





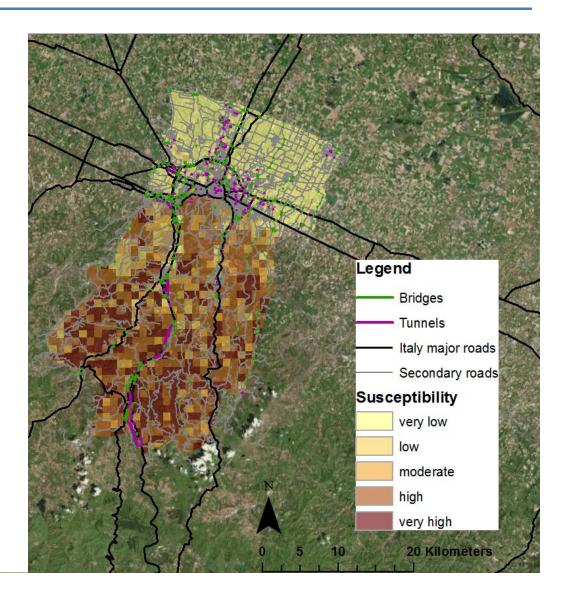






- Landslide susceptibility





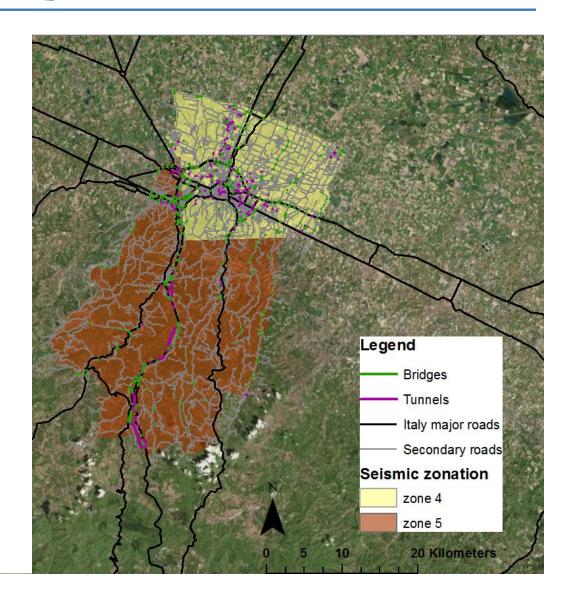






- Seismic zonation





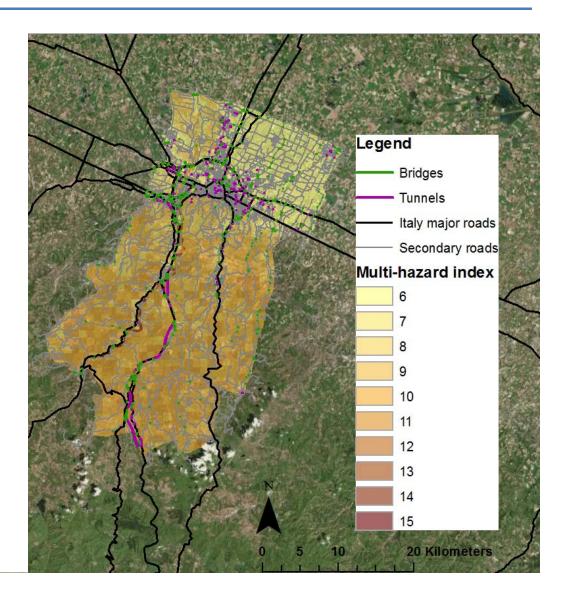






- Aggregated hazard







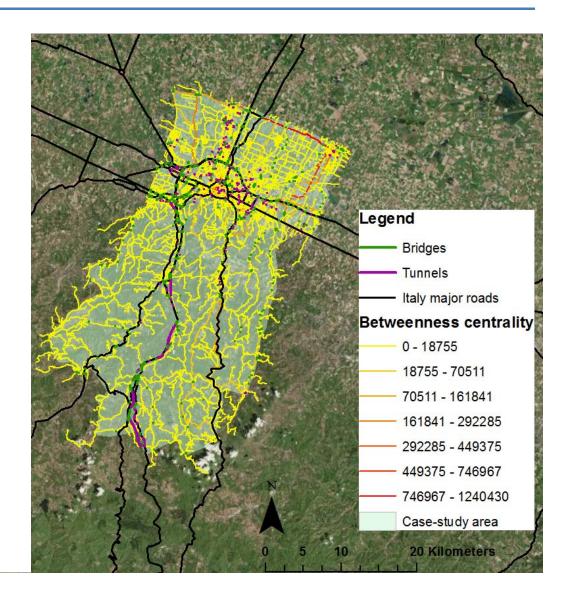




#### **Criticity of infrastructure**

- Betweenness centrality











### **Exposure model**

- Taxonomy of bridges

Name: Type of Column section 1: Rectangular

Note: Type of Column section 2: Solid

 Where: 11.295521, 44.494518
 Spans: Multi-span

 Material MM1: Concrete
 Span length: 25-45m

Material MM2: Prestressed concrete Connection to abutment: Isolated (through bearings)

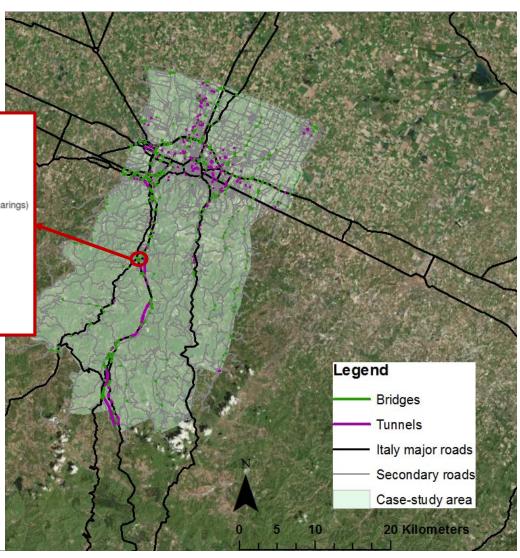
Bridge width: <20m Bridge configuration: Regular
Bridge length: <50m Type of deck 1: Undefined
Deck structural system: Simply supported Type of deck 2: Undefined

Pier to deck connection: Isolated (through bearings) Number of columns for pier: Undefined

Type of pier: Multi-column pier Pier height: Undefined

Level of seismic design: Seismic design Number of spans: Undefined



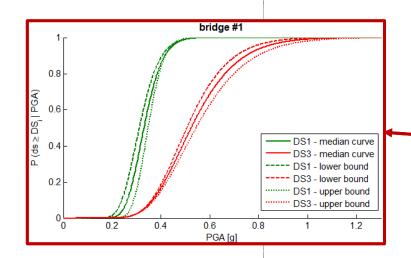


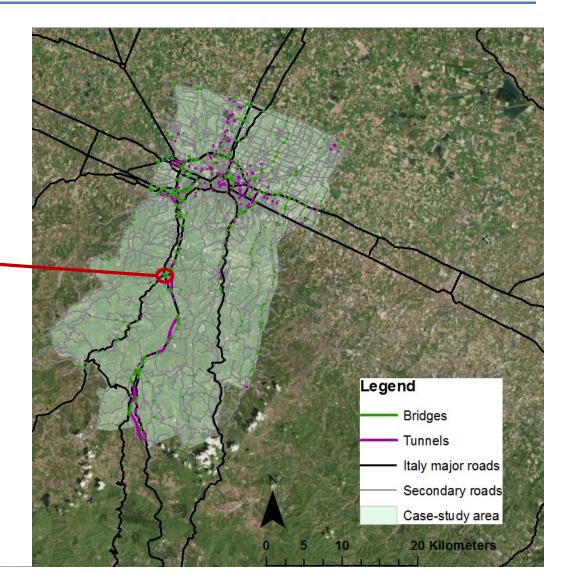






- Seismic fragility curves













- Multi-risk fragility functions



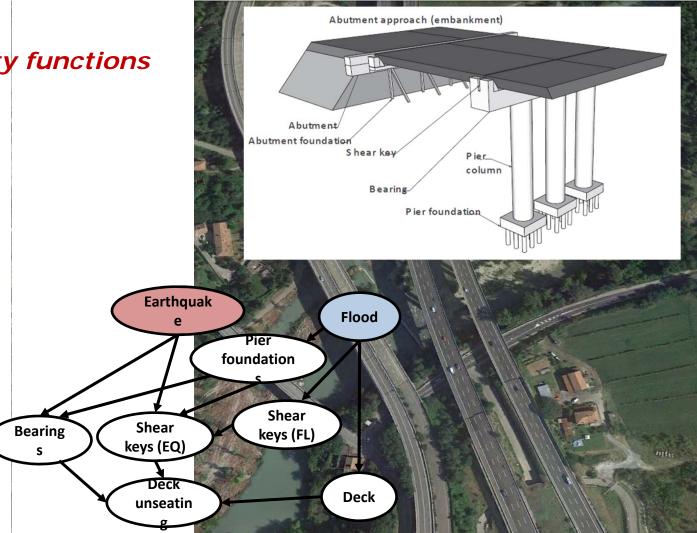








- Multi-risk fragility functions











#### Abutment approach (embankment) Fragility model - Multi-risk fragility functions Abutment Abutment foundation Shear key 8.0 column Bearing (Ö \_\_ 0.6 ☐ 0.8 O 0.4 ☐ 0.4 Pier foundation 0.2 4000 6000 Earthquak 1000 2000 3000 5000 Q [m<sup>3</sup>/s] Flood foundation Shear Shear **Bearing** keys (FL) keys (EQ) INFR Deck Deck unseatin







#### Abutment approach (embankment) Fragility model - Multi-risk fragility functions Abutment Abutment foundation Shear key column ----- Scour = D0 ; Flood = D0 Bearing ---- Scour = D1 ; Flood = D0 Scour = D2; Flood = D0 Pier foundation Scour = D0; Flood = D1 P (Ds ≥ D<sub>i</sub> I Q) Scour = D1; Flood = D1 Scour = D2 ; Flood = D1 0.4 Earthquak 0.2 Flood 16 PGA [m<sup>2</sup>/s] foundation Shear Shear **Bearing** keys (FL) keys (EQ) INFR Deck Deck unseatin







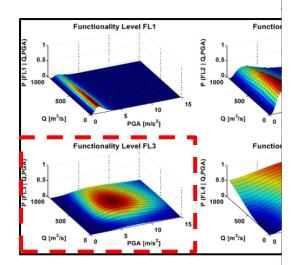
#### Abutment approach (embankment) Fragility model - Multi-risk fragility functions Functionality Level FL1 Functionality Level FL2 Abutment Abutment foundation Shear key column Bearing PGA [m/s<sup>2</sup>] PGA [m/s2] Pier foundation Functionality Level FL3 Functionality Level FL4 **Earthquak** Flood 5 PGA [m/s<sup>2</sup>] foundation Shear Shear **Bearing** keys (FL) keys (EQ) INFR Deck Deck unseatin



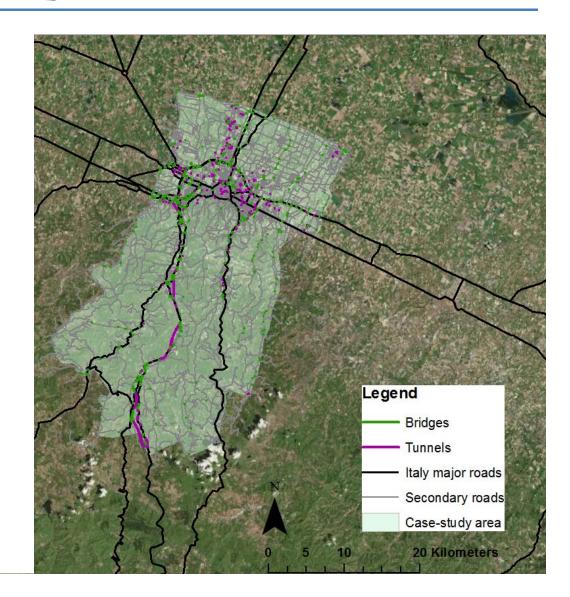




### - Multi-risk fragility functions











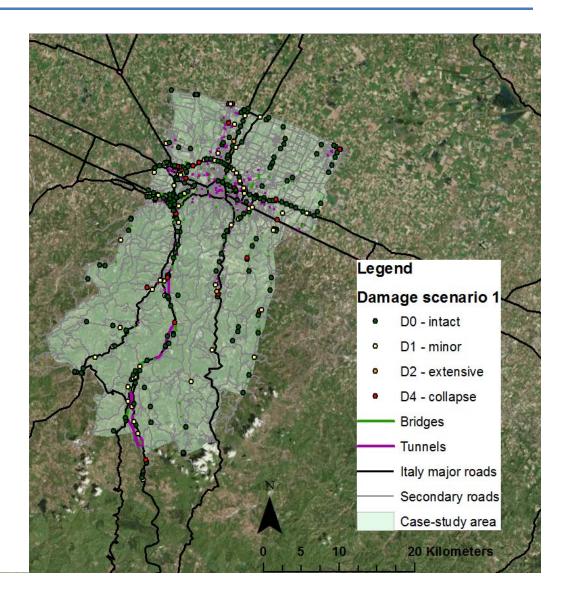


#### Physical damage map

- Seismic damage to bridges

Damage states are randomly sampled given the damage probabilities









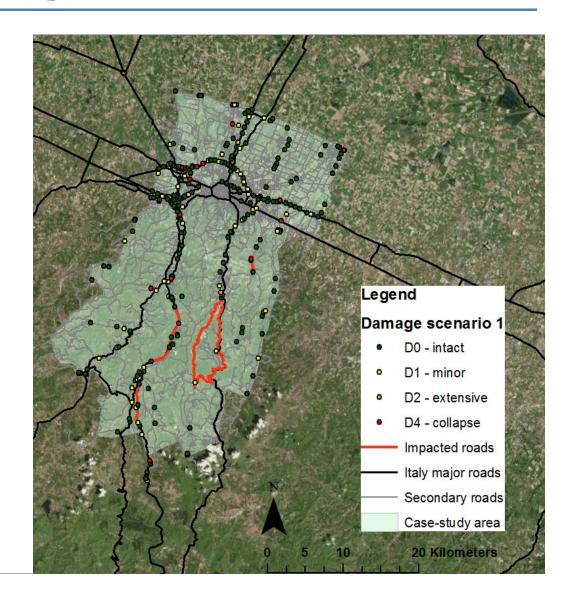


## Functional consequences

- Impacted road segments

Damage states are randomly sampled given the damage probabilities









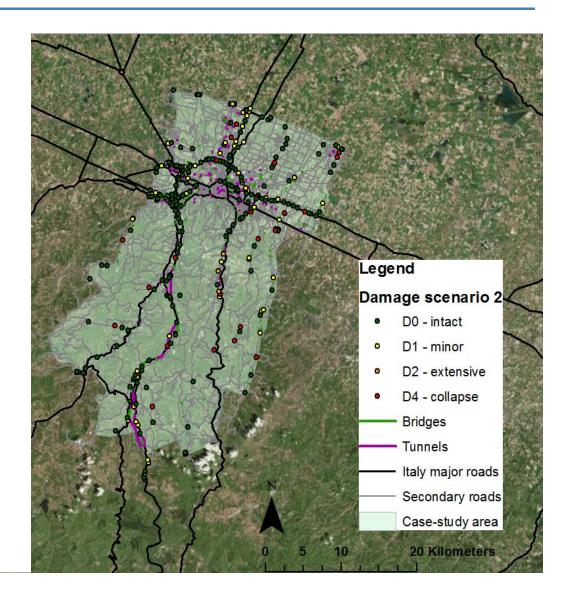


#### Physical damage map

- Seismic damage to bridges

Damage states are randomly sampled given the damage probabilities









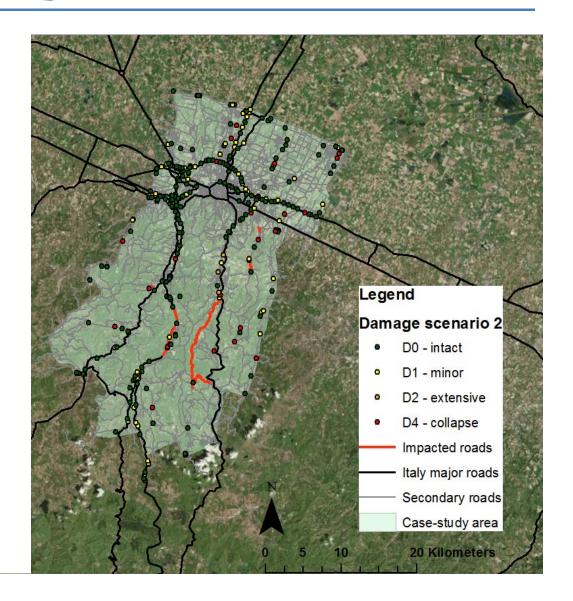


# Functional consequences

- Impacted road segments

Damage states are randomly sampled given the damage probabilities









# From Physical damage to functionality loss and resilience

# Final Dissemination Conference 29 September 2016, Madrid, Spain







## Bridge failure modes

> Identification of around 50 damage mechanisms → what are their effects on

the bridge functionality?



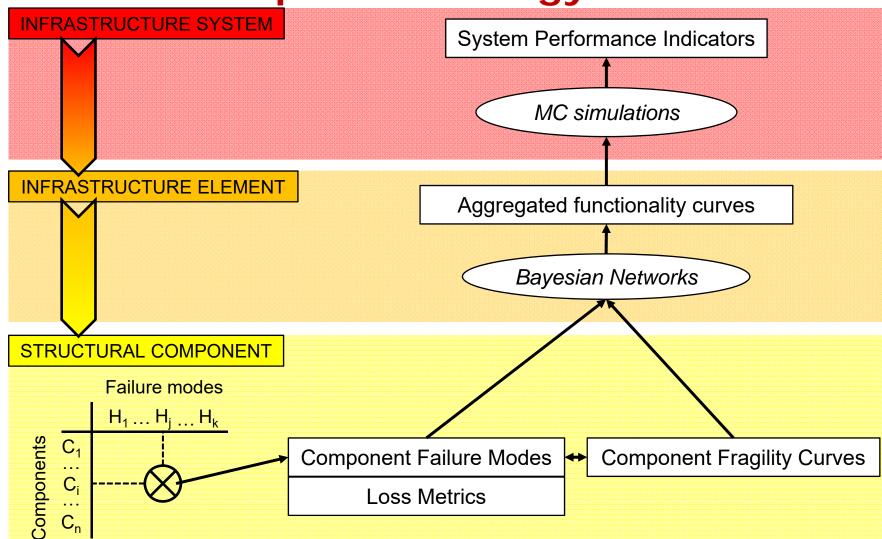
Review and taxonomy of qualitative damage scales

/pe	Failure mode	Damage 'Severity'	Description
	Debris accumulation	-	- Reduction of flow capacity - Backup of water flow
	Channel modification	-	- Shifting/migration of waterway channel alignment





# **Proposed strategy**

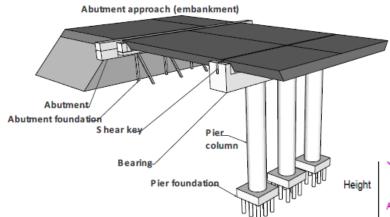








# Application to a bridge example



Multi-Span Simply-Supported Concrete (MSSSC) bridge proposed by Nielson (2005)

22 vulnerable components when considering both loading directions:

1 324	B <sub>3</sub> B <sub>4</sub> SH <sub>4</sub>	SH <sub>5</sub>	2x A2px
Along Aligh	,		721
Y direction	P <sub>ty</sub>	P <sub>2y</sub>	B <sub>6</sub>
SH <sub>1</sub>	P tx	- 1	

				Damage 'Severity'			
ID	Component	Failure mode	EDP	DS1	DS2	DS3	DS4
1	Pier	Bending	Section curvature	0.005	0.008	0.014	0.020(X)
				0.015	0.024	0.041	0.061 (Y)
4	Abutment	Piles	Deformation in	7.6	25.4	200.0	-(X)
			tension [mm]	7.6	25.4	200.0	-(Y)
5	Abutment	Backfill	Deformation in	19.2	25.4	_	192.0 (X)
			compression [mm]	_	_	_	-(Y)
6	Shear key	-	Deformation [mm]	_	_	_	-(X)
				25.0	25.5	25.5	$406.0 \; (Y)$
13	Fixed	-	Deformation [mm]	10.5	10.5	12.5	152.0 (X)
	bearing			_	_	_	-(Y)
	Expansion	-	Deformation [mm]	10.5	25.0	34.5	$152.0\ (X)$
	bearing			_	_	_	-(Y)

Identification of 18 failure modes at the component level

X direction





# Functionality models at component level

Expert-based survey

Functionality models for downtime duration and functional losses

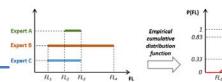


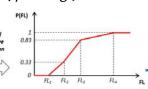
#### Current limits:

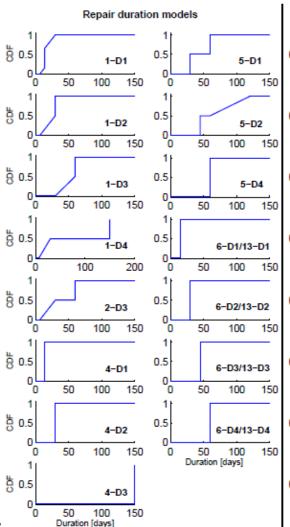
- Limited amount of data points
- No 'seed' questions

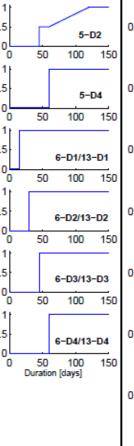


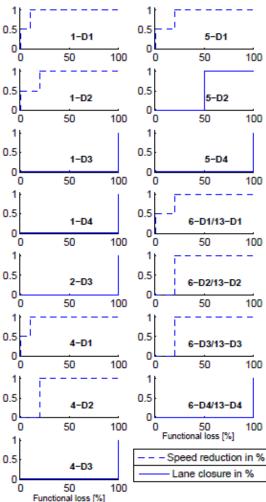
#### Statistical treatment ('pooling')











Functional loss models

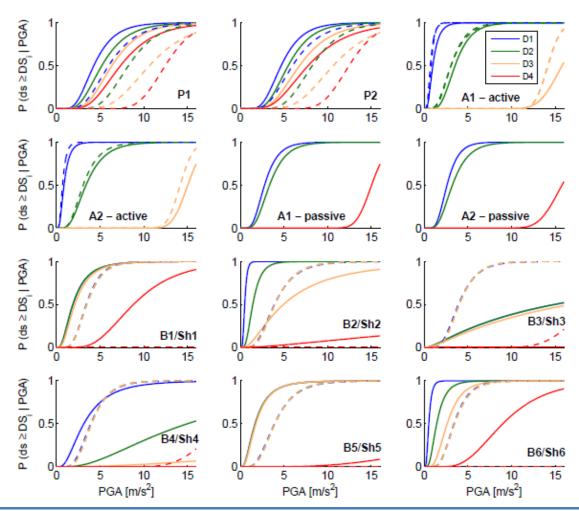






## Component fragility curves

- Non-linear dynamic time-history analyses of a finite element model of the bridge:
- The response of each component is taken separately to derive component fragility curves
- The responses of all components are used to build a correlation matrix (accounting for statistical dependence)





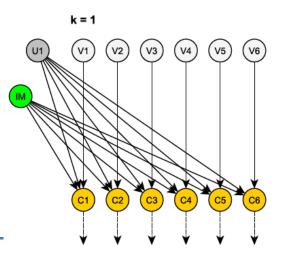


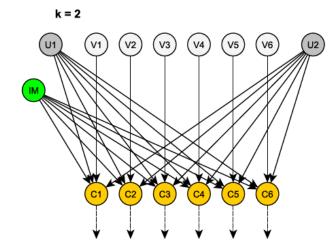
# Correlation between damage events Statistical dependence Introduction of a Dunnett-Sobel class of variables:

$$Z_i = \sqrt{1-\sum_{j=1}^k r_{ij}^2} \cdot V_i + \sum_{j=1}^k r_{ij} \cdot U_j$$
 Approximation of the correlation matrix between of  $Z_i$  safety factors:

$$\rho_{il} \approx \sum_{ij}^{k} r_{ij} \cdot r_{lj}$$

- $V_i \rightarrow$  Standard normal variable specific to each component
- $U_i \rightarrow$  Standard normal variable common to all components



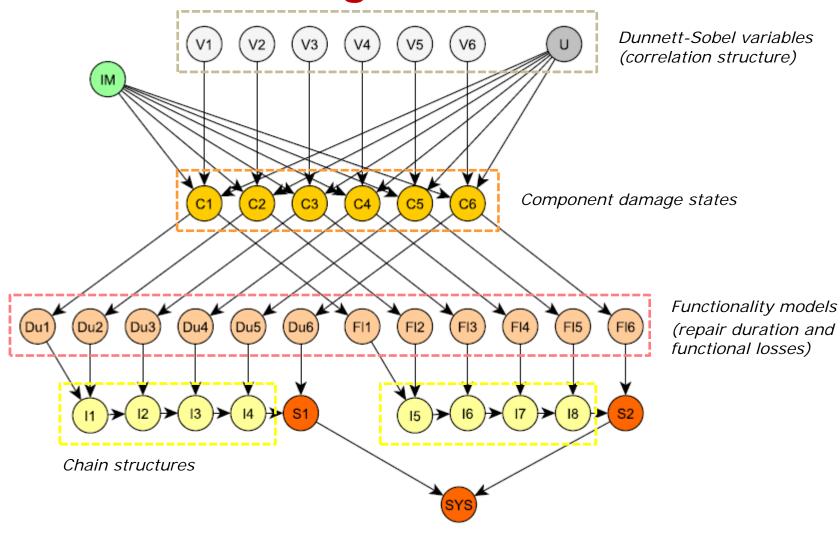


Representation of the variables in a Bayesian Network





# Assembling failure modes

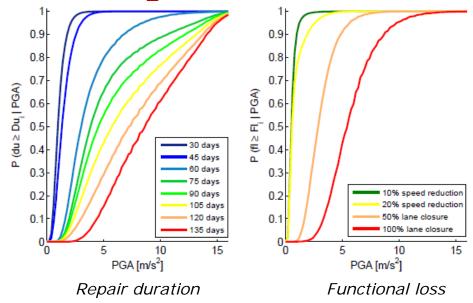




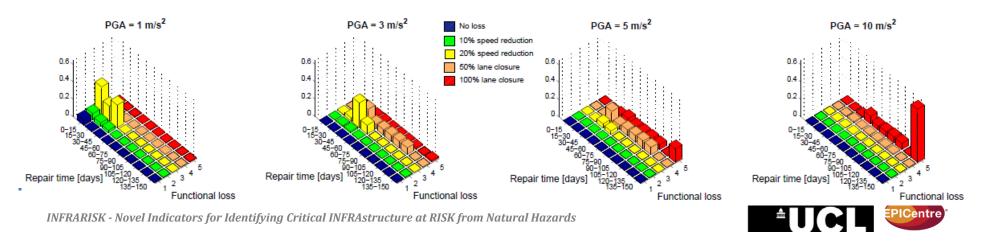


# Derivation of functionality loss curves

- Solving of the Bayesian Network for increasing values of IM
- Observing the updating of the probabilities at nodes S1 and S2

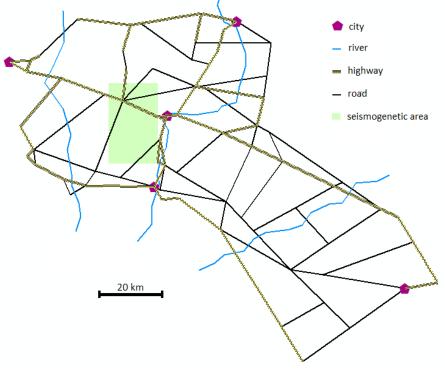


 Observing the updated probability at node SYS provides access to joint probabilities of occurrence:





# Application to a road network analysis



- Virtual proof-of-concept for illustration purposes
- Each edge is assumed to contain a bridge (111 bridges)
- Seismic events are probabilistically sampled (Monte-Carlo simulation)
- Network is assumed to link 5 cities of interest

Performance Indicator 1 = averaged ratio of increased travel times between selected cities:

$$R_{TT} = \frac{1}{n} \sum_{i=1}^{n} \frac{TT_{i,d}}{TT_{i,0}}$$

For n inter-city travels (n = 10)

**Performance Indicator 2 =** *single connectivity loss between each city:* 

$$SCL = 1 - \left\langle \frac{N_{s,j,d}}{N_{s,j,0}} \right\rangle_{j}$$

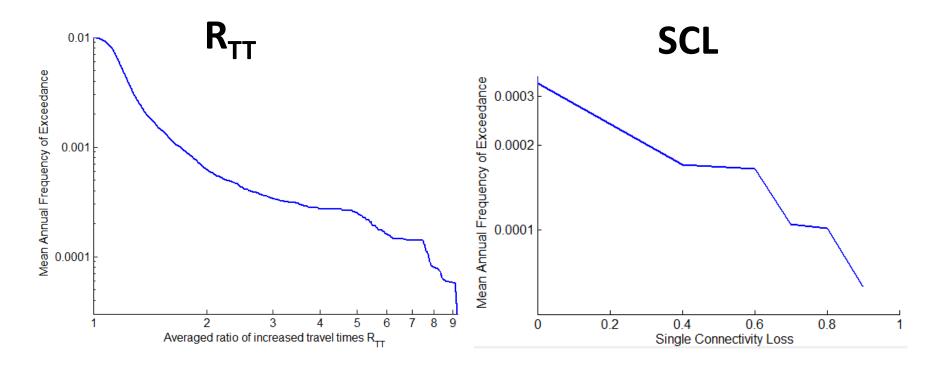
For *j* = 1..5 (# of cities)





# Annual probability of exceedance

- The empirical CDF of the performance indicator is derived from 5,000 runs
- Assumed seismic activity parameter: 0.01 annual rate of EQ occurrence



More refined capacity-based performance indicators would require high computational costs (e.g. traffic models, etc.)





# Computation of the resilience index Performance indicator (system loss): $1 \sum_{n=1}^{n} TT_{i,d}$

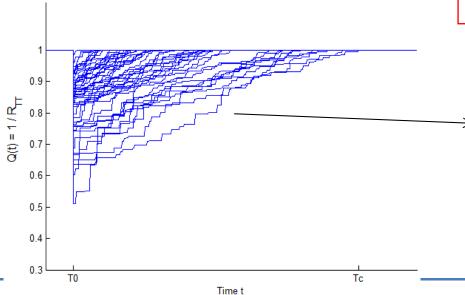
$$R_{TT} = \frac{1}{n} \sum_{i=1}^{n} \frac{TT_{i,d}}{TT_{i,0}}$$

Proposed measure for remaining functionality:

$$Q(t) = \frac{1}{R_{TT}}$$

Definition of the resilience index:

$$R = \int_{t=0}^{T_C} \frac{Q(t)}{T_C} dt$$



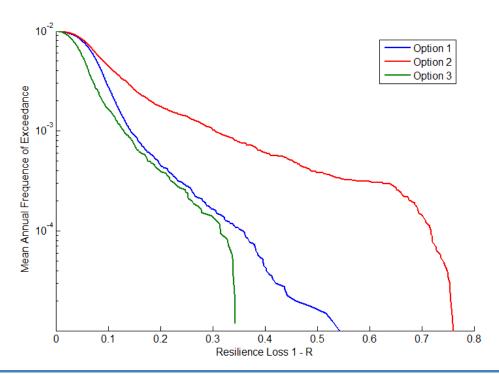
Each sampled damage scenario leads to a different resilience index

→ probability distribution?



# Evaluation of restoration strategies Assumption : only one repair team available (restoration sequence)

- Three restoration schemes are evaluated:
  - 1. Work in priority on the bridges with heaviest functional losses
  - 2. Work in priority on the bridges with lightest functional losses
  - 3. Work in priority on the bridges that have the highest impact on the network performance







### Conclusions

- Merits of Bayesian Networks to assess joint probabilities of occurrence and to decompose complex events at smaller scales (from system to components and viceversa)
- Component-level damage mechanisms provide a better resolution of the functional consequences
- Efficient and innovative seismic hazard approach to handle low-probability extreme ground motions and derive associated deterministic scenarios
- The two procedures above can be successfully sued to determine network physical damage scenarios
- Need to improve the knowledge of functionality models for various failure modes
- Functionality curves may be derived for other hazard types since they provide a harmonized 'damage' scale
- Application to a real-life network is underway







# www.infrarisk-fp7.eu



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 603960







#### Case Studies: TEN-T Road and Rail Networks

Julie Clarke, Robert Corbally Roughan & O'Donovan Ltd. Dublin, Ireland



**Final Dissemination Conference** 

29<sup>th</sup> September 2016, DRAGADOS, Madrid, Avda. Camino Santiago 50, 28050 Madrid, Spain





# **Case Studies: Aims and Objectives**

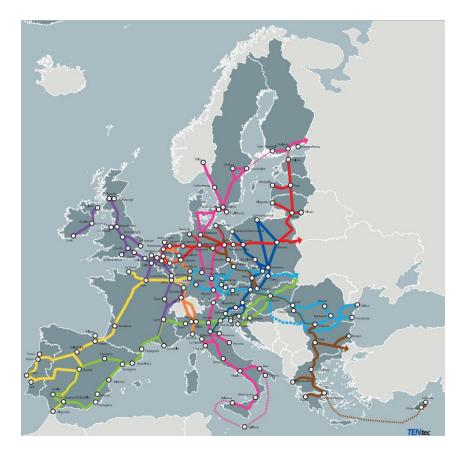
**Risk Profiling of Natural** 

**Hazards and Infrastructure Single Risk Assessment Overarching** Risk **Assessment Space-Time Modelling of Case Study** Methodology **Structural Behaviours and** Simulation **Natural Hazards Stress Tests for Multi-Risk Scenarios** Implementation Strategy





# **Critical European Road and Rail Infrastructure**



**Trans-European (TEN-T) Network** 







# **Stress Tests due to Natural Hazards**

- Physical damage
- Travel disruption
- Losses







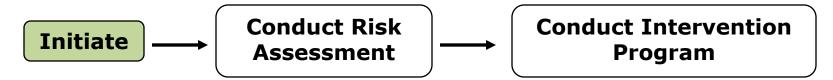






#### **Stress Tests**

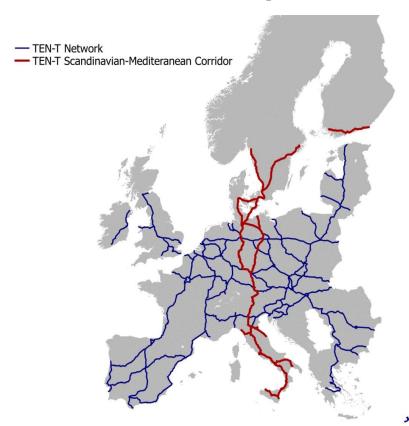
#### General process to ensure acceptable levels of risk:

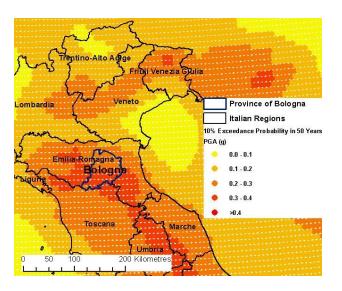






#### Italian Case Study



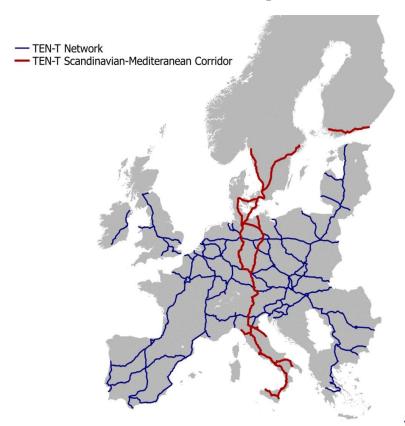


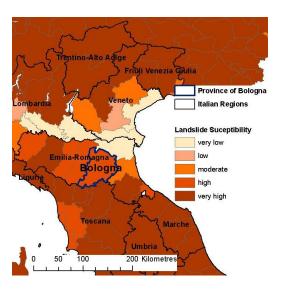






#### Italian Case Study



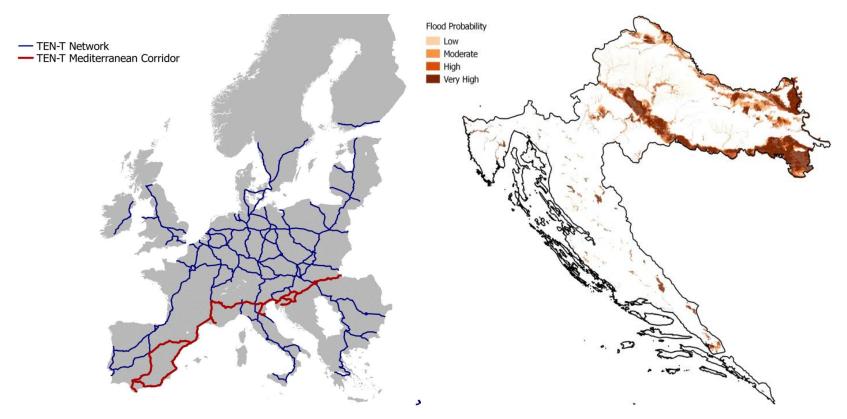








#### Croatian Case Study

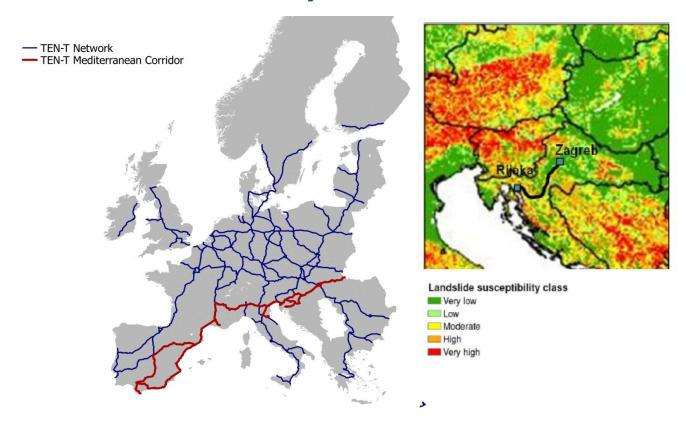








#### Croatian Case Study









#### **Stress Tests**

#### General process to ensure acceptable levels of risk:

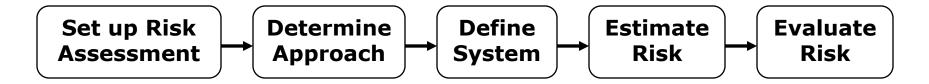






#### **Stress Tests**

#### **Conduct Risk Assessment:**









- Low probability, high consequence seismic scenarios
- Cascading landslide hazard effects
- Direct and indirect consequences









- Low probability, high consequence seismic scenarios
- Cascading landslide hazard effects
- Direct and indirect consequences
- Quantitative risk assessment



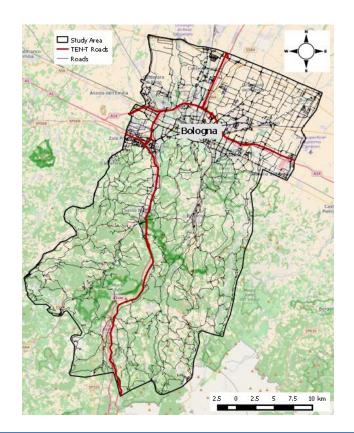






#### **Spatial Boundaries**

- 3140 km roads
- Area 990 km<sup>2</sup>
- Metropolitan area of Bologna





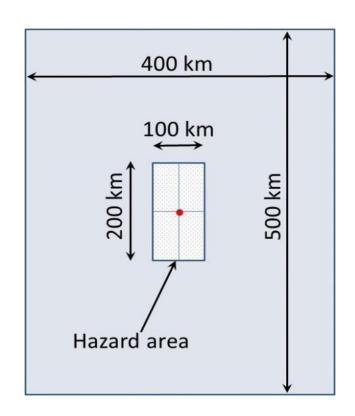






#### **Seismic Hazard Model**

- Ground-motion fields
  - Seismic activity model
  - Ground motion model
  - > Hazard level
  - ➤ Percentile of extreme ground motion values at reference site (shown in red)





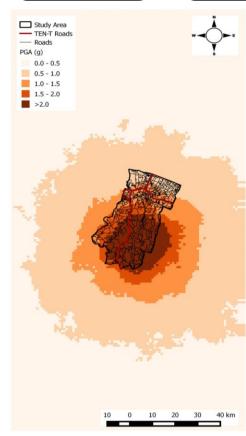






#### **Seismic Hazard Model (Stress Test)**

- Example GM field
  - > SHARE Active
  - Low attenuation ground motion
  - ➤ 10,000 year return period
  - > 90% fractile
- Linked to 'critical network element'
  - > Betweenness centrality method



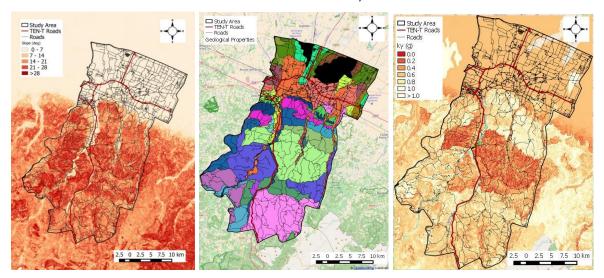






#### **Earthquake-triggered landslides**

- Rigid sliding block approach
  - ➤ Landslide yield acceleration values (k<sub>y</sub>)







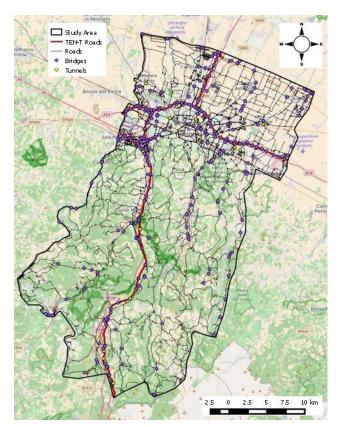




#### **Network Vulnerability**

- 340 bridges, 30 tunnels
- 10m road sections on slopes >10°

Network Element	Hazard
Bridges	Earthquakes
Tunnels	Earthquakes
Road Sections	Earthquake- triggered landslides





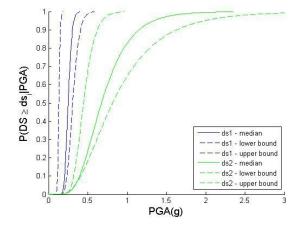






#### **Network Vulnerability - Bridges and Tunnels**

- Structural data gathered using Google Maps
- Four damage states defined
  - Slight
  - > Moderate
  - > Extensive
  - Complete



Fragility functions assigned based on existing database

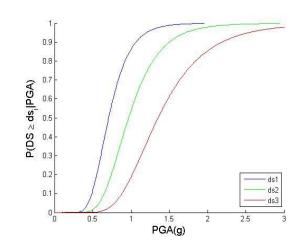






#### Network Vulnerability - Road Sections

- Three damage states defined
  - > Slight
  - ➤ Moderate
  - Extensive/Complete
- Fragility functions assigned based on  $k_y$  value and road type









#### **Network Vulnerability – Functionality Loss**

- Defined per network element type in terms of individual damage states
  - > Functionality capacity loss
  - Restoration duration
  - > Repair cost



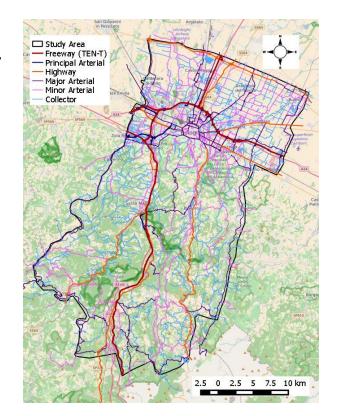






#### <u>Network Vulnerability – Travel Delays</u>

- Regional traffic analysis
  - NEXTA traffic modelling software





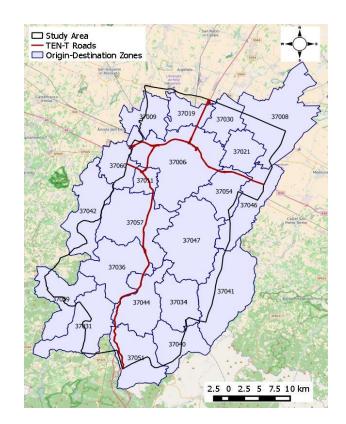






#### **Network Vulnerability - Travel Delays**

- Regional traffic analysis
  - NEXTA traffic modelling software
  - > Origin-Destination data obtained from Italian 2011 census data to represent traffic demand





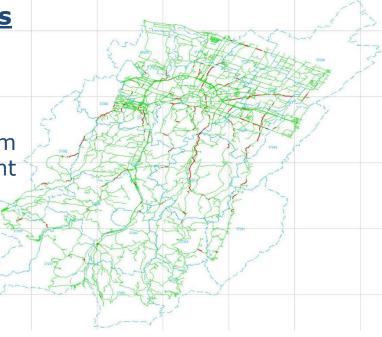






#### **Network Vulnerability – Travel Delays**

- Regional traffic analysis
  - NEXTA traffic modelling software
  - ➤ Origin-Destination data obtained from Italian 2011 census data to represent traffic demand
  - Simulation of post-event traffic





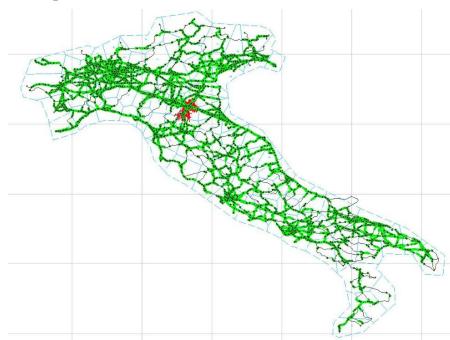






#### **Network Vulnerability – Travel Delays**

- National traffic analysis
  - NEXTA traffic modelling software
  - Wider impacts











Network Vulnerability – Travel Delays

National traffic analysis

NEXTA traffic modelling software

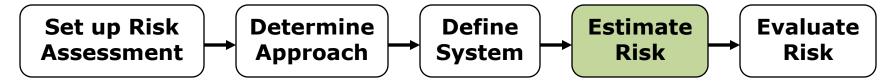
Wider impacts

Origin-Destination (O-D) data obtained from ETIS project to represent traffic demand

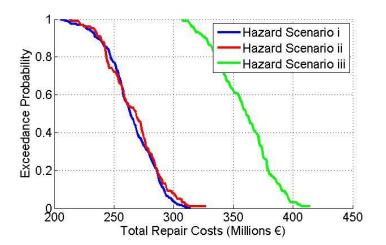








- Monte Carlo sampling method
  - > Epistemic uncertainty
- Direct consequences
  - > Total network repair cost

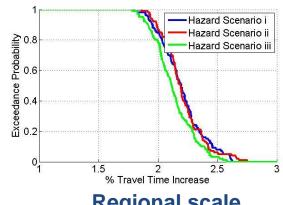








- Monte Carlo sampling method
  - > Epistemic uncertainty
- Direct consequences
  - > Total network repair cost
- Indirect consequences
  - Average increase in travel time



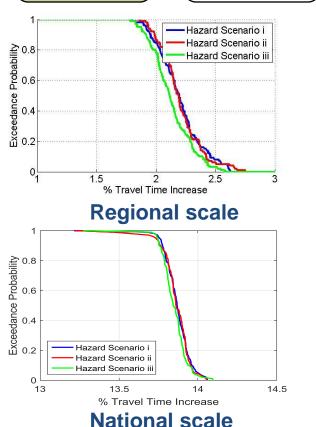
Regional scale







- Monte Carlo sampling method
  - > Epistemic uncertainty
- Direct consequences
  - > Total network repair cost
- Indirect consequences
  - > Increase in average travel time









- Adequacy of risk assessment
- Determine outcome of stress test
  - Risk acceptability
  - > Interventions (i.e. repair works)















- Low probability, high consequence flood scenarios
- Cascading landslide hazard effects
- Direct and indirect consequences









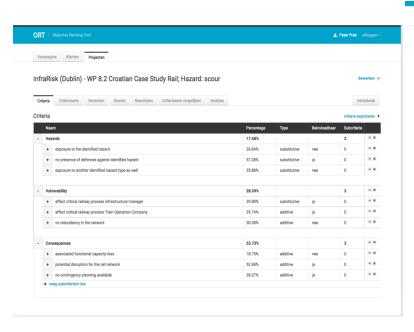
- Low probability, high consequence flood scenarios
- Cascading landslide hazard effects
- Direct and indirect consequences
- Qualitative ORT application







- ORT Application
- > Identification of rail sections most at risk
- Based on principles of similarity judgement, the Delphi method and an Analytical Hierarchy Process



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Criteria Criteriasets Varianten Scores Resultaten				rts vergelijk	en /	Analyse	Adresboek									
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Scores invullen voor Croatian Rail Network TEN-T Corri ▼							scoreblad exporteren .									
		M202: Zagreb GK - Trešnjevka	M202: Trešnjevka - Delta	M202: Delta - Hrvatski Leskovac	M202: Hrvatski Leskovac - Horvati	M202: Horvati - Zdenčina	M202: Zdenčina - Jastrebarsko	M202: Jastrebarsko - Draganići	M202: Draganići - Karlovac	M202: Karlovac - Mrzlo Polje	M202: Mrzło Polje - Duga Resa	M202: Duga Resa - Zvečaj	M202: Zvečaj - Generalski Stol	M202: Generalski Stol - Gornje Dubrave	M202: Gornje Dubrave - Kukača	
Hazards	17.68%															
exposure to the identified hazard	26.84%	1 =	0 -	0 ~	0 -	0 ~	0 ~	1 -	0 ~	1 ~	0 ~	0 -	0 ~	1 ×	0 -	
no presence of defences against identified hazard	37.28%	1 ~	0 ~	0 -	0 -	0 ~	0 ~	1 ~	0 ~	1 ~	0 ~	0 ~	0 ~	1 ~	0 -	
exposure to another identified hazard type as well	35.88%	0 ~	0 -	0 ~	0 -	0 ~	1 -	1 -	0 ~	1 ~	0 ~	1 ~	1 -	1 -	1 -	
/ulnerability	28.59%															
affect critical railway process infrastructure manager	39.88%	1 ~	0 -	0 ~	0 -	0 ~	0 ~	1 ~	0 ~	1 ~	0 -	0 -	0 ~	1 -	0 -	
affect critical railway process Train Operation Company	29.74%	1.0 ~	0.0 -	0.0 ~	0.0 ~	0.0 ~	0.0 ~	1.0 ~	0.0 ~	1.0 ~	0.0 ~	0.0 ~	0.0 ~	1.0 ~	0.0	
no redundancy in the network	30.38%	0.0 ~	0.0 ~	0.0 ~	0.0 ~	0.0 ~	0.0 ~	1.0 ~	0.0 ~	1.0 ~	0.0 ~	0.0 -	0.0 ~	1.0 ~	0.0 ~	
Consequences	53.73%															
		1.0 ~	0.0 -	0.0 ~	0.0	0.0 ~	0.0 ~	1.0 -	0.0 ~	1.0 -	0.0 ~	0.0 -	0.0 ~	1.0 -	0.0 -	
associated functional capacity loss	18.75%	1.0 ~	0.0	0.0	0.0	0.0										









- Low probability, high consequence flood scenarios
- Cascading landslide hazard effects
- Direct and indirect consequences
- Qualitative ORT application
- Quantitative risk assessment



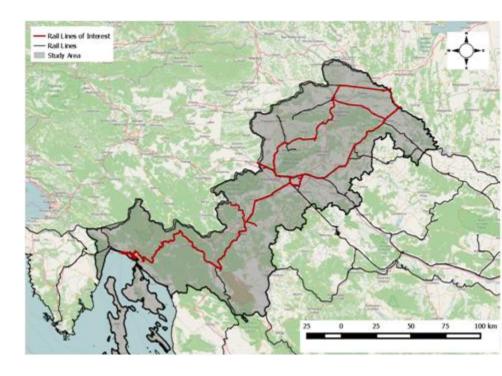






#### **Spatial Boundaries**

- 800 km of rail
- Area of 35,000 km<sup>2</sup>
- Vital link from port of Rijeka to city of Zagreb
- International connections to Slovenia and Hungry











#### **Flood Hazard Model**

- Bridge scour
- Track inundation
- Track blockages due to rainfall-triggered landslides









#### Flood Hazard Model - Bridge Scour

Kupa Karlovac bridge



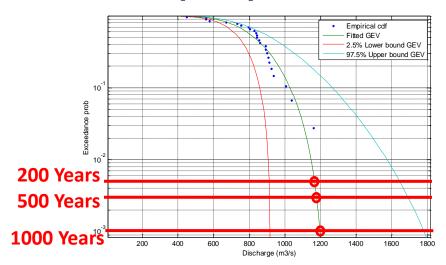






#### Flood Hazard Model - Bridge Scour

- Kupa Karlovac bridge
- Historical daily max. values of water flow (m³/s)





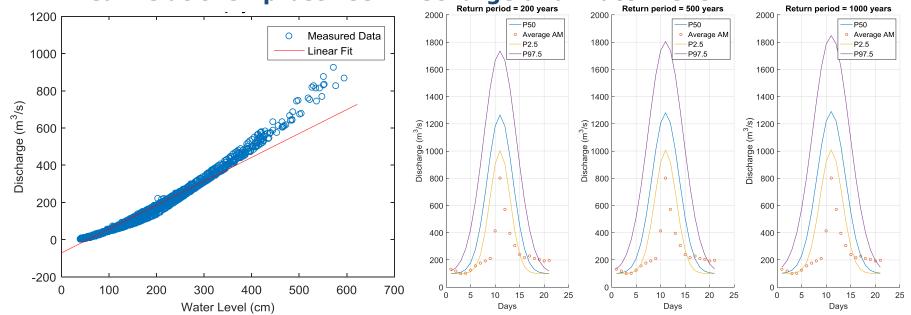






#### Flood Hazard Model - Track Inundation

Linear relationship between Discharge and Water Level





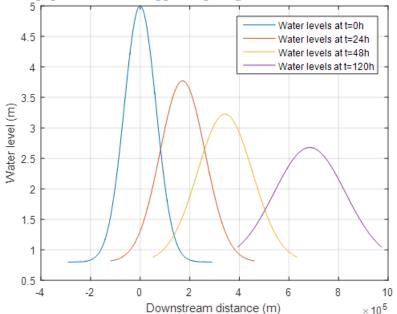






#### Flood Hazard Model - Track Inundation

• Linear hydrodynamic modelling approach (propagation of flood wave downstream)



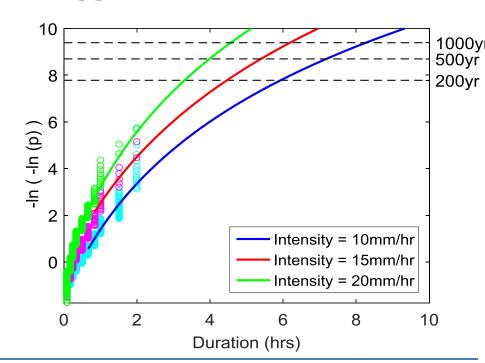






#### Rainfall Hazard Model - Rainfall Triggered Landslides

- Daily rainfall data
- Probabilistic extrapolation
- 200, 500 & 1000 yr durations





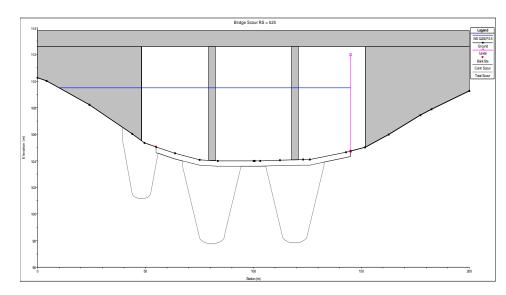






#### Network Vulnerability - Karlovac Bridge

- Historical daily max. values of water flow (m³/s)
- Kupa Karlovac bridge
- Scour calculation
  - > General scour
  - > Contraction scour
  - > Local scour



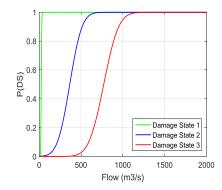


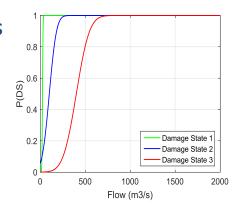




#### Network Vulnerability - Karlovac Bridge

- Development of fragility functions
  - > Three damage states defined
    - 1. Limit train speed during repair works
    - 2. Total traffic interruption during repair works
    - 3. Total collapse
  - Defined for bridges piers and abutments







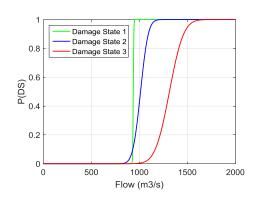






#### Network Vulnerability - Karlovac Bridge

- Development of fragility functions
  - Three damage states defined
    - 1. Limit train speed during repair works
    - 2. Total traffic interruption during repair works
    - 3. Total collapse
  - Defined for bridges piers and abutments
  - Consideration of scour protection measures





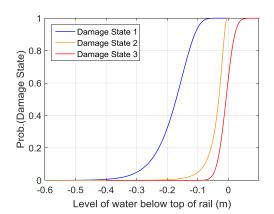


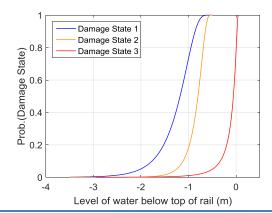




#### **Network Vulnerability - Track Inundation**

- Visual inspection of flood hazard maps
- Susceptible rail segments identified
- Three damage states defined
  - > Slight
  - ➤ Moderate
  - > Extensive/Complete
- Fragility functions developed for:
  - > Rails on grade or in cut
  - > Rails on embankments



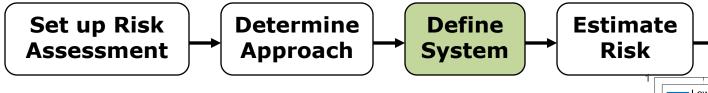






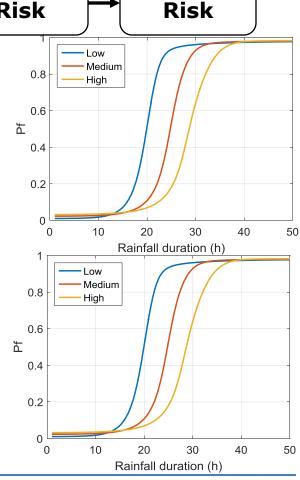
**Evaluate** 

## **Italian Case Study**



#### <u>Network Vulnerability – Landslides</u>

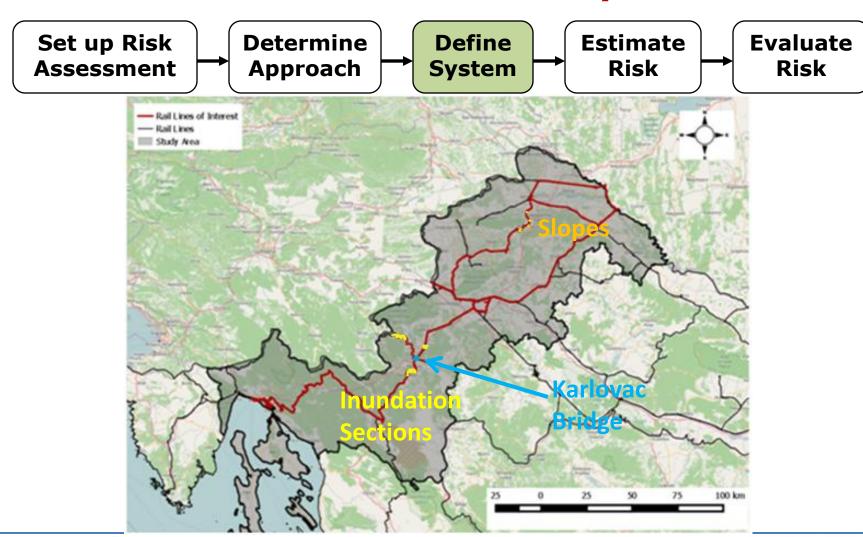
- Visual inspection of Google Maps
- Susceptible slopes identified
- Three damage states defined
  - > Low
  - > Medium
  - > High
- Fragility functions developed for:
  - > Different rainfall intensities









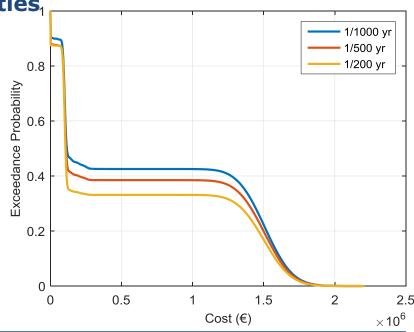








- Monte Carlo sampling method
  - Aleatoric and epistemic uncertainties<sub>1</sub>
- Direct consequences
  - > Total network repair cost

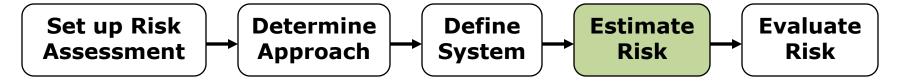


Scour + Inundation







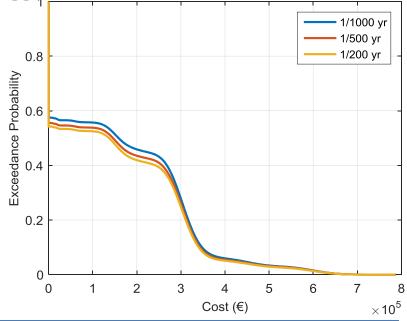


Monte Carlo sampling method

Aleatoric and epistemic uncertainties

- Direct consequences
  - > Total network repair cost

#### **Rainfall Induced Landslides**



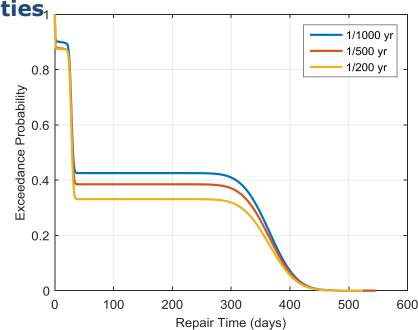








- Monte Carlo sampling method
  - Aleatoric and epistemic uncertainties<sub>1</sub>
- Direct consequences
  - > Total network repair cost
- Indirect consequences
  - >Time to repair network



Scour + Inundation



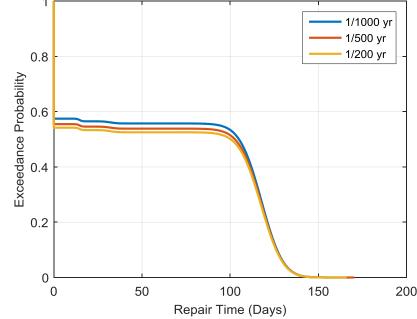






- Monte Carlo sampling method
  - Aleatoric and epistemic uncertainties,
- Direct consequences
  - > Total network repair cost
- Indirect consequences
  - >Time to repair network

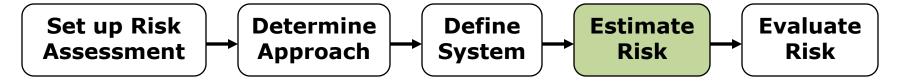
#### **Rainfall Induced Landslides**



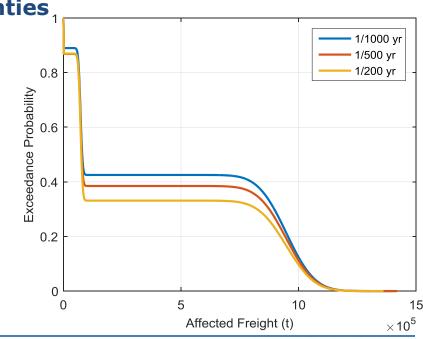








- Monte Carlo sampling method
  - Aleatoric and epistemic uncertainties
- Direct consequences
  - > Total network repair cost
- Indirect consequences
  - >Time to repair network
  - >Level of affected freight



Scour + Inundation





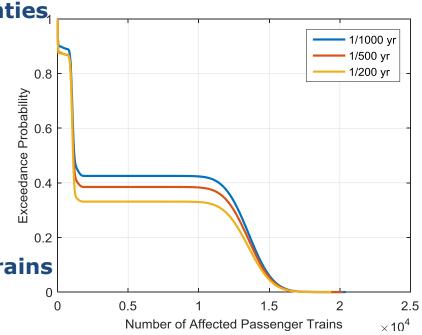




Aleatoric and epistemic uncertainties,

#### Direct consequences

- > Total network repair cost
- Indirect consequences
  - >Time to repair network
  - >Level of affected freight
  - > Number of impacted passenger trains

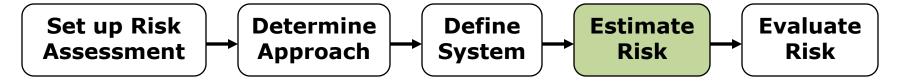


Scour + Inundation









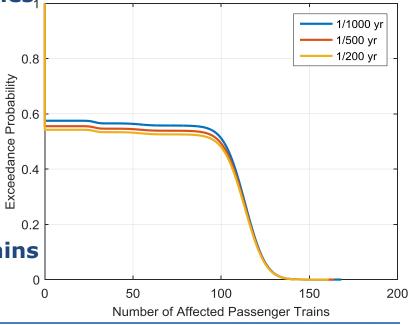


Aleatoric and epistemic uncertainties,

#### Direct consequences

- > Total network repair cost
- Indirect consequences
  - >Time to repair network
  - >Level of affected freight
  - >Number of impacted passenger trains

#### **Rainfall Induced Landslides**









#### **Further Information**

**Deliverable 8.2 Case Study Results** 





# FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate change)





Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

www.infrarisk-fp7.eu

#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960





# INFRARISK: Consortium Meeting WP7

# "The Integrated Decision-Support Tool"



**Dr Zoheir Sabeur, Science Director** 

**University of Southampton IT Innovation Centre** 

Southampton

**INFRARISK Progress Meeting** 

29th September 2016, DRAGADOS, Madrid, Spain







## IDST Design, Architecture

#### **IDST Software Design**

- Portal build using Django Framework
- Dynamic content using JavaScript (jQuery, Bootstrap)
- PostgreSQL (PostGIS modules)
- Mapping using OpenSteetMap data

#### **IDST** services

Current releases:

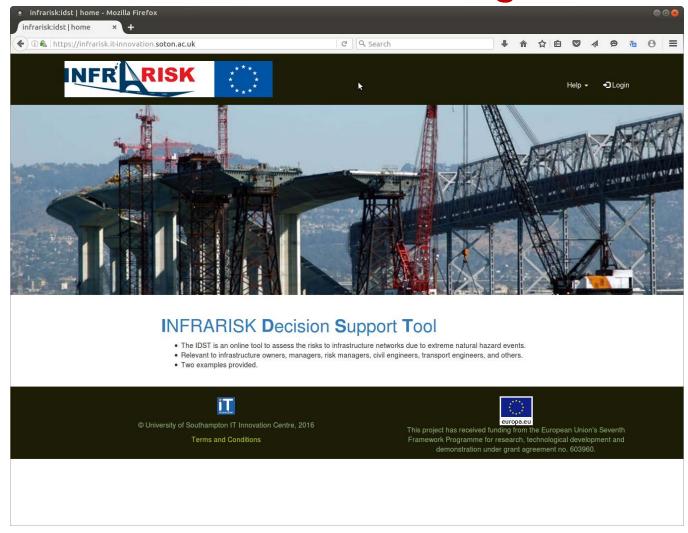
http://infrarisk.it-innovation.soton.ac.uk







### The IDST Portal Page



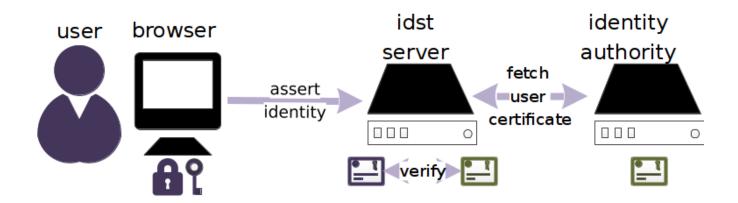




## **IDST Authentication System**

#### Authentication in IDST is based on

- Local user account authentication (exclusive for admin users)
- Third party authentication services (for normal users), e.g.
  - Mozilla
  - Google
  - Yahoo
  - LinkedIn

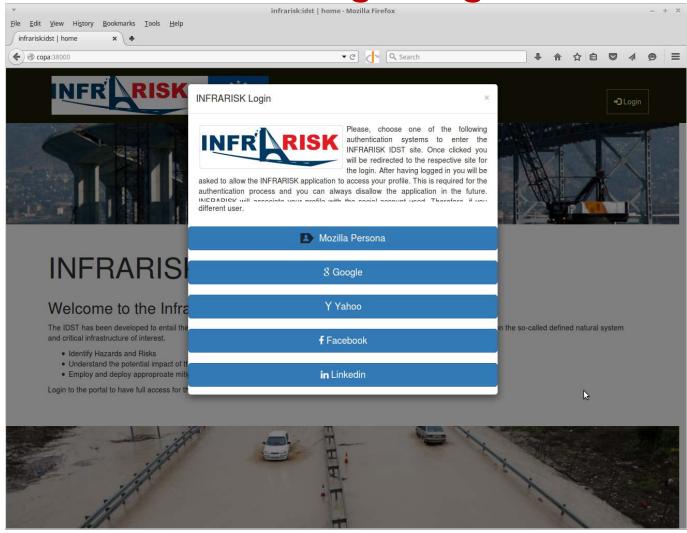








# **IDST Login Page**



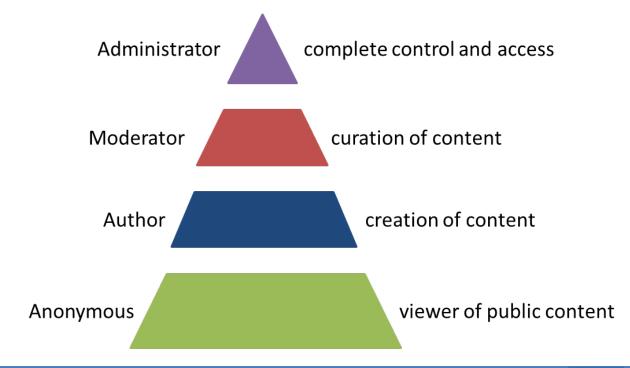






#### **Authorisation and User Roles in IDSP**

Authorisation in IDST is based on Roles Role assigns what rights a user has A user can have multiple roles

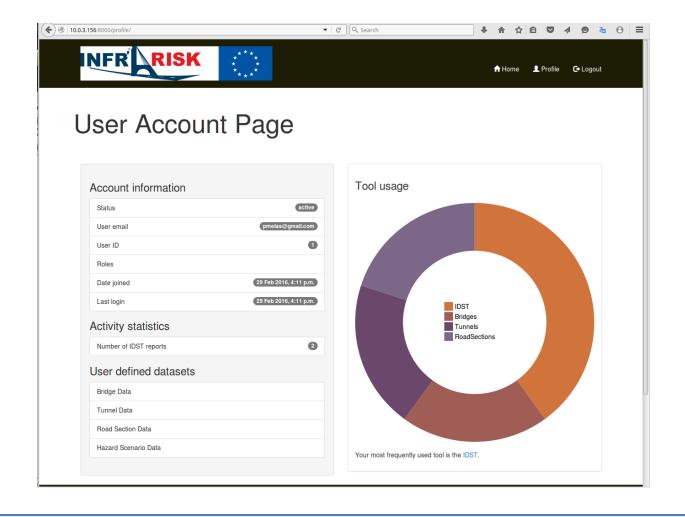








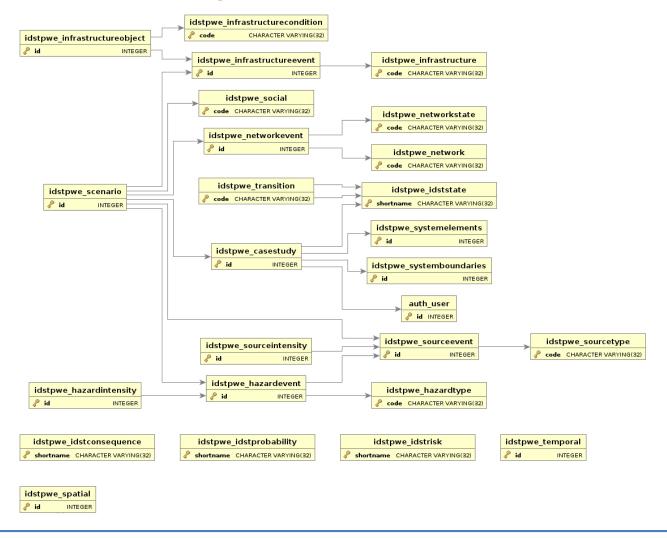
## User profile, status in IDST







## The Case Study Information Model in IDST









### **IDST** modelled data

- OSM data sources
  - Bridge
  - Road
  - Tunnel
- Hazard data (supported by Ground Motion Models)
  - PGA
- Structural data
  - Bridges
  - Tunnels
  - Road sections







### OSM data models, DB schemas in IDST

osm_bridge				
2	id INTEGER			
	osm_id	CHARACTER VARYING(11)		
	name CHARACTER VARYING(48			
	ref CHARACTER VARYING(16)			
	type CHARACTER VARYING(16			
	oneway	INTEGER		
	<b>bridge</b> INTEGER			
	tunnel INTEGER			
	maxspeed INTEGER			
	length	INTEGER		
	geom	USER-DEFINED		

osm_road					
🧳 id	id INTEGER				
osm_id	CHARACTER VARYING(11)				
name	CHARACTER VARYING (48)				
ref	ref CHARACTER VARYING(16)				
type	CHARACTER VARYING(16)				
oneway	INTEGER				
bridge	INTEGER				
tunnel	tunnel INTEGER				
maxspeed	INTEGER				
geom	USER-DEFINED				
geom	USER-DEFINED				

osm natural

osm\_id CHARACTER VARYING(11)

USER-DEFINED

CHARACTER VARYING (48)

CHARACTER VARYING(16)

INTEGER

id

geom



osm_tentroad			
🧳 id	id INTEGER		
osm_id	CHARACTER VARYING(11)		
name	CHARACTER VARYING (48)		
ref	ref CHARACTER VARYING(16		
type	CHARACTER VARYING(16)		
oneway	INTEGER		
bridge	INTEGER		
tunnel	tunnel INTEGER		
maxspeed	maxspeed INTEGER		
geom	USER-DEFINED		

osm_landuse			
8	id	INTEGER	
	osm_id	CHARACTER VARYING(11)	
	name	CHARACTER VARYING(48)	
	type	CHARACTER VARYING(16)	
	geom	USER-DEFINED	

osm\_railway

id INTEGER
osm\_id CHARACTER VARYING(11)
name CHARACTER VARYING(48)
type CHARACTER VARYING(16)
geom USER-DEFINED

	osm_building			
2	id INTEGER			
	osm_id	CHARACTER VARYING(11)		
	name	CHARACTER VARYING(48)		
	type	CHARACTER VARYING(16)		
	geom	USER-DEFINED		

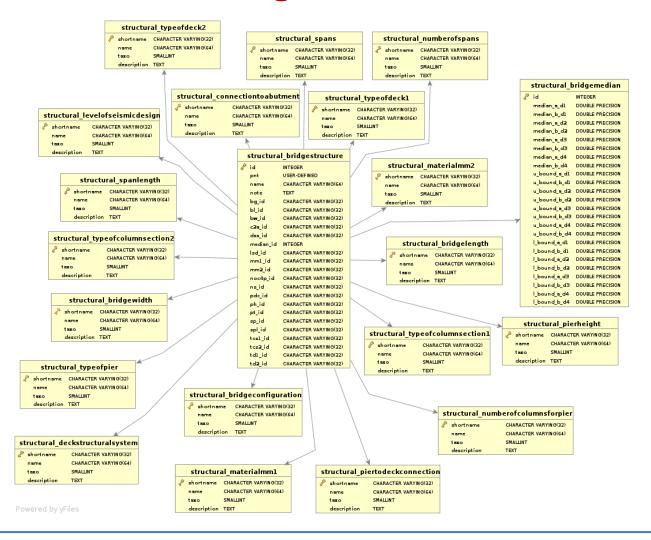
Powered by yFiles







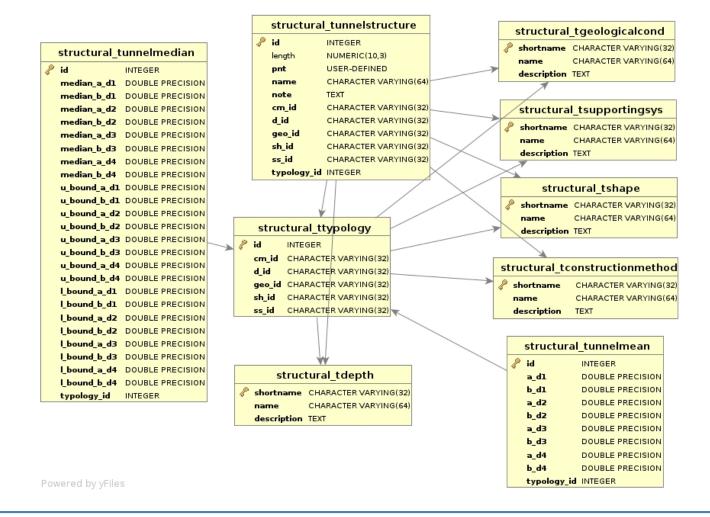
## The IDST Bridge structural model







### The IDST Tunnel structural model







### The IDST Case Study

### **IDST Terminology:**

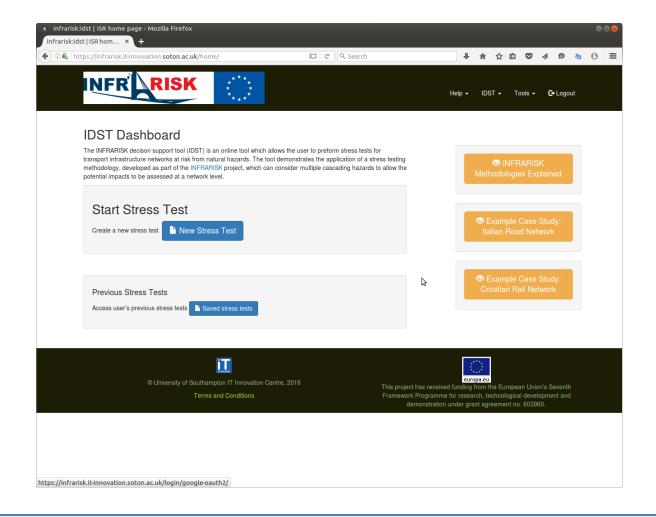
- An IDST Process Workflow Engine run is a Case Study or scenario
- An IDST case study stores all necessary information to run a workflow.
- Users can create and manage multiple Case Studies, i.e.
  - Create
  - Run
  - Edit
  - Delete







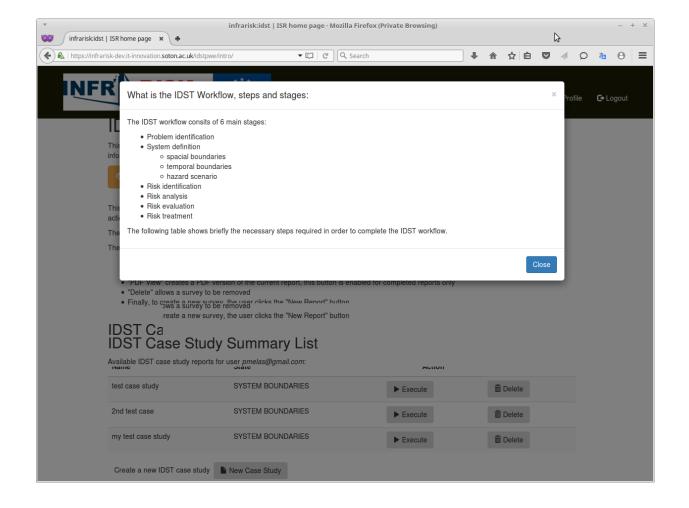
## IDST case study dashboard







## IDST on-line help page







### **Process Workflow Engine Implementation**

- Governed by Overarching Risk Management Framework (ORMF), implemented as a Case Study in IDST
  - Define a new Case Study, i.e. name, description
  - Define system boundaries
  - Define the hazard scenario, i.e. hazard source, assign hazard events
  - Configure hazard event assigned models
  - Define the network scenario, i.e. network type, assign network elements and their fragility curves models
  - Define network characteristics, (datasets)
  - Derive damage states for each element using their fragility curves and hazard intensity (e.g.PGA values)
  - Provide results for further processing outside the IDST







## Case Study Northern Italy Scenario

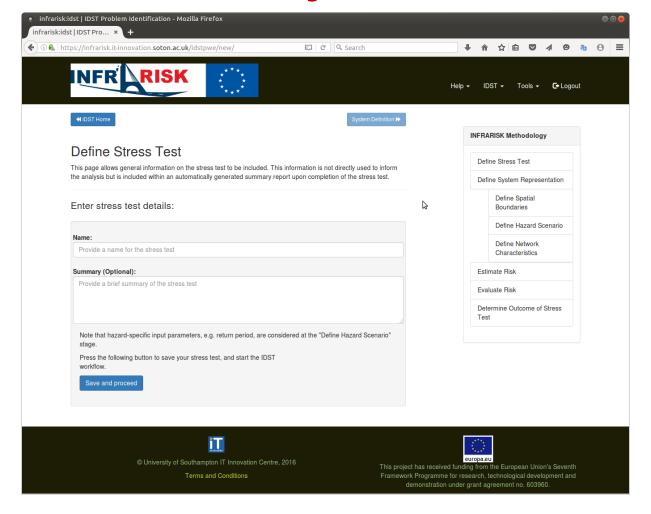
- Target area: Region of Bologna, Northern Italy
- Network: Road network, (European TEN-T network)
- Hazards source: Earthquake
  - Hazard event: Ground motion (primary)
  - Hazard event: Earthquake-triggered landslides (secondary)
- Network element types:
  - Bridges
  - Tunnels
  - Road sections
- Determine element characteristics, i.e. network elements in IDST database datasets for bridges, tunnels, road section, or upload user defined.
- Stress tests: determine risk associated with an earthquake hazard event on the road network
- Calculate direct costs







## Create a new Case Study, Problem Identification

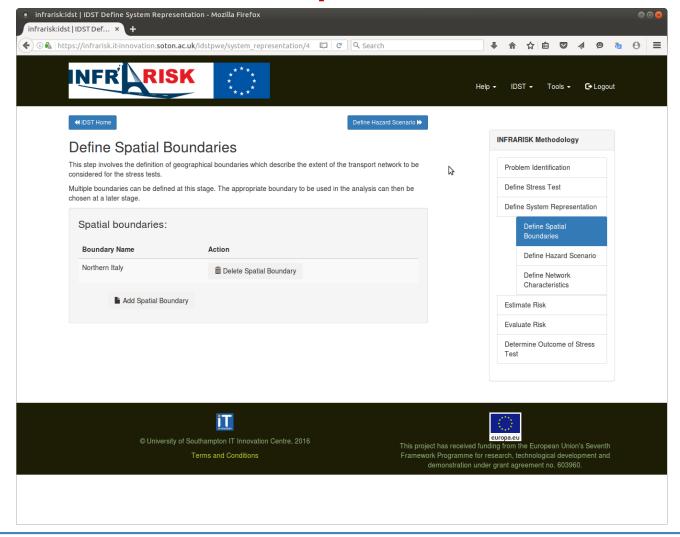








## **IDST:** Define spatial boundaries

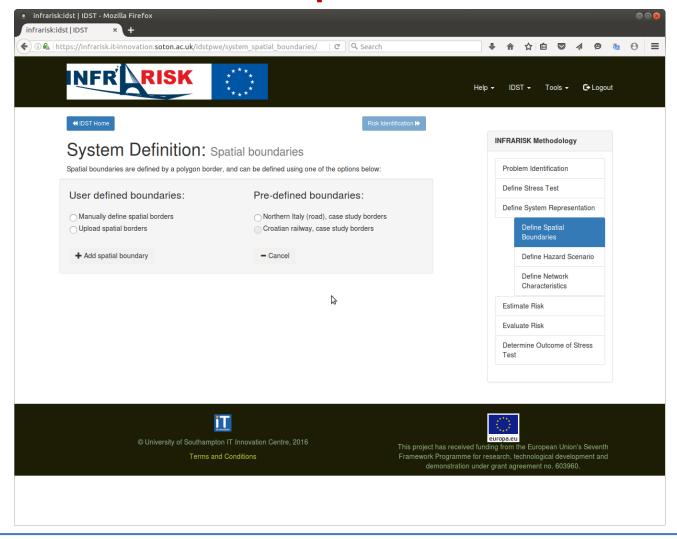








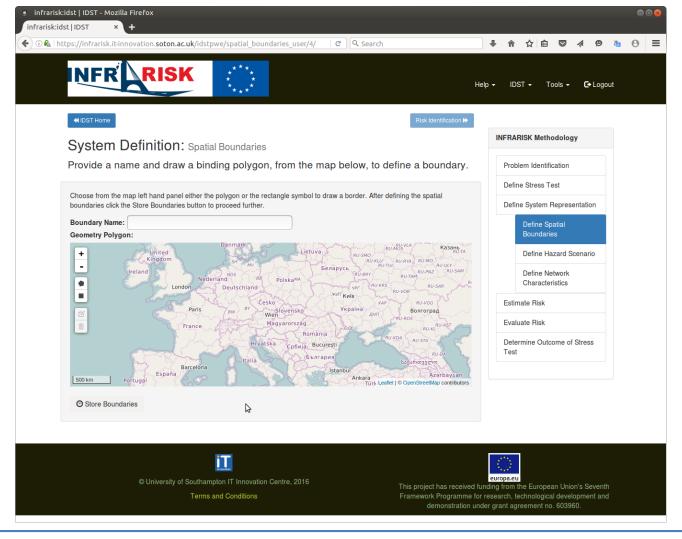
## **IDST:** Define spatial boundaries







## IDST: Define spatial boundaries manually









#### IDST: define hazard scenario

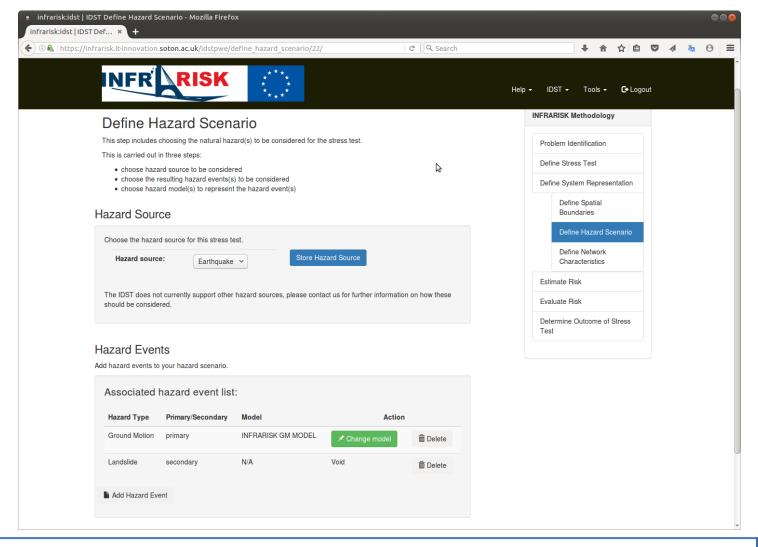
- Source event: e.g. earthquake
- Hazard events:
  - A ground motion hazard
  - and the cascading effects, i.e. earthquake-triggered landslides







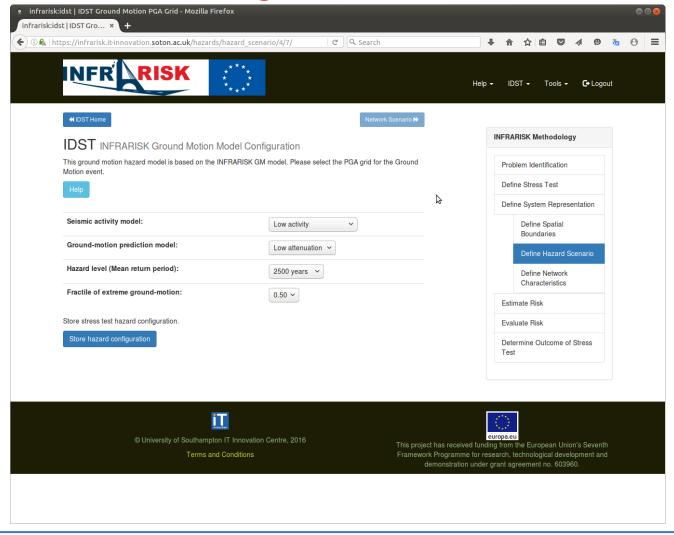
### IDST: define hazard scenario







# **IDST:** configure hazard model

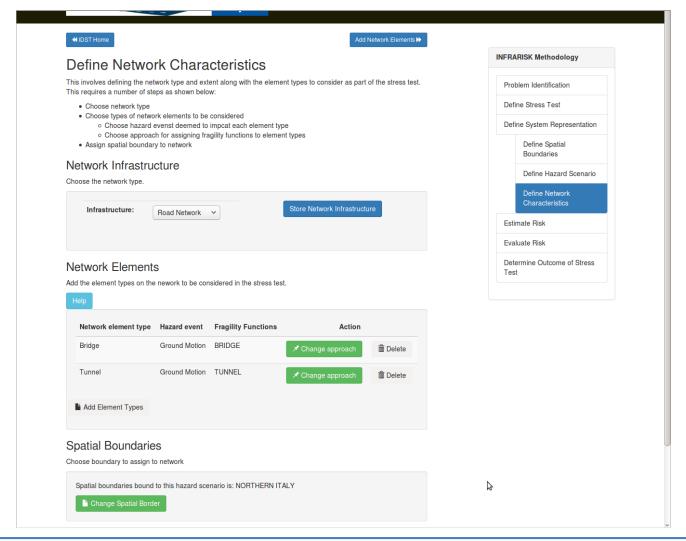








### IDST: define network scenario







## Assigning Bridge, Tunnel Fragility Curves

- Median fragility curves with confidence bounds is ported to IDST
- Bridge and tunnel structural data modelled and ingested in IDST, 340 bridges, 30 tunnels
- Mean and standard-deviation for all damage states is calculated for 4 damage states
- Damage state sampling algorithm is also ported in IDST for a given hazard intensity (IM)

a/a	Damage State	Description
0	DS0	No damage
1	DS1	Slight damage
2	DS2	Moderate damage
3	DS3	Extensive damage
4	DS4	Complete damage







## **Assigning Road Section Fragility Curves**

Structural Road sections data are modelled

Landslide data are modelled

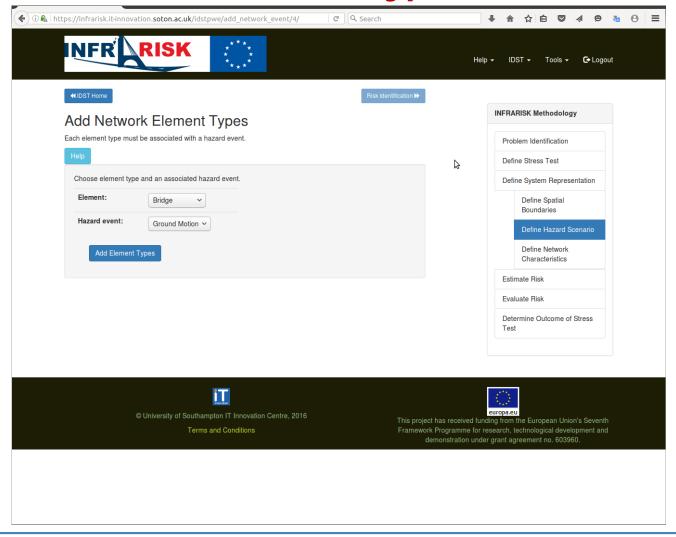
Fragility Curves calculation porting to IDST is implemented

a/a	Damage State	Description
0	DS0	No damage
1	DS1	Slight damage
2	DS2	Moderate damage
3	DS3	Extensive damage





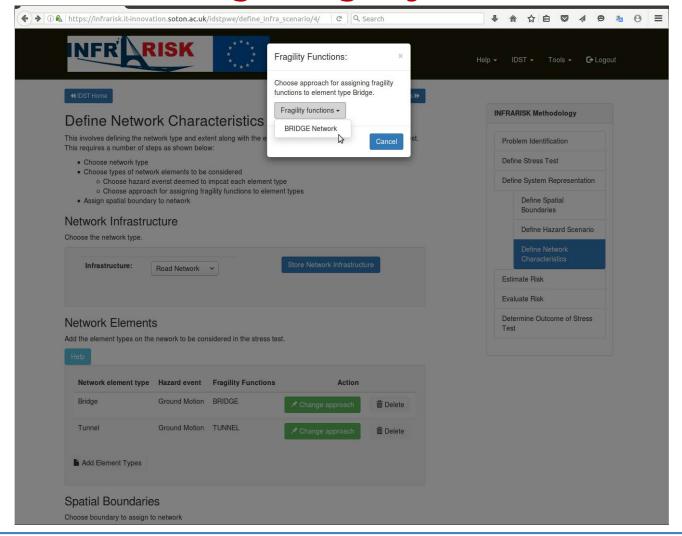
## IDST: add network type elements







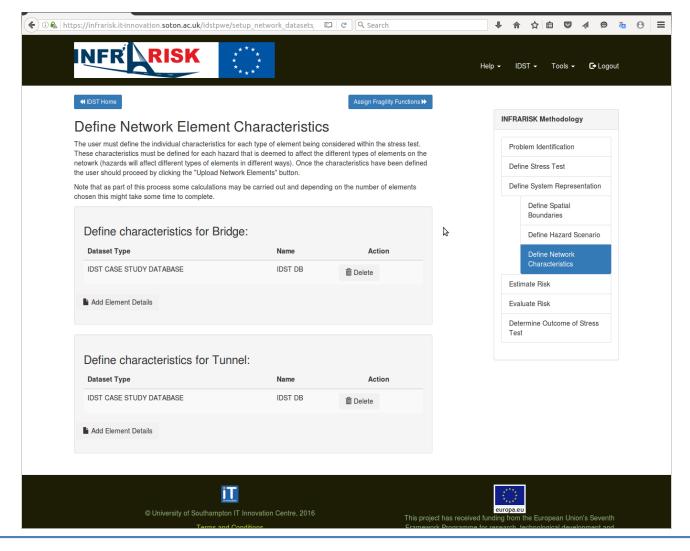
## **IDST:** assign fragility functions







### IDST: Define network element characteristics

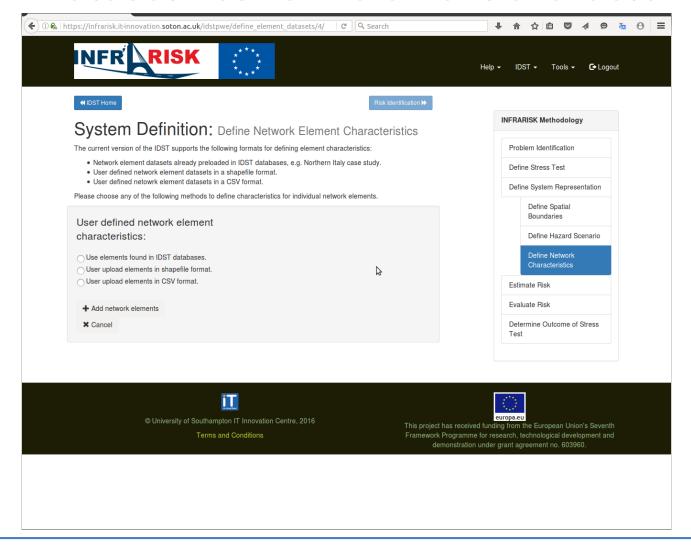








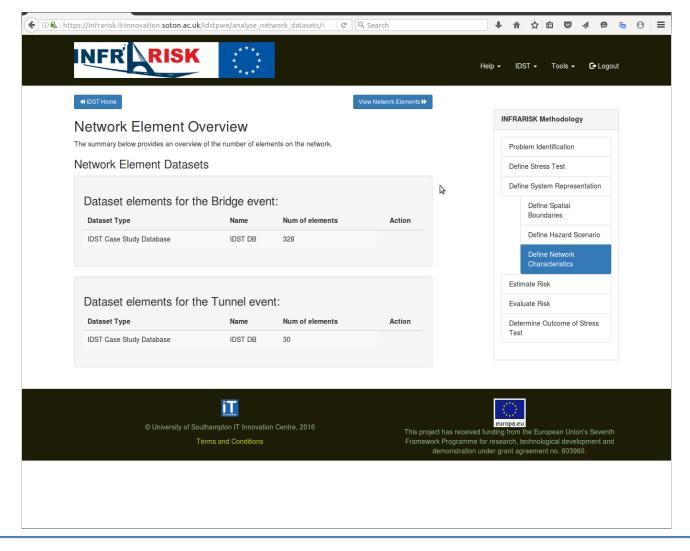
### **IDST:** Dataset network element characteristics







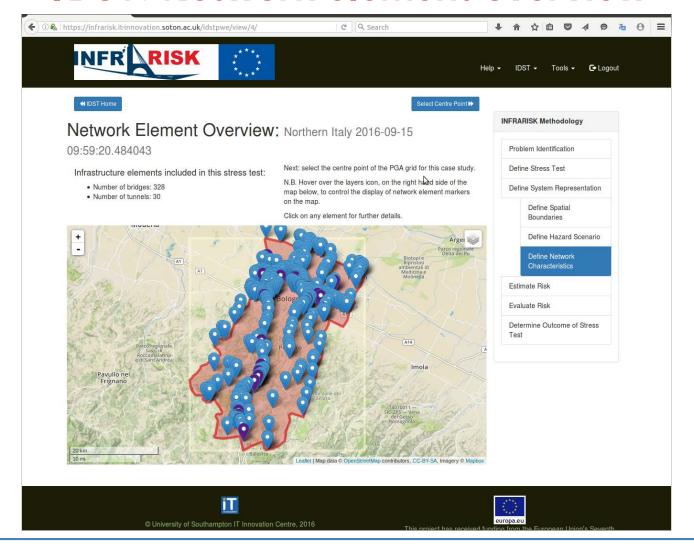
### **IDST: Overview of network element datasets**







#### **IDST: Network element overview**

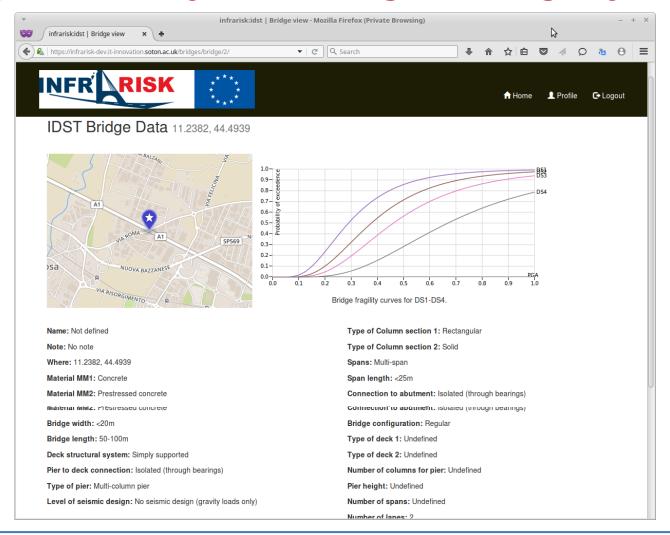








## Bridge summary with assigned Fragility Curves

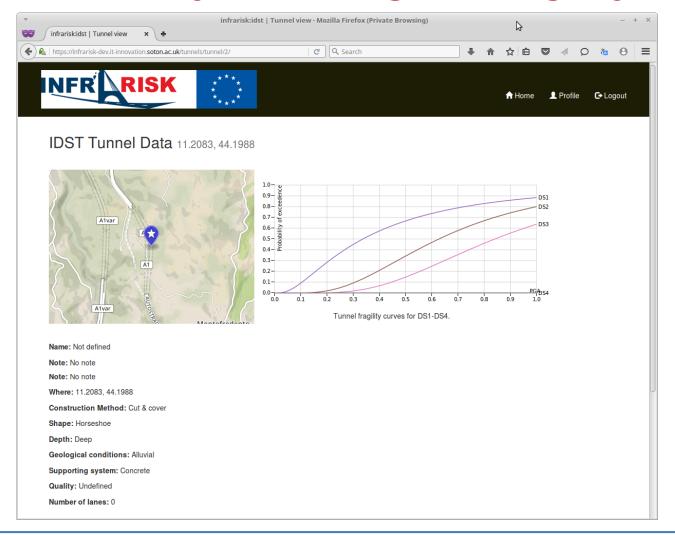








# **Tunnel summary with assigned Fragility Curves**

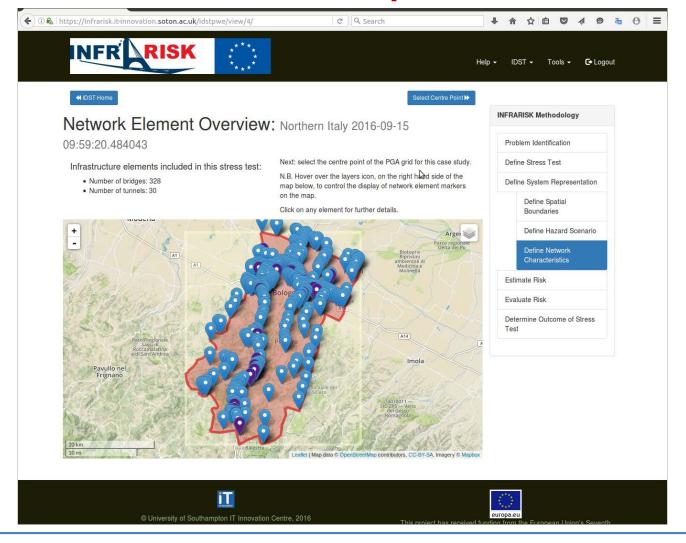








## **IDST:** Choose centre point of interest

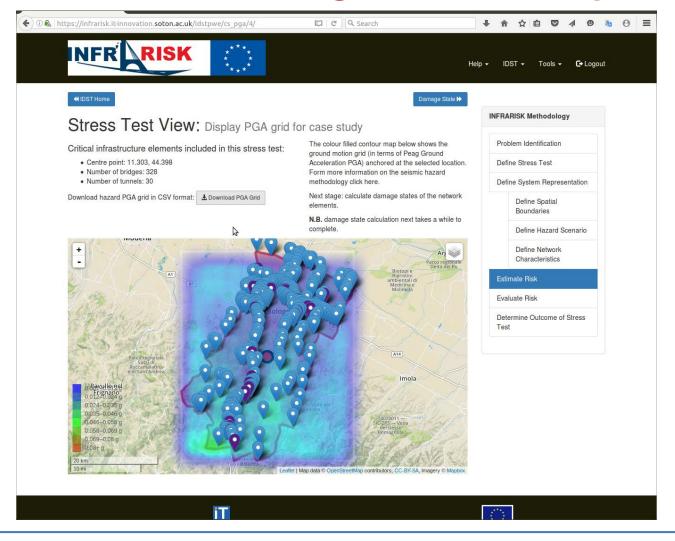








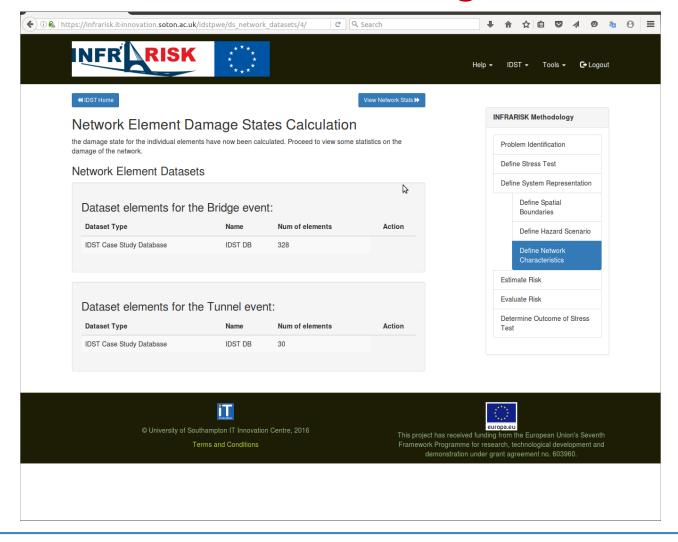
## **IDST:** Anchor PGA grid on centre point







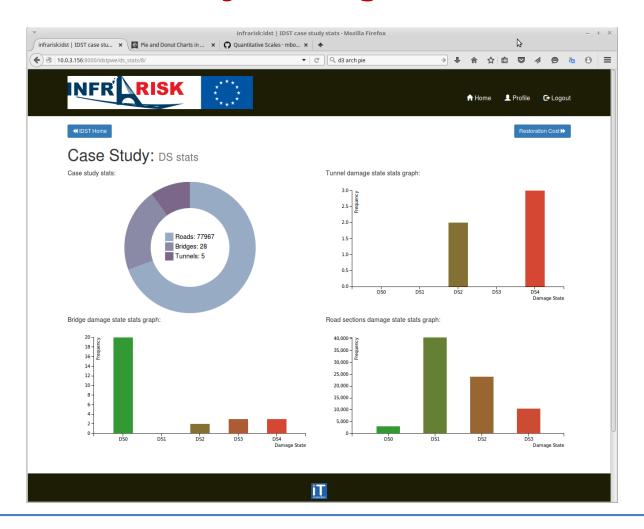
## **IDST: Calculate Damage States**







## **Case Study Damage State stats**







## Assigning provisional consequence parameters

	Functional Capacity Loss	Functional Capacity Loss during Restoration	Restoration Time	Restoration Cost
	(% Lane Closure)	(% Lane Closure)	(Days)	(Euros)
Pavements (All)				
No Damage	0	0	0	0
Slight/Minor	0	0.5	1	500
Moderate	0.5	0.5	1	1000
Extensive/Complete	1	1	1	3500
Bridges (All)				
No Damage	0	0	0	0
Slight/Minor	0	0.5	120	100000
Moderate	0.5	0.5	120	750000
Extensive/Major/Severe	1	1	150	1000000
Complete/Collapse/Failure	1	1	150	1000000
Tunnels (All)				
No Damage	0	0	0	0
Slight/Minor	0.75	0.75	120	150000
Moderate	1	1	120	1000000
Extensive/Major/Severe	1	1	120	3000000
Complete/Collapse/Failure	1	1	365	10000000





### Join us to run the IDST

https://infrarisk.it-innovation.soton.ac.uk/

### **Thank You**





# FP7 2013 Cooperation Work Programme Theme 6: Environment (Including Climate change)





Novel Indicators for identifying critical **INFRA**structure at **RISK** from Natural Hazards

#### Website

www.infrarisk-fp7.eu

#### **Acknowledgement**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960



# INFRARISK GIS Knowledge Base

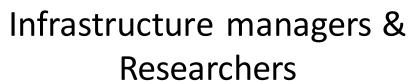
Dumitru Roman

dumitru.roman@sintef.no



An integrated knowledge base about major infrastructure failures with natural hazard events





(risk management, transportation, civil engineering, natural sciences, etc.)



To gather and present valuable information on the outcomes of natural hazard events on critical transport infrastructure

### HOW

A Linked Data approach

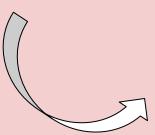


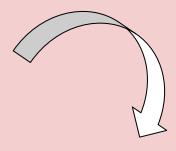
# From tabular data to insightful information

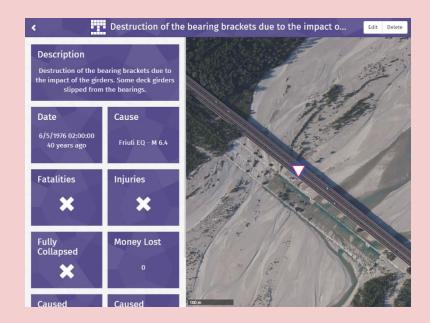
	Main diagram					?	?		Consequence diagram								
CSV file:	Infrastructure Rail F	Road GEOGRAPHICAL FE	Infrastru	cture_compone	Slope		,	Soil	Mass			Cons	Monetary	Societal_I	Loss	Usability	probl
input lines from CSV file:	infrasimportanerail sr	oad_ID	Infracian	e description	slope_II heigh	nt rock_namislop	e_soil_name	soil_namesoil_categ	mas:depth	rock_namirun_out	soil_name volume	cons	mone mor	socithas_t	fahas i	usal cond	x conce
data source:		Open Street Map?	оре	en source: repor	rts, artid after	propen sour afte	r popen source	open sour open sour	ce: d open so	ur open sour open so	ur open sour open sour	oper	sourc open	sou open	open	sou oper	open
Hatfield Colliery	1 high 1	line (also, point XY	1	4 Soil cutting in	1 X	sandstoneX	Alluvium - d	Alluvium -silt	1 X	sandstonenegligib	le Alluvium · X	1	1 X	1 No	No	1 Yes	No
A85 Glen Ogle	2 medium	1 line (also, point XY	2	2 Natural slope	2 X	semipeliteX	Till and more	Till and metill	2 0.6-1.8	m semipelite>400 m	Till and m: 50 t	2	2 X	2 No	No	2 No	Yes
Rest and Be Thankful	3 medium	2 line (also, point XY	3	2 Natural slope	3 X	schist X	Peat and col	Peat and ccolluvium	3 0.6-1.8	m schist >400 m	Peat and c 100 t	3	3 X	3 No	No	3 No	Yes
Harbury tunnel	4 high 2	line (also, point XY	4	2 Soil cutting	4 30 m	mudstone X	Glaciolacust	Glaciolacuclay	4 20 m	mudstone negligib	le Glaciolacu 350,000 t	4	4 X	4 No	No	4 Yes	No
Rosyth	5 medium 3	line (also, point XY	5	2 Soil cutting	5 5 m	limestone 31"	Till	Till till	5 0.5-1.0	m limestone4m	TIII X	5	5 X	5 No	No	5 No	Yes

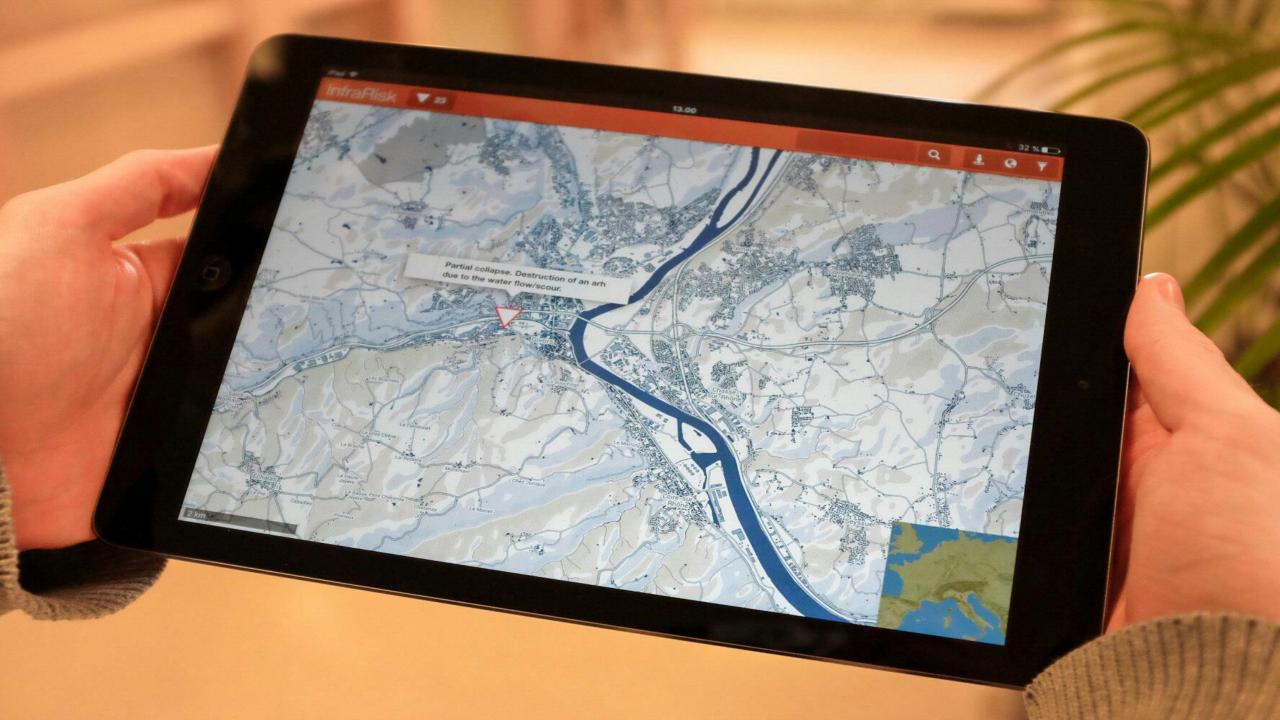
	Main diagram	?	?	Consequence diagram				
CSV file:	Infrastructure Rail Road GEOGRAPHICAL FE Infrastructure compone Slope	Soil	Mass	Cons Monetary I	Societal Loss	Usability probl		
input lines from CSV file:	Infra: Importanerall_road_ID	soil_name soil_categ	massdepth rock_nam run_out_soil_namevolume	cons mone mon	sociihas_fzhas_i	usal conce conce		
data source:	Open Street Map? open source: reports, articl after pi open sour after piopen source	e open sour open sou	rce: d open sour open sour open sour open sour open sour	open sourc oper	sou open open	sou open open:		
San Benedetto Po bridge	1 medium 1 45.04.27 / 10.56.01 1 2 bridge - RC - 4span - continuous			1 1	1 no no	1 no no		
Finale Emilia bridge	2 medium 2 44.50.17 / 11.18.40 2 2 bridge - RC - 4span - Independent - SS			2 2	2 no no	2 no no		
Mirandola bridge	3 medium 3 44.52.14 / 11.04.02 3 2 bridge - arch masonry - single span - 25m			3 3	3 no no	3 no no		
Pontelagoscuro bridge	4 medium 4 44.53.18 / 11.36.29 4 2 bridge - steel deck, rectangular masonry piers, RC abutm	ents - 4span - Indepen	ident - SS	4 4	4 no no	4 no no		
Bomporto bridge	5 medium 5 44.43.38 / 11.02.43 5 2 bridge - RC arch - 3span - continuous - SS			5 5	5 no no	5 no yes		
San Felice sul Panaro bridg	6 medium 6 44 49 35 / 11 08 28 6 2 bridge - RC girder - multi span - SS			6 6	6 no no	6 no no		
Fossa Station bridge	7 medium 7 42.18.14 / 13.30.12 7 2 bridge - RC - 3span - continuous			7 7	7 no no	7 yes no		
Onna Village bridge	8 low 8 42.19.27 / 13.28.41 8 1 bridge - RC - 3span - continuous			8 8	8 no no	8 no no		

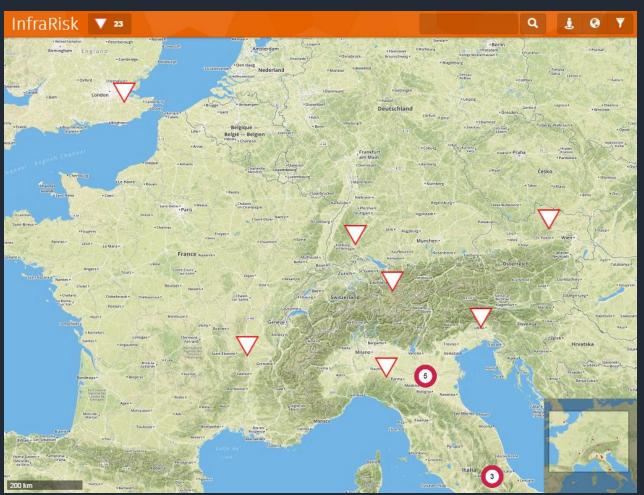


















Previous damage. Cracking of some structural and non-...

### Description

Previous damage. Cracking of some structural and non-structural elements (as the abutment and a opened hole in the sidewalk)

#### Date

20/5/2012 03:00:00 4 years ago

#### Cause

Emilia EQ - M 6.0

#### **Fatalities**



### Injuries

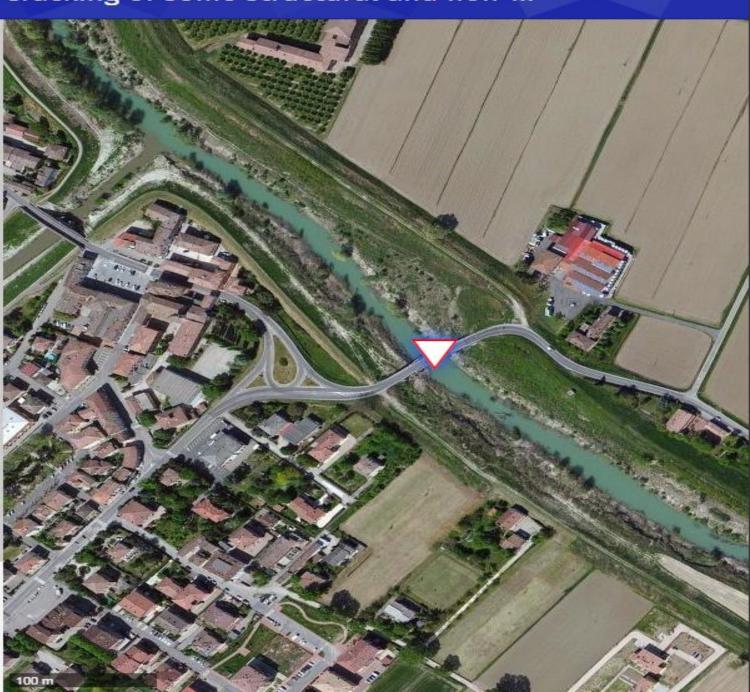


Fully Collapsed



### **Money Lost**

0



# Features of the approach

- End-user friendly Web application
- Grounded on a comprehensive data model for infrastructure components an natural hazards
- Easy to onboard data (e.g. upload spreadsheets)
- Data hosting/access
- Data provisioned as Linked Data
- Structured querying (SPARQL)

Easy to use

And can contribute

Relevant data

Relevant data

Relevant data

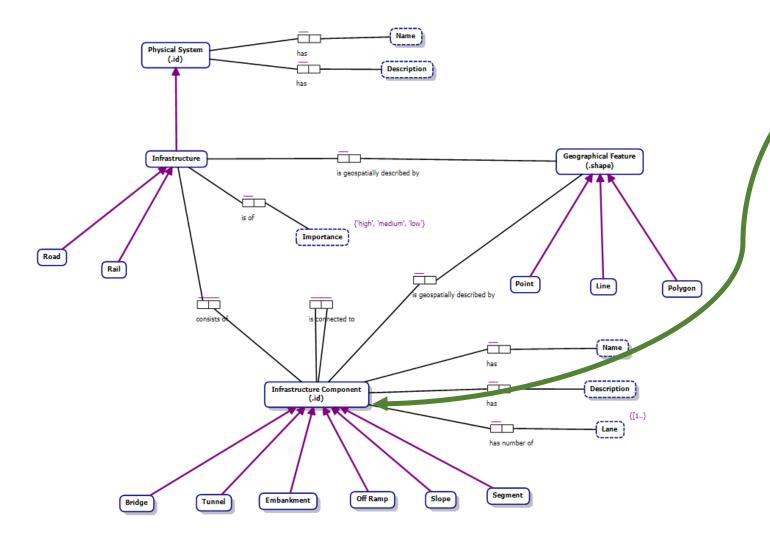
You don't need to worry about technicalities

Simple to link "our" data with other data sources

Powerful querying capabilities

Ruis later

### Schema



### Vocabulary – example

#### "Infrastructure Component" Object Type 1

#### Summary

Infrastructure Component is an entity type.

Reference Scheme: Infrastructure Component has Infrastructure Component\_id.
Reference Mode: .id.

#### Fact Types

- . Each Bridge is an instance of Infrastructure Component.
- . Each Embankment is an instance of Infrastructure Component.
- . Infrastructure Component Failure concerns full collapse of Infrastructure Component.
- Infrastructure Component Failure concerns partial collapse of Infrastructure Component.
- · Infrastructure Component has Description.
- Infrastructure Component has Infrastructure Component\_id.
- Infrastructure Component has Name.
- Infrastructure Component has number of Lane.
- Infrastructure Component is connected to Infrastructure Component.
- . Infrastructure Component is geospatially described by Geographical Feature.
- Infrastructure consists of Infrastructure Component.
- Each Off Ramp is an instance of Infrastructure Component.
- Each Segment is an instance of Infrastructure Component.
- Each Slope is an instance of Infrastructure Component.
- Each Tunnel is an instance of Infrastructure Component.
- . Usability Problem concerns closure of Infrastructure Component.
- Usability Problem concerns reduced traffic on Infrastructure Component.
- Related Types
  - Description
  - · Geographical Feature
  - Infrastructure
  - · Infrastructure Component Failure
  - Infrastructure Component\_id
  - Lane
  - Name
  - Usability Problem

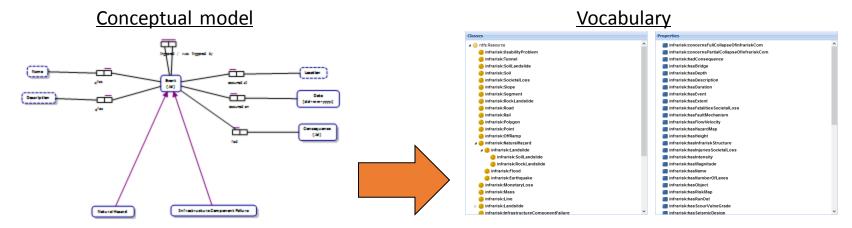
#### Super Types

There are no items for this section.

#### Sub Types

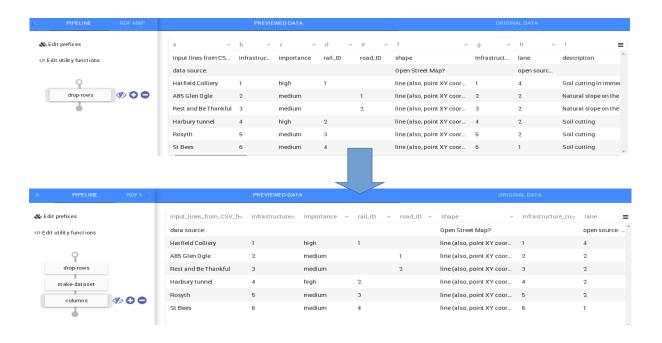
- Bridge
- Tunnel
- Embankment
- Off Ramp
- Slope
- Seament

Defined data representation format in graph format



Collected dataset samples (CSV format)

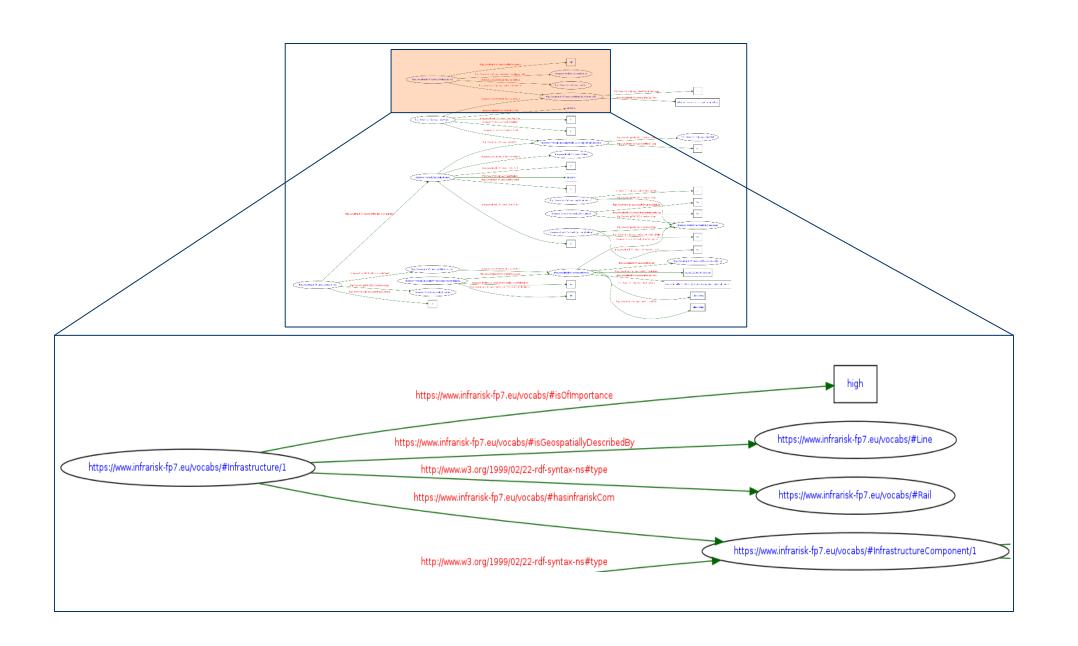
Dataset	Description	Filename
Events#1	Sample data about landslides, bridge failures and	ETHZ-Contribution-to-D2.2.xlsx
	road failures in Europe.	
Floods #1	Sample data about floods in Europe.	database floods yuliya.xls
Floods #2	Sample data about floods in Spain.	EVENTS_DRA.xlxs
Bridge failures #1	Sample data about bridge failures in Europe.	events.xlsx
Bridge failures #2	Sample data about motorway bridge failures in	events_failures_CSIC_T2.2.xlsx
	Europe.	



# **DataGraft**

https://datagraft.net



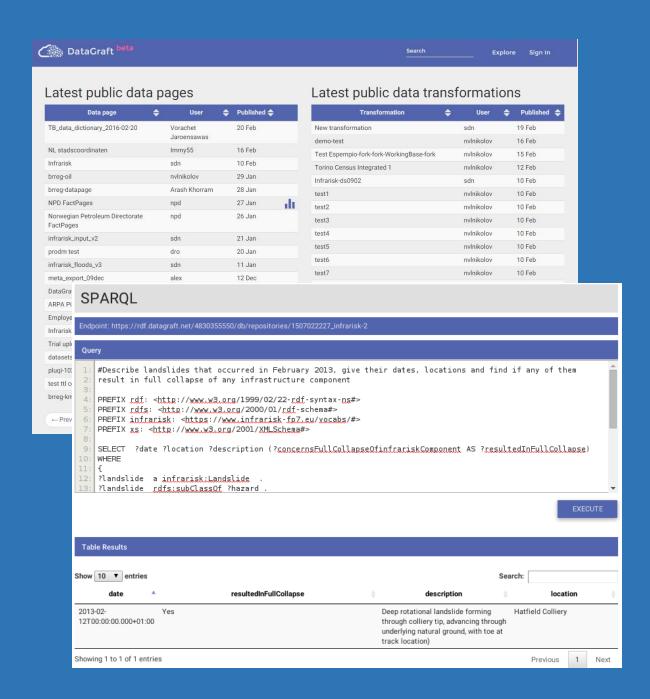


# Sample queries

 Describe landslides that occurred in February 2013, give their dates, locations and find if any of them result in full collapse of any infrastructure component

 Describe landslides that resulted in displacement of mass containing clay

- GIS Knowledge Base
  - Based on DataGraft
- Onboarding of INFRARISK data
  - Data cleaning & mapping (tabular to graph)
  - Executable data transformations
  - Data queries (in SPARQL)
- Development of GUI application prototype



# Thank you! Q&A

Contact: dumitru.roman@sintef.no







### **INTACT Project: Guiding The User**

Final Dissemination Event INFRARISK, Madrid, Spain

### **Peter Petiet**

**TNO (Netherlands Organisation for Applied Scientific Research)** 

This research has received funding from the European Union Seventh Framework Programme under grant agreement no 606799. The information and views set out in this presentation are those of the author(s) and do not necessarily reflect the official opinion of the European Union.

### **INTACT Objectives**

INTACT is an EU FP7 project which aims

to offer **Decision Support** 

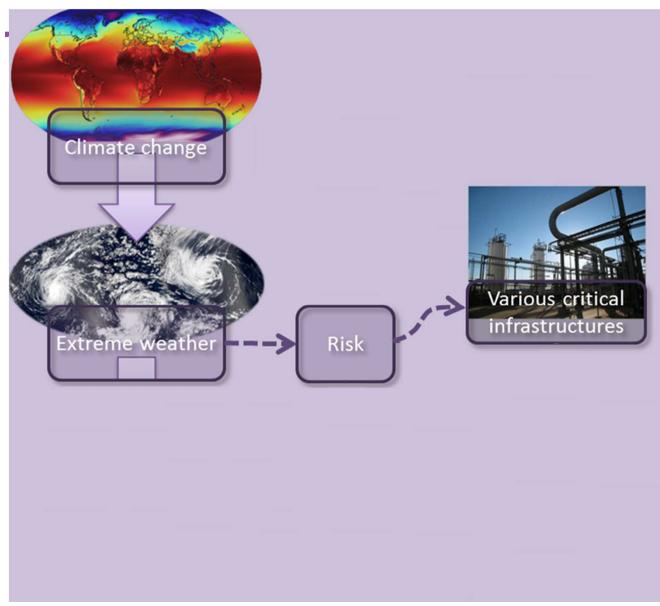
to CI operators and policy makers

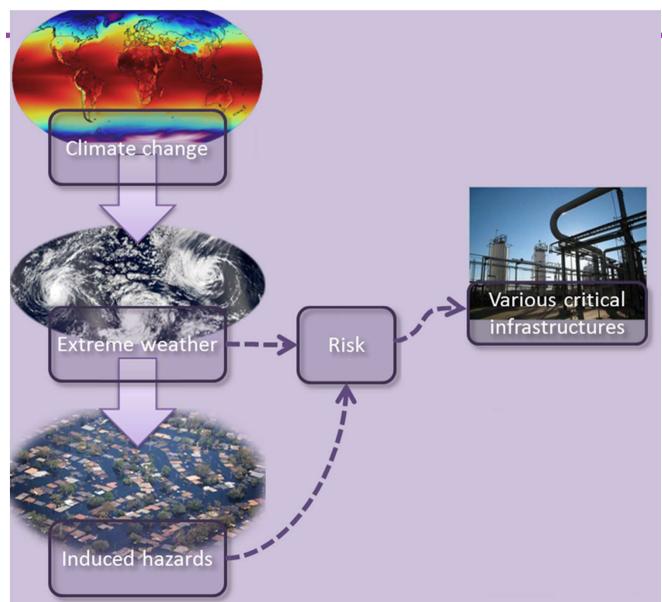
regarding Critical Infrastructure Protection (CIP)

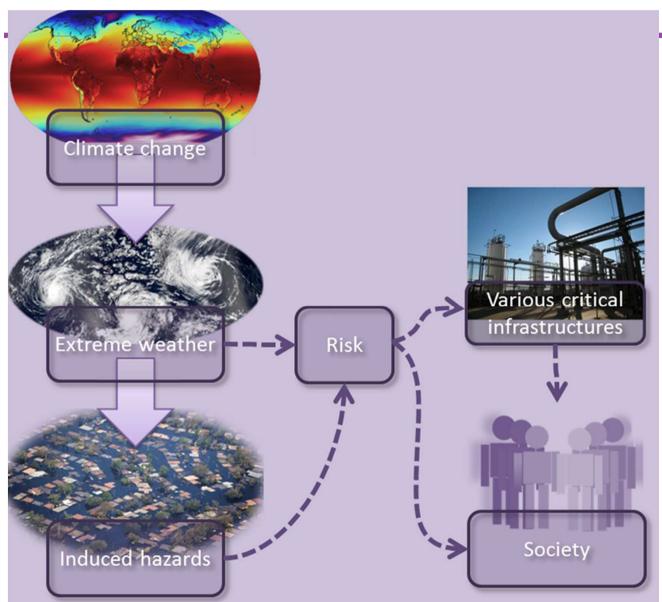
against changing Extreme Weather Event (EWE) risks

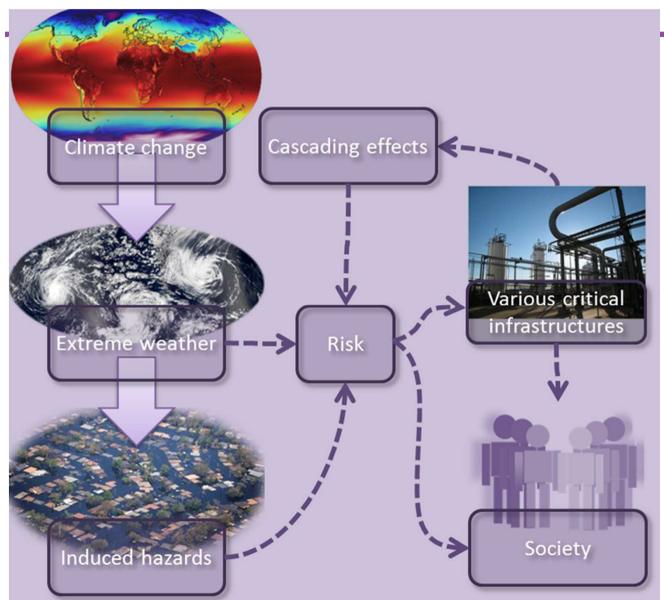
caused by climate change





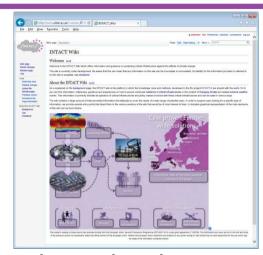






# INTACT main results: Wiki (1/2)

### www.intact-wiki.eu



### The **INTACT Wiki** is:

- A platform in which the knowledge, tools and methods, developed in the project are shared with the world.
- On it, you can find information, references, guidance and experiences on how to ensure continued resilience of CIs in the context of changing climate and related EWEs.
- This information is primarily directed at operators of CIs and policy makers involved with these.





(based on ISO 31000)

### The **Decision support framework** is:

 A proven risk management process that can be applied to assess and increase the resilience of CI to changing climate and changing EWE:

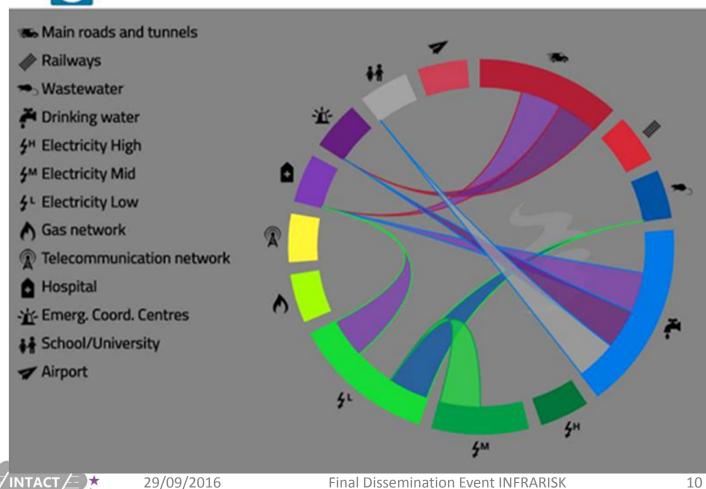
> In each step, the user is guided with which tools/ sources of information are useful for what reason and how to interpret subsequent outputs.



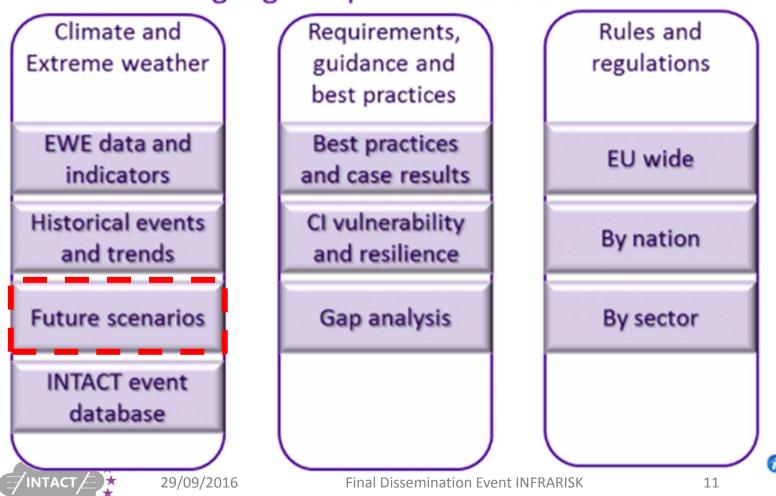
Tool / method	Scope definition	Risk identification	Risk estimation	Risk evaluation	Proposals for action	redu
Delphi method	<b>√</b>	<b>✓</b>	<b>\</b>	<b>✓</b>	1	
Storyline approach		✓	✓	✓	✓	
CIRCLE tool	<b>√</b>	✓				
Hazards and operability study (HAZOP)			<b>✓</b>	<b>✓</b>	<b>✓</b>	
Scenario analysis	<b>√</b>	<b>✓</b>	<b>✓</b>	<b>✓</b>	<b>✓</b>	
Analytic hierarchy process (AHP)		<b>✓</b>			<b>✓</b>	
Risk index			<b>✓</b>	<b>✓</b>		



Circle - Critical Infrastructure: Relations and Consequences for Life and Environment



### Highlighted process elements



### Selecting Future scenarios using **Interactive Maps**

Select time period

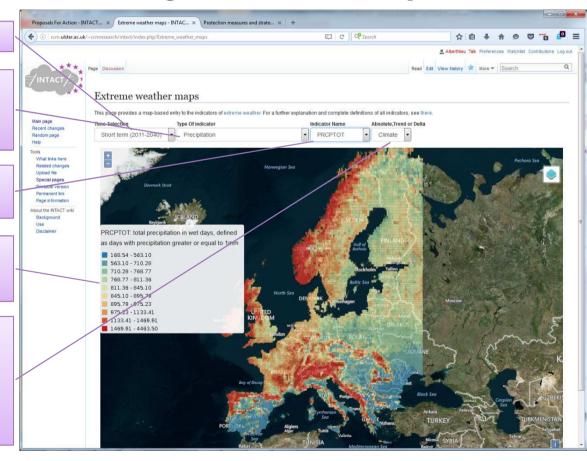
Select type of extreme weather (precipitation, snow, temperature, wind, or combinations of these)

Select Extreme Weather Indicator (EWI) associated with the above event

View legend with explanation of EWI and scales

Select whether to illustrate:

- Expected values;
- Change of values compared to now;
- Expected change of value per year.





# INTACT input & (current) feedback: Case Studies

#### Case Study B – Port of Rotterdam, The Netherlands

Port of Rotterdam and its hinterland transport connections under local EWEs.

### Case Study A – South West Region of Ireland

Extreme Weather Events which have impacted upon CI.

### Case Study C – Southern/Central Italy

Rainfall induced landslides in the different geomorphologic contexts.

#### **Case Study E – Southern Spain**

Effects of drought, heatwaves and flash floods on CIs.

#### **Case Study D – Southern Finland**







### **INTACT Project: Guiding The User**



www.intact-project.eu/

www.intact-wiki.eu/

**INTACT End Event:** 23 March 2017, Delft, NL



Peter Petiet, TNO, Netherlands

**Email** 

– peter.petiet@tno.nl

Contact Number - 00 31 888 66 4006







# INFRARISK Final Dissemination Conference Dragados, Madrid

### New hazards and transport infrastructures

### Jesús Rodríguez

Dr. civil engineer

Managing Director, PTEC

Associated professor in concrete structures (UPM)





### **PTEC**



- Created in 2004 as a mirror of the European Construction Technology Platform ECTP
- Contributing to the construction sector through promoting public-private partnerships in research, development and innovation, carried out among enterprises, industrial associations, universities, research centres, technological centres and customers.







### Working groups

- Internationalisation of R&I: Acciona, Ferrovial
- Promoting innovation: OHL, University of Cantabria
- Transport infrastructures: Dragados, Vías
- The city of the future: Cartif and Tecnalia research organisations
- Construction processes: CYPE, Itainnova, Technical University of Madrid (UPM)





# **Conferences Workshops**











### Internationalisation

- Coordination of NTPs network (15-20 countries)
- Partner at REFINET CSA (<u>www.refinet.eu</u>) on transport infrastructures, coordinated by ECTP Infrastructure & Mobility Committee
- Member of INFRAVATION Scientific Panel (road infrastructures)







# New scenarios for transport infrastructures

- Climate change
- Extreme natural and man-made hazards
- Earthquakes, flood, landslides, heat and wind increasing, rainfalls, etc.
- Cascading effects: vulnerability during successive hazards







### Requirements for infrastructures

### XX and XXI century:

- Ultimate Limit States: safety against partial or total collapse under loads
- Serviceability Limit States: deformations, vibrations, cracking in concrete, etc.
- Durability during the service life (50, 100, 300 years)
- Sustainability: energy impact and other environmental considerations, recycling, etc.
- Climate change: new hazards







### New scenarios for transport infrastructures

- Preventive strategies
- Remedial strategies
- The selection of strategies has to be considered in the framework of social and financial issues (Ex.: cost of traffic delay after extreme hazards versus higher initial investment)







#### New & modified standards to consider these "new" scenarios

- Actions due to extreme hazard events
- √ Resilient materials
- ✓ Resilient infrastructures: bridges, tunnels, earthworks (slopes and embankments), pavements, rails, breakwaters, etc.
- √ Foundations







#### New design considerations

- ✓ Foundations to avoid scours: protection in piers and abutments; piles versus footings; longer spans in bridges avoiding piers in the water
- ✓ Structural redundancy & robustness
- ✓ Earthwork slopes: lower angle, land cover, etc.
- ✓ Improved drainage systems
- ✓ Combination of fibres and steel bars in concrete
- ✓ New asphalt mixes avoiding rutting due to heat increasing, etc.
- ✓ Longer runways in airports due to heat increasing
- ✓ Height increasing of breakwaters & crest walls to reduce overtopping events





#### **Maintenance**

- Relevance of the maintenance for better performance of infrastructures under extreme hazards
- Collection of data from the conditions of the infrastructures (network management systems):
  - For operation & exploitation
  - For durability considerations (repairs, etc.)
  - For improving strategies during/after extreme hazard events







#### **Upgrading**

- Upgrading of existing infrastructures is a urgent need, due to:
  - ✓ Material deterioration
  - ✓ New demands: traffic,
  - ✓ Climate change



**√** ...

#### .... and a opportunity







## Shall we need more research and innovation to deal with transport infrastructures and climate change?

#### **Many thanks**

Jesús Rodríguez

director@plataformaptec.es





#### GOVERNMENTAL SPANISH CRISIS MANAGEMENT SYSTEM

JOSE LÓBEZ

EMERGENCY AND COORDINATION AND CRISIS MANAGEMENT
UNIT
MINISTRY OF TRANSPORT AND PUBLIC WORKS



#### Agenda





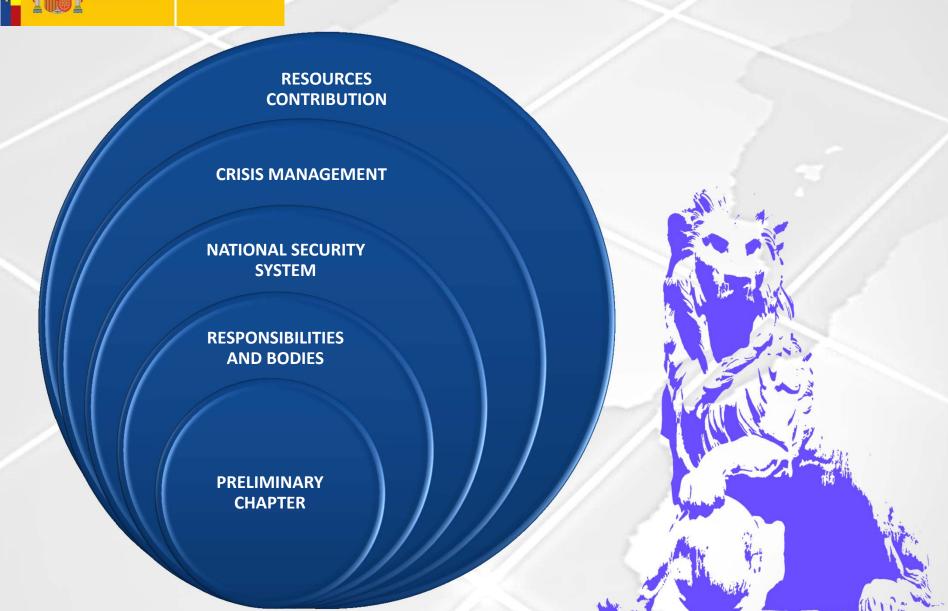
MINISTERIO
DE FOMENTO

#### **RISKS & THREATS**





#### **NATIONAL SECURITY LAW**





## NATIONAL SECURITY SYSTEM

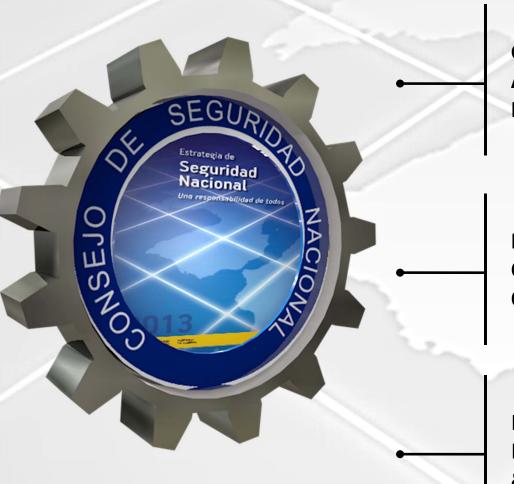
#### PRIME MINISTER

• NATIONAL SECURITY COUNCIL





## NATIONAL SECURITY COUNCIL



GOVERNING BODY IN CHARGE OF ACHIEVING PRIME MINISTER DECISIONS RELATED TO NATIONAL SECURITY POLICY

PROVIDES GUIDANCE FOR PLANNING & COORDINATION, MANAGES CRISIS, OVERSEES NATIONAL SECURITY SYSTEM

HEADED BY **THE PRIME MINSTER**, and MADE UP BY **the DEPUTY PRIME MINSTER & OTHER GOVERNMENT MEMBERS**.



## NATIONAL SECURITY COUNCIL





## NATIONAL SECURITY SYSTEM

#### **PRIME MINISTER**

NATIONAL SECURITY COUNCIL

#### **SITUATION COMMITTEE**

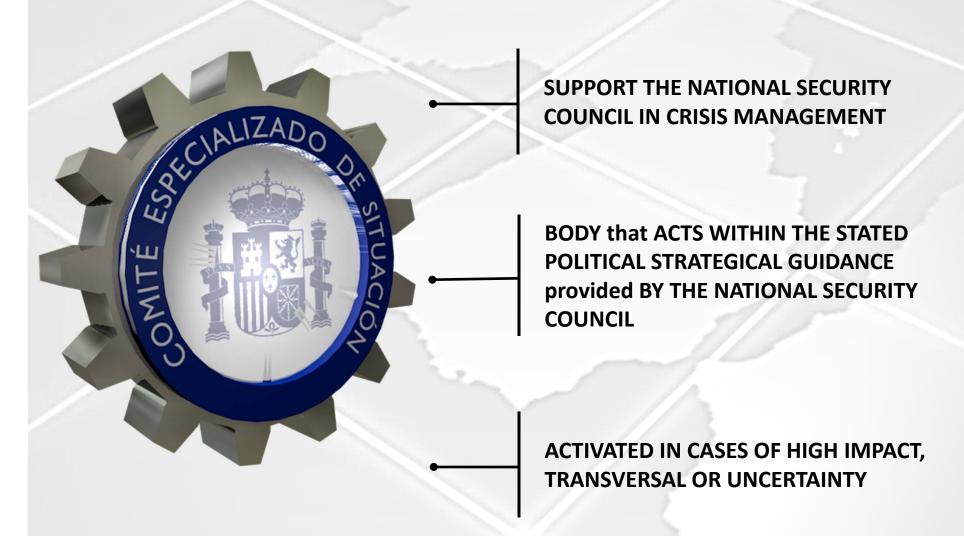
SPECIALIZED COMMITTEES

#### **NATIONAL SECURITY DEPARTMENT**

SECRETARY AND PERMANENT SUPPORT CELL



#### SITUATION COMMITTEE



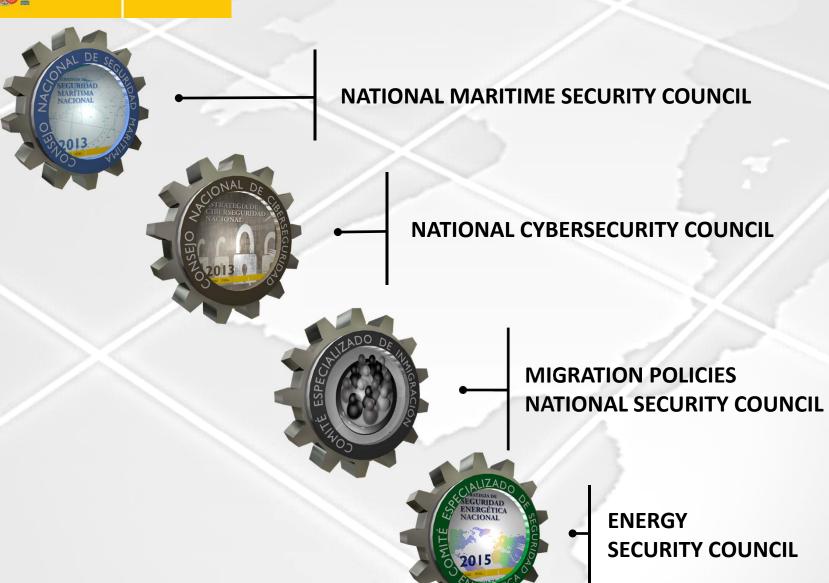


#### SITUATION COMMITTEE





#### **PERMANENT SUPPORT BODIES**



## THE HEAD & THE EXECUTIVE ARMS

#### NATIONAL LEVEL





VICEPRESIDENCIA DEL GOBIERNO MINISTERIO DE LA PRESIDENCIA



MINISTERIO DE DEFENSA





























**UECGC** 



























MINISTERIO DE EMPLEO Y SEGURIDAD SOCIAL





CIVIL PROTECTION, as an instrument of the national security, is the public service that protects people and goods by guarantying the adequate response to the different types of emergencies or catastrophes caused by natural or man made hazards accidentally or intentionally provoked.







#### NATIONAL/REGIONAL level

**Floods** 

**Earthquakes** 

**Chemical** 

**Radiological** 

**Biological** 

**Transports of dangerous goods** 

**Forest fires** 

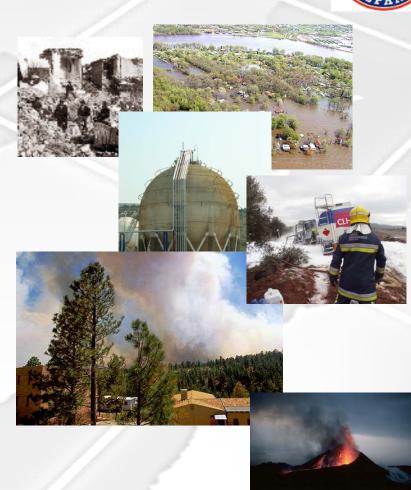
Volcanic

**Tsunamis** 

**Air accidents** 

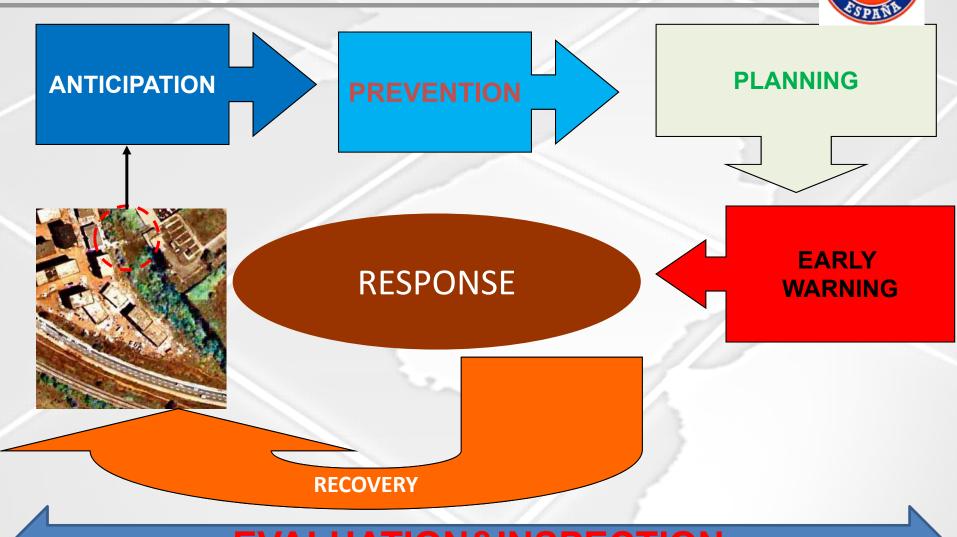
#### NATIONAL level

Nuclear War









**EVALUATION&INSPECTION** 











# EMERGENCY AND COORDINATION AND CRISIS MANAGEMENT UNIT

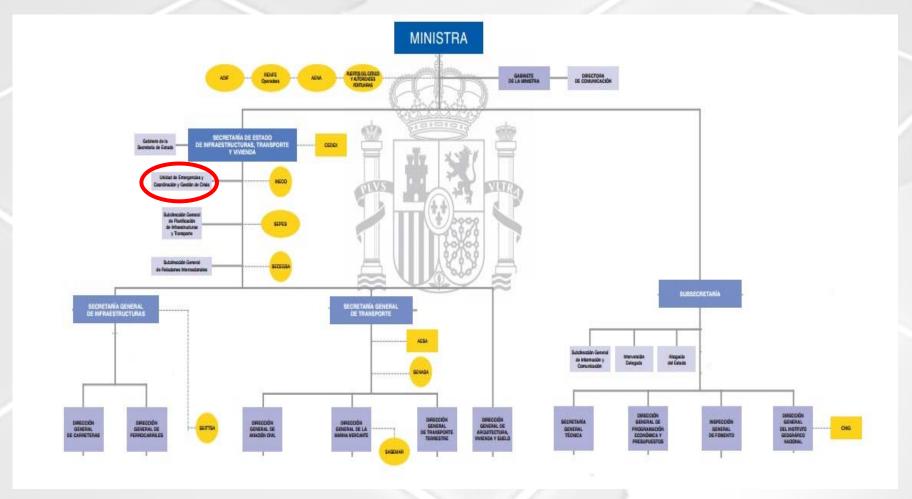
MINISTRY OF PUBLIC WORKS
AND TRANSPORT

UECGC



#### MINISTERIO DE FOMENTO











#### **ASSISTING THE SECRETARY OF STATE IN**

DEFINING, ADOPTING, MANAGING, CONTROLLING AND ASSESSING

MEASURES AND PROCEDURES WITHIN THE MINISTRY COMPETENCES, TO ENSURE

#### **FULLY RESTORING OPERATIONAL**

FOR TRANSPORTATION SERVICES AND INFRASTRUCTURES







#### **TASKS:**

- ☐ ASSIST MINISTRY DEPARTMENT HEADS
- ☐ INTER-MINISTRY RELATIONS
- ☐ STANDARDIZATION OF PROCEDURES
- ☐ INCIDENT ANALYSIS AND SUPERVISION
- SYNERGIE EXPLOITATION
- ☐ TRACK INCIDENT INFORMATION IN REAL TIME
- ☐ PROMOTE PREVENTION AND RISK MANAGEMENT
- ☐ VICTIMS ASSISTANCE OFFICE (similar to US TDA)
- ☐ CLASSIFIED INFORMATION CONTROL





#### **SUMMARIZING...**

#### **CRISIS MANAGEMENT**

NATIONAL SECURITY DEPARTMENT

CIVIL PROTECTION

NATIONAL SECURITY COUNCIL

TRANSPORT EMERGENCY UNIT

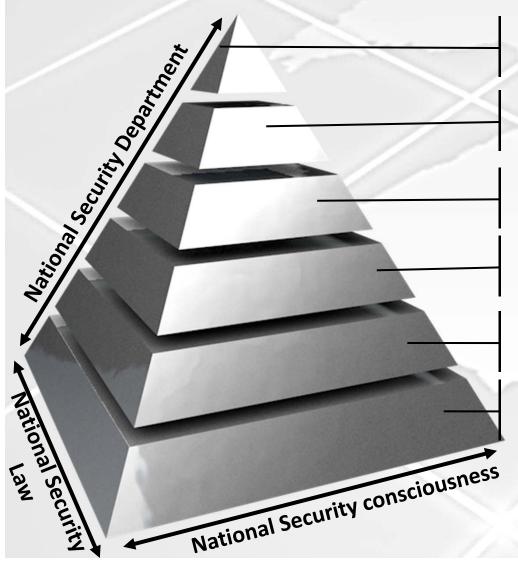
NATIONAL
CENTRE FOR
CRITICAL
INFRASTRUCTURE
PROTECTION

REGIONAL AND LOCAL ADMINISTRATION

SITUATION COMMITTEE



#### **NATIONAL SECURITY SYSTEM**



**PRIME MINISTER** 

**NATIONAL SECURITY COUNCIL** 

**SUPPORT BODIES** 

PUBLIC SPANISH ADMINISTRATION (NATIONAL/REGIONAL/LOCAL)

**PUBLIC-PRIVATE COLLABORATION** 

**SPANISH SOCIETY** 



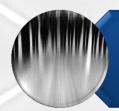
#### CONCLUSIONS



**STARTING POINT:** different challenges, new actors, unknown risks and threats



NATIONAL SECURITY SYSTEM: Inclusive, transversal and pro-active



MANAGEMENT CRISIS SYSTEM:
Comprehensive and shared system



**THE FUTURE: more** interdependency, more uncertainty, tech disruption, adaptability



#### **THANK YOU** FOR YOUR ATTENTION

JOSE LÓBEZ **HEAD OF CRISIS MANAGEMENT** 

**2**91 5975085 **4** 91 5977310





#### **APPENDIX E: Report on Communication Actions**

#### **Communication Actions**

Press Releases: 2

Call Press: 1

Media: More than 250 European journalists or media contacted by Email. Also, correspondents in Spain, different European organizations, among them the Press Office of Spanish European Commission.

Social Networks

#### **Press Releases**

"New stress tests will reveal whether critical infrastructure in Europe is prepared to withstand extreme natural hazards" — September 12<sup>th</sup>. 2016

"We can not prevent disasters from occurring, but we can invest to keep from such a severe impact that costs a region or a country a lot to recover"

Europe has a tool to assess the risks of natural disasters on transport infrastructure

September 29<sup>th</sup>. 2016

#### **Call Press**

How resilient is European critical infrastructure to natural hazards?

The INFRARISK expert group presents a tool that will enable infrastructure managers to minimise the impact of natural disasters

- •Different organizations including universities, research institutions, SME's and Large Enterprise of Ireland, Spain, Norway, Netherlands, United Kingdom, Sweden and Switzerland have worked for 3 years in this European project.
- •The analysis tool to aid decision making will be presented in a conference to be held in Madrid, next Thursday.

September 26th, 2016

#### **Online Media**



#### **Cordis- Events**



#### New stress tests will reveal whether critical infrastructure in Europe is prepared to withstand extreme natural hazards

Contributed by: Infrarisk Project

The INFRARISK European project has developed stress tests to establish the resilience of European Critical Infrastructures to rare low frequency extreme events and to aid decision making in the long term, contributing to robust infrastructure development and protection of existing infrastructures

The INFRARISK Consortium consists of 11 members from seven different countries, a well balanced and strong partnership among universities, research institutions, SME's, and Large Enterprise (LE).

In the last decade, 80,000 people have died in Europe and there have been economic losses of 95 billion euro as a result of natural disasters. Such damage could be mitigated if the most vulnerable points are known and risks to infrastructure and population can be anticipated. This has been the objective of the European project INFRARISK, to develop new indicators for identifying critical infrastructures at risk from natural hazards.

Cordis - News



#### Nuevos test de estrés permitirán saber si las infraestructuras críticas en Europa están preparadas ante desastres naturales extremos

lunes, 12 septiembre 2016, 17:03, por Melania Bentué - Comunicación

En la última década, 80.000 personas han muerto en Europa y se han producido pérdidas económicas por valor de 95 billones de euros como consecuencia de las catástrofes naturales. Estos daños pueden mitigarse si se conocen los puntos más vulnerables y se pueden prever los riesgos para las infraestructuras y la población. Este ha sido, precisamente, el objetivo del **proyecto europeo INFRARISK**, desarrollar indicadores nuevos para la **identificación de infraestructuras críticas en riesgo** de ser afectadas por **catástrofes naturales**.

Durante tres años, un equipo multidisciplinar formado por científicos e ingenieros de 11 organizaciones europeas ha desarrollado nuevos test de estrés y una herramienta de análisis para la toma de decisiones mediante la que se podrán crear modelos que determinen la resistencia de infraestructuras críticas ante eventos naturales extremos que, aunque poco frecuentes en Europa, cuando se producen pueden tener un impacto devastador en el sistema de infraestructuras críticas europeas.

#### **Press People**



Indagando TV



Indagando TV









HOME > NEWS & EVENTS > EVENTS > EVENT DETAIL

29.09.2016 | Madrid (ES)

#### INFRARISK Project Final Conference, 29 September, Madrid (ES)

INFRARISK, an EU-funded project (2013-2016), brings together 11 members to develop a strategy to ensure that levels of infrastructure related risk due to natural hazards are acceptable.

The final conference organized on 29 September 2016 at Dragados venue in Madrid aims to communicate the results and outputs of the project. New research will be presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

The event is free but registration is needed and limited to the capacity of the conference hall.

To register, send your full name along with the name of your institution/company/project and your contact details via E-mail to info@infrarisk-fp7.eu

 $\label{lem:continuous} \mbox{Access more information and the programme from INFRARISK website here.}$ 

**ECTP Innovative Built Environment** 



#### **INFRARISK Final Dissemination Conference**

Type: Meeting or Conference Organizer: European Union (EU) Date: 29 Sep 2016

Location: Spain (Madrid)

Venue: DRAGADOS headquarters, Avda. Camino Santiago 50, 28050-Madrid, Spain

The INFRARISK Final Dissemination Conference aims to communicate the results and outputs of the EUfunded INFRARISK project. New research will be presented regarding the development of optimal stress testing techniques for European Critical Infrastructure, which focuses on potential impacts to the European TEN-T (road and rail) network due to natural hazards, such as earthquakes, floods, and landslides.

INFRARISK, an EU-funded project (2013-2016), brings together 11 members with a well-balanced and strong partnership amongst universities, research institutions, small and medium-sized enterprises (SMEs), and a Large Enterprise, to develop a strategy to ensure that levels of infrastructure-related risk due to natural hazards are acceptable. Stress tests are implemented through an operational framework that supports the work of managers, operators, stakeholders and policy makers, providing insight into the impact of extreme natural hazard events and enabling the vulnerability of their infrastructure networks to be assessed

#### **UNISDR**

Nuevos test de estrés permitirán saber si las infraestructuras críticas en Europa están preparadas ante desastres naturales extremos

12 DE SEPTIEMBRE DE 2016

El proyecto europeo INFRARISK ha creado una herramienta que permite analizar el riesgo ante fenómenos naturales al que están sometidas las infraestructuras críticas



Visit web

## Infrarisk looking for a safer Europe with the study of their infrastructure

indagando 
 ○ June 22, 2016 
 News 
 ○ 0 Comments 
 ○ 25 Views



AB-Bilgi European Project - Website





#### Europa cuenta con una herramienta que permitirá evaluar los riesgos de las catástrofes naturales sobre las infraestructuras de transporte

jueves, 29 septiembre 2016, 19:04, por Melania Bentué - Comunicación

La herramienta ha sido creada por INFRARISK, un grupo de trabajo formado por 11 organizaciones europeas

El proyecto se ha desarrollado durante 3 años y ha contado con un presupuesto de  $\,$  2,8 millones de euros

El proyecto europeo INFRARISK ha creado una herramienta que permite evaluar las consecuencias que tienen las catástrofes naturales sobre las infraestructuras de transporte críticas para el funcionamiento económico y social de la Unión Europea. Esta herramienta aportará información para mejorar la resiliencia de las infraestructuras y para minimizar el impacto de terremotos, inundaciones o deslizamientos de tierra.

Infrarisk Decission Support Tool (IDST), como se llama la herramienta, se ha presentado en una conferencia en la que han participado representantes de todas las organizaciones implicadas en el proyecto. "Nuestra IDST ha desarrollado una serie de módulos en los que incorporamos la información que tenemos sobre los riesgos naturales y cómo afectan a las infraestructuras", explica la investigadora del CSIC, María José Jiménez, "de esta forma los operadores y gestores de las infraestructuras, tienen información que les ayudará a tomar decisiones para hacerlas más resilientes y soportar el impacto que puede suponer, por ejemplo, un terremoto".

**Press People** 



#### **CORDIS**

Community Research and Development Information Service

mission > CORDIS > News and Events > Helping Europe prepare for when natural disaster strikes

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**NEWS & EVENTS** 

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#### Helping Europe prepare for when natural disaster strikes

EU-funded researchers have created a tool to assess the impact of natural disasters on transport infrastructure in order to save

The tool, developed through the EU-funded INFRARISK initiative, was presented during the final project conference at the end of September 2016. The ultimate goal of the innovation is to help policy makers and industry experts identify ways of improving the resilience of bridges, roads and rail networks in the face of catastrophic events such as earthquakes, floods and landslides.

Over the past decade, some 80 000 people have died in Europe as a result of natural disasters. Putting in place considered prevention and mitigation schemes will help to save lives.





From this, a series of modules incorporating information on natural hazards and how they affect infrastructure was put together by the team. Importantly, these modules take into account the 'cascade effect' of disasters. For example, a landslide not only makes roads and railway networks inaccessible, but also isolates whole populations. This has knock-on economic consequences and implications for how emergency services and rapid response teams organise themselves.

#### Cordis - European Commission (EN/DE/ES/FR/IT/PL)



#### **Noticias**

#### Hacia una mejor preparación de Europa frente a catástrofes naturales

Investigadores financiados con fondos europeos han creado una herramienta que ayuda a evaluar el impacto de catástrofes naturales sobre las infraestructuras de transportes, a fin de salvar vidas y reducir el gasto.

FUENTE | CORDIS: Servicio de Información en I+D Comunitario

10/10/2016

Compartir noticia Me gusta Compartir < 3







Sugiéranos su noticia Suscríbase

La herramienta, desarrollada en el marco de la iniciativa InfraRisk -apoyada por la Unión Europea-, fue presentada en el congreso de clausura del proyecto, a finales de septiembre de 2016. En úttimo término, con esta innovación se pretende ayudar a las autoridades legislativas y a los especialistas del sector a dar con modos de aumentar la resiliencia de puentes, carreteras y redes ferroviarias frente a fenómenos catastróficos como seismos, inundaciones y corrimientos de tierras.

En el último decenio han sido más de ochenta mil las personas que han fallecido en Europa a consecuencia de catástrofes naturales. La con el muno decenio nan suo mas de occienta min las personas que nan naiectao en Europa a consecuencia de catastrores naturales. La puesta en práctica de planes de prevención y mitigación rigurosos ayudará a salvar vidas. Los impulsores del proyecto han creado la herramienta de apoyo a las decisiones de InfraRisk (IDST) para ayudar a superar el reto correspondiente. Se trata de un programa informático desarrollado empleando información extraída a partir de estudios de casos relativos a redes ferroviarias y de carreteras de diversos lugares de Europa. En dichos estudios de casos se analizó de qué manera se habían dañado las infraestructuras de transportes y se efectuó una evaluación de las condiciones generales del transporte.

#### Madrid+d



Canal 24 Horas – La 1 TVE. (Video, minute: 17:46)



#### Ingeniería, industria y construcción todos Hacia una mejor preparación de Europa frente a catástrofes naturales Investigadores financiados con fondos europeos han creado una herramienta que ayuda a evaluar el impacto de catástrofes naturales sobre las infraestructuras de transportes, a fin de salvar vidas y reducir el gasto. La herramienta, desarrollada en el marco de la iniciativa INFRARISK apoyada por la Unión Europea—, fue presentada en el congreso de clausura del proyecto, a finales de septiembre de 2016. En último término, con esta innovación se pretende ayudar a las autoridades legislativas y a los especialistas del sector a dar con modos de aumentar la resiliencia de puentes, carreteras y redes ferroviarias frente a fenómenos catastróficos como seísmos, inundaciones y corrimientos de tierras. En el último decenio han sido más de ochenta mil las personas que han fallecido en Europa a consecuencia de catástrofes naturales. La puesta en práctica de planes de prevención y mitigación rigurosos ayudará a salvar vidas

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## Hacia una mejor preparación de Europa frente a catástrofes naturales



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## INFRARISK: Hacia una mejor preparación de Europa frente a catástrofes naturales

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#### < Gobierno Vasco

Fecha de publicación: 07/10/2016

# Hacia una mejor preparación de Europa frente a catástrofes naturales

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EU-funded researchers have created a tool to assess the impact of natural disasters on transport infrastructure in order to save both lives and money.

CARIE, Cyprus Association of Research and Innovation Enterprises

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Helping Europe prepare for when natural disaster strikes

Aiutare l'Europa a prepararsi per quando è colpita da disastri naturali

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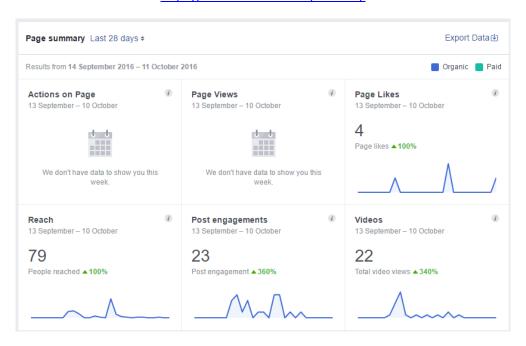
Ricercatori finanziati dall'UE hanno creato uno strumento per valutare l'impatto dei disastri naturali sulle infrastrutture di trasporto che permetterà di salvare vite e risparmiare denaro.

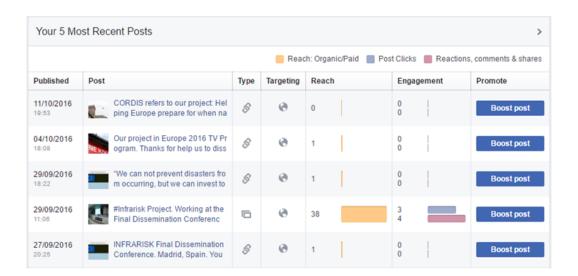
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Country	People Reached	City	People Reached	Language	People Reached
Spain	49	Zaragoza, Aragón	21	Spanish	37
Peru	16	Lima, Lima Region	14	Spanish (Spain)	36
France	6	Madrid, Comunidad de	7	English (US)	9
Chile	5	Adra, Andalucía	5	French (France)	6
Greece	5	Boltaña, Aragón	3	Greek	5
Italy	4	Antofagasta, Antofagas	3	English (UK)	4
United Kingdom	3	Alcorcón, Comunidad d	3	Italian	3
United States of America	3	Berlin, Berlin	2	Swedish	1
India	3	Almería, Andalucía	2	Portuguese (Brazil)	1
Germany	2	London, England	2	German	1











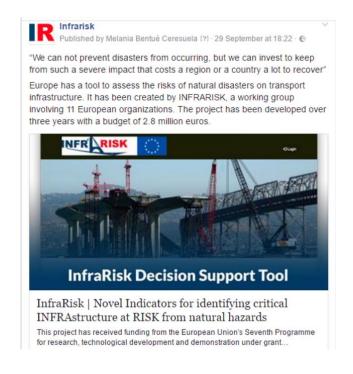
Infrarisk added 4 new photos.
Published by Melania Bentué Ceresuela [?] · 29 September at 11:06 · €

#Infrarisk Project. Working at the Final Dissemination Conference... Nice day!











#### Melania Bentué, Estrategias de Comunicación ha

compartido el vídeo de Infrarisk.

22 de septiembre a las 7:14 · €

El proyecto europeo #Infrarisk estudia las infraestructuras y su resistencia ante desastres naturales. Durante tres años, investigadores de distintos países han trabajado para desarrollar herramientas para mejorar la seguridad.



#### Infrarisk

Publicado por Snap [?] · 29 de octubre de 2015 · €



#### Melania Bentué, Estrategias de Comunicación ha compartido la publicación de Graziella Almendral.

20 de septiembre a las 10:47 - €

¿Están preparadas las infraestructuras ante desastres naturales? Un grupo de investigadores han trabajado durante tres años en el proyecto europeo Infrarisk.



### Graziella Almendral ► Indagando TV 19 de septiembre a las 9:51 · @

Científicos e ingenieros de 11 organizaciones europeas han desarrollado nuevos test de estrés para conocer la resistencia de infraestructuras críticas ante desastres naturales extremos Vídeos: te enseñamos qué es un desastre natural, una infraestructura cítrica y un test de estrés





#### IndagandoTV

19 de septiembre a las 9:47 · @

Nuevos tests de estrés para conocer la resistencia de infraestructuras críticas ante eventos naturales extremos

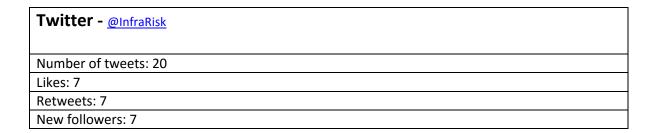
Vídeos: te enseñamos qué es un desastre natural, una infraestructura cítrica y un test de estrés

http://www.indagando.tv/.../nuevos-test-estres-permitiran-sa.../

#### Nuevos test de estrés permitirán saber si las infraestructuras críticas en Europa están preparadas ante desastres naturales extremos | Indagando TV

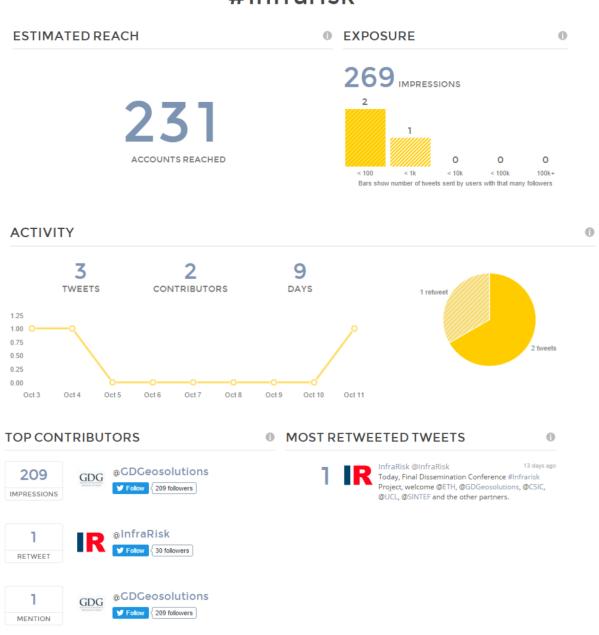
En la última década, 80.000 personas han muerto en Europa y se han producido pérdidas económicas por valor de 95 billones de euros como consecuencia de las catástrofes naturales. Estos daños pueden mitigarse si se conocen los puntos más vulnerables y se pueden prever los riesgos para las infraestruc...

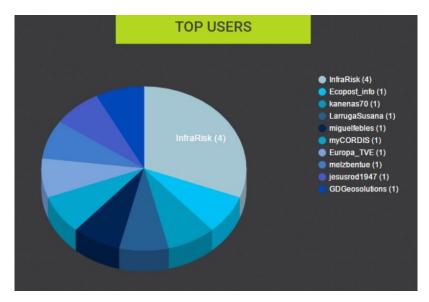
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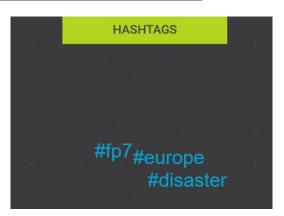
## #infrarisk























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