WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

DISASTER PREVENTION RESEARCH INSTITUTE

Practical demonstration of some available tools for Natech risk assessment, risk mitigation and emergency planning for various types of natural hazards.

DPRI-KU

KYOTO UNIVERSITY KYOTO JAPAN FOUNDED 1897

13/03/2017
Kyoto University, Uji Campus
Collaborative Research Hub / Building 77 / Room 301

WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

Workshop Chairs:
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Shin-ichi Aoki, Osaka University

WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

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Images

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ISBN 978-4-901768-22-1

WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

DPRI, KYOTO UNIVERSITY

WHAT IS A NATECH ACCIDENT?

A Natech accident is a technological accident triggered by natural hazard events such as earthquakes, floods, storms, lightning, landslides, etc.

In this context, a technological accident is understood as:

- Damage to and hazardous-materials releases from fixed chemical plants.
- Damage to and hazardous materials releases from oil and gas pipelines.

At least 50% of surveyed EU Member States and OECD Member Countries have experienced one or more Natech accidents, sometimes with fatalities and injuries, environmental and/or economic damage.

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Cruz Lab, Workshop on Tools for Natech Risk Management, Center for Disaster Reduction Systems, DPRI, Kyoto University, Japan, Report, 13 March, 2017.

AKNOWLEDGMENTS

This publication was put together by a group of international experts under the auspice of the Disaster Prevention Research Institute (DPRI), Kyoto University.

Its content reflects the multi-perspective contributions and international experiences presented at Kyoto University, Uji Campus, in March 2017, within the framework of the Workshop on Tools for Natech Risk Management.

We would like to thank the workshop speakers Prof. Kaoru Takara, Director, DPRI, Kyoto University; Prof. Shin-ichi Aoki, Osaka University; Mr. Jaime Pacheco, First Secretary of the Colombian Embassy in Japan; Ms. María Camila Suarez, DPRI; Prof. Felipe Muñoz Giraldo, Universidad de los Andes, Colombia; Dr. Elizabeth Krausmann, Joint Research Centre, European Commission, Italy; Prof. Valerio Cozzani, Università di Bologna, Italy; Prof. Ernesto Salzano, Università di Bologna, Italy; Emeritus Prof. Naomi Kato, Osaka University, Japan; Dr. Tomoaki Nishino, Building Research Institute, Japan; Prof. Mauricio Sánchez, Universidad de los Andes, Colombia; and Dr. Takeshi Komino, CWS, Japan.

We would also like to acknowledge the contribution of the members of the Disaster Risk Management Laboratory (Cruz Lab) to the preparation of this report under the guidance of Prof. Felipe Munoz Giraldo.

The Natech Workshop was partly funded by the Disaster Prevention Research Institute, Kyoto University, for which we are grateful.

About the Disaster Risk Management Laboratory (Cruz Lab):

Our lab is multidisciplinary, integrating skills and knowledge from a variety of disciplines such as engineering, sociology, economics, and disaster risk management (DRM), benefiting synergistically by working in association with local, national and international students, researchers and faculty (www.natech.dpri.kyoto-u.ac.jp). Cruz Lab is part of the Center for Disaster Reduction Systems (DRS) at DPRI, Kyoto University. *Its purpose is to promote research and practices to build a safe and resilient society by reducing disaster risks.*

SUMMARY

The Workshop on Tools for Natech Risk Management was organized and hosted by the Disaster Prevention Research Institute (DPRI) at Kyoto University, Uji Campus, on March13th 2017. The Natech workshop was carried out in an effort to do a hands-on practical demonstration of some available tools for Natech risk assessment, risk mitigation and emergency operations planning for various types of natural hazards. The workshop was attended by participants from 12 countries, including experts, students and stakeholders involved in Natech disaster risk reduction and similar topics.

The event included talks on available Natech tools, their strengths, implementation and development of case studies. A discussion of key elements and needs in the Natech context was the way to conclude the workshop. Identification of priorities, gaps and future research road map were the main outcomes of the event.

DESCRIPTION AND OPENING CEREMONY

On 13th March 2017, the Disaster Prevention Research Institute (DPRI, Kyoto University) hosted the Workshop on Tools for Natech Risk Management. Participants included representatives from Afghanistan, Bulgaria, China, Colombia, Egypt, Germany, Japan, India, Italy, Mexico, South Korea and Philippines (see Annex 4). The event was opened by the Director of the Disaster Prevention Research Institute, Prof. Kaoru Takara; Prof. Ana Maria Cruz, DPRI, KU; Prof. Shin-ichi Aoki, Osaka University; and Mr. Jaime Pacheco, First Secretary of the Colombian Embassy in Japan. Prof. Takara highlighted Natech's place in the Sendai framework for Disaster Risk Reduction.

During the opening ceremony speakers remarked the fact that Natech is a very recent concept and mentioned the need to better understand its complex accidental dynamics within interdisciplinary teams. They encouraged researchers to continue working towards prevention, mitigation and protection measures. The Colombian Embassy manifested their interest to support the development of research on Natech issues.

SECTION 1

State of the Art in Natech Risk Management

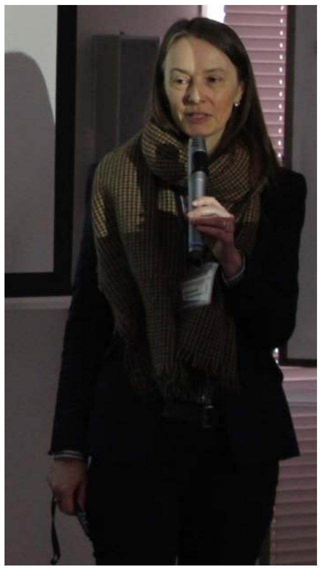
María Camila Suarez, DPRI; Felipe Muñoz Giraldo, Universidad de los Andes Colombia; Ana Maria Cruz, DPRI

This presentation was given by María Camila Suarez, a Ph.D. student at DPRI. She presented the state of the art in Natech Risk Management based on two stages of analysis. The first stage focused on a review of the literature concerning potential Natech accidents, mainly an apriori approach, and the second stage focused on a review of the literature concerning past Natech events, a posteriori approach. Classification by hazards and different types of analysis for the methodologies proposed so far has been conducted. The findings demonstrated the necessity for further research and outlined the way forward on this relatively recent topic.

RAPID-N: Earthquake Natech Risk Assessment

Elisabeth Krausmann, Joint Research Centre, European Commission, Italy

RAPID-N is a web based semi-quantitative tool for Natech risk assessment and mapping developed by the Joint Research Centre (JRC) of the European Commission. Rapid-N includes an integrated methodology able to analyze Natech risks by estimating the natural-hazard severity (e.g. earthquake) at a hazardous site, the damage caused by the natural hazard using fragility curves, and the consequences of the damage. The results give an overview of the impacted area around the accident site with respect to heat radiation and toxic concentrations. The JRC is the science body of the European Commission. Its mandate is to support policy making by providing scientific guidance to the European Commission. Through its activities, the JRC also supports EU Member States and operators in the identification and reduction of Natech risks.



SECTION 2

Natech Quantitative Risk Assessment by the ARIPAR software

Valerio Cozzani, LISES-DICAM, Università di Bologna, Italy

Natech events are characterized by a high level of complexity. They are categorized among the high impact, low probability events. As a consequence, Quantitative Risk Assessment (QRA) of Natechs is a challenging issue. The ARIPAR-GIS tool was developed under the ARIPAR project, which started since 1988. ARIPAR-GIS considers the impact area, vulnerability centers, demographics, meteorology and a combination of scenarios (e.g. 10,000-200,000 combination of scenarios) to give risk indexes as an output. For each risk source, event and failure trees are used, as well as geographical information. Vulnerability maps of the final scenarios are managed by the software. It has been applied to analyze several Italian industrial areas and it has proved to be a robust tool. The first complete approach to Natech QRA was published in 2007, but it needed a computational tool. As a consequence, ARIPAR-GIS has now been modified to implement a specific method for Natech QRA, allowing the calculation of the specific contribution of Natech scenarios to the overall industrial risk figures.

Quantitative Assessment of Earthquake and Tsunami Natech scenarios

Ernesto Salzano, Università di Bologna, Italy

The complexity of Natech scenarios is such that Quantitative Risk Assessment requires a complex, multi-disciplinary analysis, involving several engineering and natural science disciplines. Under the STREST project, the fishbone diagram of industrial risk analysis was adopted and natural hazards and their interactions incorporated in order to analyze a case study of a refinery in Milazzo, Italy. Earthquake and Tsunami were the natural hazards considered. Thus, Probabilistic Seismic and Tsunami Hazard Analysis (PSHA) were developed. Results were obtained using the Risk Curves/Effect TNO tool. The results given by the tool are based on available standards for vulnerability and for consequence analysis. Therefore, they can only be used for comparative purposes and as preliminary inputs for land use planning. It was concluded that the general complexity of Natech scenarios, which includes natural hazard analysis, is partially reduced by the similarities industrial facilities share worldwide and the availability of data associated to them .

SECTION 3

Oil and Gas Releases during Large Earthquakes and Tsunami

Shin-ichi Aoki and Naomi Kato, Osaka University, Japan

Osaka bay is exposed to several hazards such as floods, earthquakes, tsunami and storm surge. The consequences of oil and gas releases due to a large earthquake and associated tsunami in Osaka Bay represent a high risk for industrial facilities and neighboring communities. Thus, a research initiative for Disaster Prevention of Petrochemical Complexes (industrial parks) which includes the case study of the Sakai-Senboku industrial area, has been presented. Onshore and offshore propagation of damages were considered, although consequences and impacts were mostly present offshore. Numerical simulations of tsunami propagation and dispersion of spilt oil, including oil spill from storage tanks due to sloshing using Meshless Moving Particle Semi-implicit (MPS) method were developed. Furthermore, laboratory experiments on tsunami-induced hydrodynamic forces at the harbor and 2D experiments on wave forces acting on a tank have been used in order to validate a proposed model, considering similarities and scale effects. Community-engagement initiatives have also been carried out exchanging opinions with residents near the industrial park areas. Finally, countermeasures that are being developed such as reduction of tsunami energy by flexible pipes and blocking tsunami by an earth bank were presented.

Development of Simulation Tool for Fire Spread on Floating Oil in Tsunamis

Tomoaki Nishino, Building Research Institute, Japan

The tsunami following the 2011 Great East Japan Earthquake caused spreading of fires at Kesennuma Bay. A large quantity of oil, which had been spilled from destroyed oil tanks, contributed to such tsunami-induced fires. Some of the fires ignited tsunami refuge buildings, and people who had escaped to the buildings from the tsunami were exposed to the fires. In addition, the fires spread to forests, resulting in wildfires involving 231 ha. These facts have raised concern among people whom must evacuate for future tsunamis of the risk from tsunami-induced fires. Nevertheless, adequante measures have not yet been taken in recent disaster prevention planning, because there is no method for predicting the big picture of tsunami-induced fires.

The Building Research Institute has been developing a computational model for fire spread on floating oil in tsunamis. The model regards the spreading fires on the sea as an assembly of burning floating oil particles, and tracks the burning zone by predicting the locations and combustion behaviors of individual particles in time series. The spreading fires on Kesennuma Bay were numerically analyzed. As a result, it was concluded that the qualitative trend of the fire spread was well predicted by the model, compared with the actual conditions which were determined from film records and survey data.

Landslide and Pipeline Natech Risk Assessment Tool

Mauricio Sánchez and Felipe Muñoz Giraldo, Universidad de los Andes, Colombia

A quantitative-mechanistic model for assessing the probability of failure along pipelines due to their interaction with landslides, named GeoRisks was presented. The objective was to develop an integrated model to evaluate the risk of pipeline subjected to multiple natural hazards. The importance of managing problem complexity was considered. Topography, geotechnical information, hydrology, and pipeline information have been considered in the analysis. Cost analysis was also presented with a particular focus on cost-efficient design. Finally, criteria for risk management and structured hierarchical decision processes have been identified.

SECTION 4

Radiation Measurement for Protection of Children in Fukushima

Takeshi Komino, CWS, Japan

This presentation focused on the important question of how to mitigate nuclear-related risks analyzing the position of the government and providing real-time data. The presentation showed that under the Technical Hazards Working Session of the Sendai Framework, a call for transparent disclosure of risks was made. The question on "how are the lessons from Fukushima being used to mitigate future losses?" was the starting point to develop the project for Sharing Lessons and Protecting the Vulnerable communities. As a result, a method that is used to measure individual levels of radiation in Fukushima was developed. The tool has been used to identify radiation hotspot, particularly in schools and other public areas which then leads to on-the-spot decontamination efforts led by local government.

The NGO CWS Japan operation pillars are related to humanitarian development assistance, advocacy and capacity building, and it works with a NGO called Shalom on the project presented.

Discussion and Wrap-up Panel Session

Chair: Ana Maria Cruz

Panelists: Elisabeth Krausmann, Ernesto Salzano, Valerio Cozzani, Takeshi Komino, Tomoaki Nishino, Naomi Kato, Felipe Muñoz, Mauricio Sánchez.

The discussion and wrap-up panel session was the opportunity to evaluate overall awareness concerning Natech risks, assess research achievements and gaps, and delineate the main conclusions from the Workshop. The panelists agreed that awareness concerning Natechs risks has increased. It was also mentioned that there is a need for interaction between people from different disciplines and exchanges within different geographical areas in order to provide guidance for industrial plants and local governments. As a consequence, integrated and useful models are needed to help decision makers take the right decisions. However, several issues remain unsolved such as how to use and interpret model results to adequately inform decision making.

All the panelists agreed that uncertainty characterization is a central issue. It needs to be further addressed and explained, in order to have models that serve a purpose and can be implemented by authorities and stakeholders. One of the panelists noted "Models may not yet address uncertainties and are not yet dynamic". But the question on how to include changeability, adaptability and flexibility in these models is still not resolved. For example, issues related to infrastructure deterioration and depreciation over time are not yet incorporated in current risk assessment models.

The importance of estimating economic losses from Natech accidental scenarios and the need to have more precise estimation tools which consider direct and indirect damages and losses was highlighted.

Another aspect that was discussed during the session was data availability. Several panelists manifested the need to have databases based on detailed descriptions of past accident scenarios, and agreed efforts to promote data sharing and recording is crucial for lessons learning. Another problem identified is the need to work towards improved risk communication and disclosure of risk information by industry to potentially affected communities. Thus, a call was made for inclusion of more social science approaches and risk communication fields in future Natech studies.

One of the participants noted that Natech risk management focuses on industrial aspects and exposure, but that it is also a risk governance problem. Risk management is in the hands of industries or though policies by government officials. Will power from

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government officials is needed. In developing countries, the problems are even greater due to lack of economic and human resources, and so on. The need for an international standard for Natech risk management, and the importance of constructing an international framework on Natechs was noted. In this context, the question concerning "What are key criteria needed for a Natech performance rating system?" was raised. The answers provide by the panelists and participants touched upon several issues including:

- Awareness about the problem
- Identification of exposure to hazards
- Knowledge creation (chemicals, quantities, etc.)
- Definition of natural hazard and level of risk
- Facilities should look at events beyond design level
- Emergency response (not captured by QRA)
- Emergency planned made by public authority.
- Early warning /forecasting in case of storms, flood etc.
- Incentives for companies
- Indicators for the relation between land use planning and governance.

Annexes

Annex 1:

Group Photo

PARTICIPANTS

Standing, left to right (First row): Ana Maria Cruz, Kaoru Takara, Valerio Cozzani, Angelica Baylon, Sandhya Babel, Jaime Pacheco, Ma. Camila Suarez, Marina Hamidzada, Luiyi Zhang.

Standing, left to right (Second row): Takeshi Komino, Dewi Dimyati, Ahmed Ibrahim, Ernesto Salzano, Shin-ichi Aoki, Shinichi Yamamoto, Horikomi Kaori, Felipe Muñoz.

Standing, left to right (Third row): Bonjun Koo, Daniel Cardoso, Atsushi Aoyama, Alexander Guzman, Elizabeth Krausmann, Toma Stoyanov, Uta Reichardt, Mauricio Sánchez, Hirokazu Tatano, Tomoaki Nishino, Irasema Alcantara, Giuseppe Aliperti, Hitomu Kotani.

Annex 2:

Program

Collaborative Research Hub, Room 301 Building 77, Uji Campus, Kyoto University March 13, 2017		
	9:00 - 9:20	Opening ceremony *Kaoru Takara, Director, DPRI, KU* *Ana María Cruz, DPRI, KU* *Shin-ichi Aoki, Osaka University* *Jaime Pacheco, First Secretary of the Colombian Embassy in Japan*
Chair: ***Ana Maria Cruz***	9:20 - 9:40	State of the Art in Natech Risk Management *María Camila Suarez, DPRI; Felipe Muñoz Giraldo, University of Andes, Colombia; Ana Maria Cruz, DPRI*
	9:40 – 10:20	RAPID-N: Earthquake Natech Risk Assessment *Elizabeth Krausmann, Joint Research Centre, European Commission, Italy*
	10:20 - 10:40	**Coffee Break**
Chair: ***Shin-ichi Aoki***	10:40 - 11:20	Natech Quantitative Risk Assessment by the ARIPAR software *Valerio Cozzani, University of Bologna, Italy*
	11:20-12:00	Quantitative Assessment of Earthquake and Tsunami Natech scenarios. *Ernesto Salzano, University of Bologna, Italy*
	12:00 - 13:30	**Lunch**
Chair: ***Felipe Muñoz***	13:30 - 14:10	Oil and gas releases during large earthquakes and tsunami *Shin-ichi Aoki and Kato Naomi, Osaka University, Japan*
	14:10 – 14:50	Damage and Effects Caused by Tsunami Fires *Tomoaki Nishino, Building Institute, Japan*
	14:50 - 15:30	Landslide and Pipeline Natech Risk Assessment Tool *Mauricio Sánchez and Felipe Muñoz Giraldo, U. Andes, Colombia*
	15:30 – 15:50	**Coffee Break**
Chair: ***Irasema Alcantara***	15:50 - 16:30	Tool for Assessment of Radiation Hotspots *Takeshi Komino, CWS, Japan*
Chair: ***Ana Maria Cruz***	16:30 - 17:45	Discussion and Wrap-up Panel Session Panelists: *Elisabeth Krausmann, Ernesto Salzano, Valerio Cozzani, Takeshi Komino, Tomoaki Nishino, Naomi Kato, Felipe Muñoz, Mauricio Sánchez*
17:45 – 18:00		Closing Ceremony

Annex 3:

Presentations

State of the art in Natech Risk Management

Workshop 2017 – Kyoto

María Camila Suarez
Prof. Ana María Cruz
Prof. Felipe Muñoz Giraldo
Research Center for Disaster Reduction Systems
DPRI, Kyoto University
suarez.camila.57u@st.kyoto-u.ac.jp

Content

1. Introduction
2. State of the art in Natech risk management
3. Conclusions

Content

1. **Introduction.**
2. State of the art in Natech risk management.
3. Conclusions.

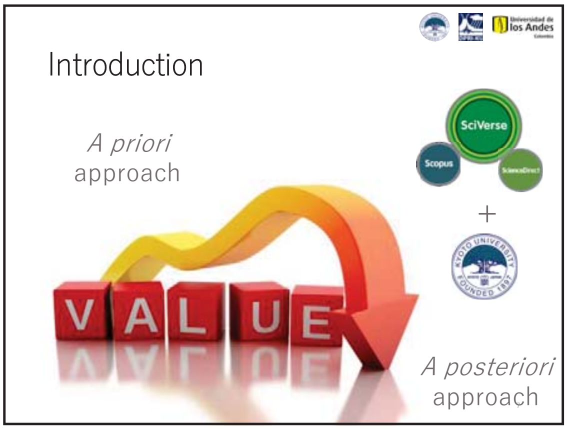
Earthquake of magnitude 7.4 Mw Turkey earthquake 1999	Hurricane Katrina 2005	Earthquake of magnitude 9.0 Mw & Tsunami (400 km² of land) Great East Japan Earthquake-Tsunami 2011
		
Intentional release of 200,000 kg of hazardous anhydrous ammonia	Release of over 30,000m³ of oil	190,000 buildings damaged (45,700 totally destroyed).
Leakage of 6.5 million kg of toxic acrylonitrile into air, soil, and water	Soil contamination	Worst nuclear power accident in Japan's history.
Liquid petroleum gas leakages and oil spills at the port terminal at an oil refinery	More than US$100 billion in damage estimated.	Industrial Production Index dramatically decreased by 15.5%. (Decline in global automobile production).

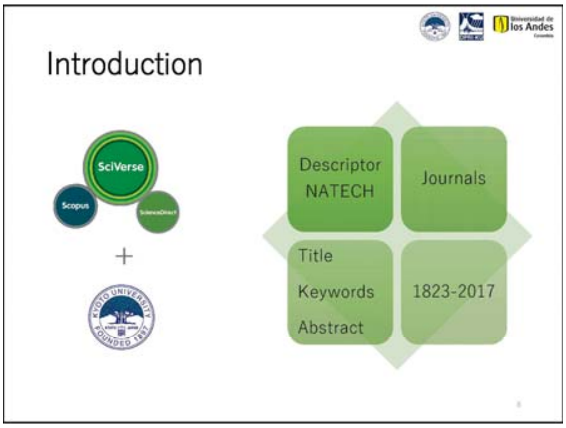
Earthquake of magnitude 7.4 Mw Turkey earthquake 1999	Hurricane Katrina 2005	Earthquake of magnitude 9.0 Mw & Tsunami (400 km² of land) Great East Japan Earthquake-Tsunami 2011
		
		
Steinberg, L. J., and A. M. Cruz (2004).	Cruz, A. M., and E. Krausmann (2009).	Krausmann, E. and A. M. Cruz (2013).

Introduction

A priori approach

A posteriori approach


Introduction
A priori
approach
SciVerse
Scopus
+
VALUE
A posteriori
approach


Introduction
SciVerse
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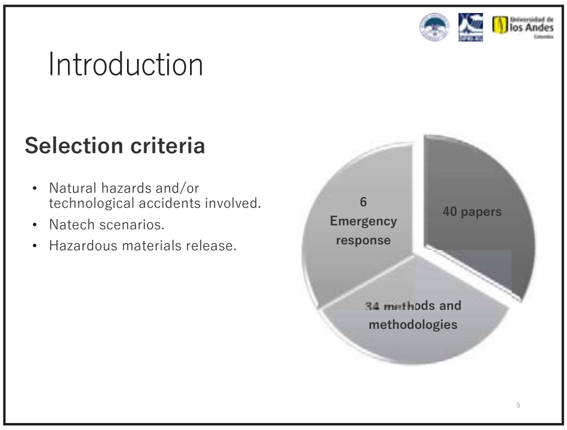
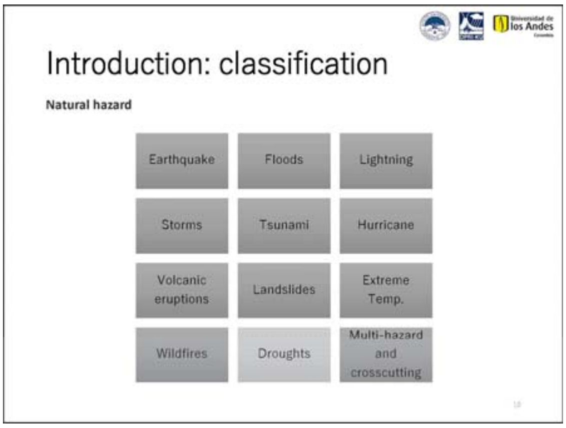
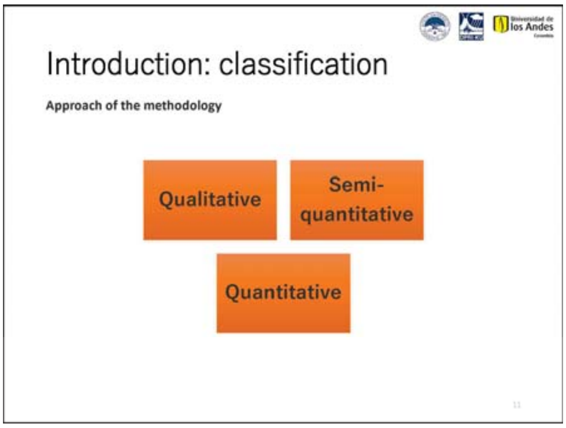
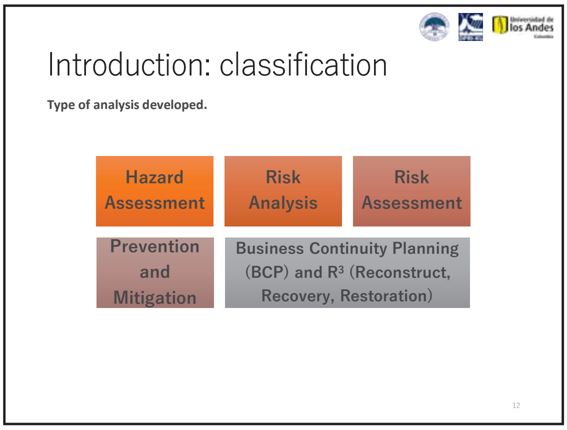
Descriptor
NATECH
Journals
Title
Keywords
Abstract
1823-2017


Introduction
Selection criteria
• Natural hazards and/or technological accidents involved.
• Natech scenarios.
• Hazardous materials release.
6
Emergency
response
40 papers
34 methods and
methodologies


Introduction: classification
Natural hazard
Earthquake
Floods
Lightning
Storms
Tsunami
Hurricane
Volcanic
eruptions
Landslides
Extreme
Temp.
Wildfires
Droughts
Multi-hazard
and
crosscutting


Introduction: classification
Approach of the methodology
Qualitative
Semi-
quantitative
Quantitative


Introduction: classification
Type of analysis developed.
Hazard
Assessment
Risk
Analysis
Risk
Assessment
Prevention
and
Mitigation
Business Continuity Planning
(BCP) and R³ (Reconstruct,
Recovery, Restoration)

Content

1. Introduction.
2. **State of the art in Natech risk management.**
3. Conclusions.

State of the art in Natech risk management

A priori analysis

Methods and methodologies	Hazard / Approach	Earthquake	Floods	Lightning	Storms	Tsunami	Hurricanes	Volcanic eruptions	Landslides	Extreme Temp.	Wildfires	Droughts	Multihazard and crosscutting
	Qualitative												
	Semiquantitative												
	Quantitative												

Low High

State of the art in Natech risk management

A priori analysis

Methods and methodologies	Hazard / Approach	Earthquake	Floods	Lightning	Storms	Tsunami	Hurricanes	Volcanic eruptions	Landslides	Extreme Temp.	Wildfires	Droughts	Multihazard and crosscutting
	Qualitative												
	Semiquantitative												
	Quantitative	45%											

Low High

State of the art in Natech risk management

A priori analysis

Methods and methodologies	Hazard / Approach	Earthquake	Floods	Lightning	Storms	Tsunami	Hurricanes	Volcanic eruptions	Landslides	Extreme Temp.	Wildfires	Droughts	Multihazard and crosscutting
	Qualitative												
	Semiquantitative												
	Quantitative		20%			15%							

Low High

State of the art in Natech risk management

A priori analysis

Methods and methodologies	Hazard / Approach	Earthquake	Floods	Lightning	Storms	Tsunami	Hurricanes	Volcanic eruptions	Landslides	Extreme Temp.	Wildfires	Droughts	Multihazard and crosscutting
	Qualitative												
	Semiquantitative												
	Quantitative			10%				10%					

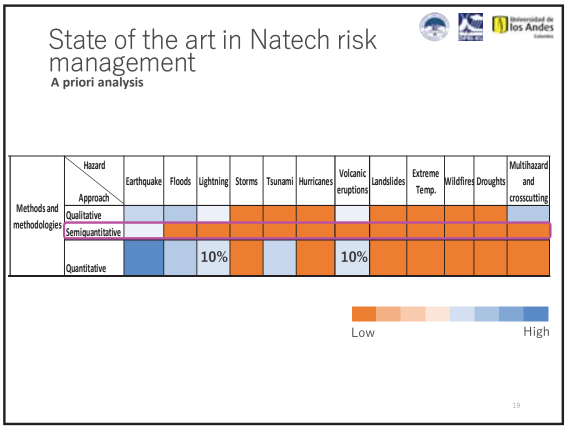
Low High

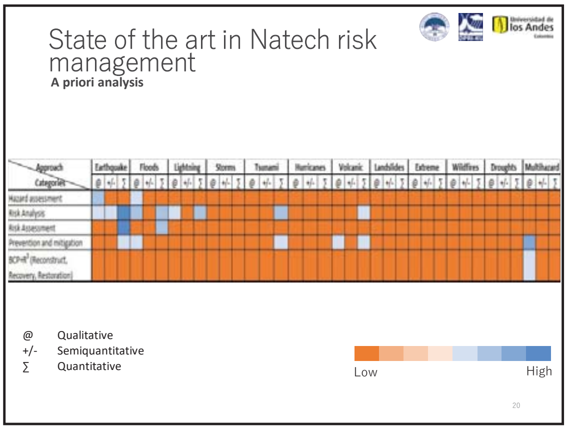
State of the art in Natech risk management

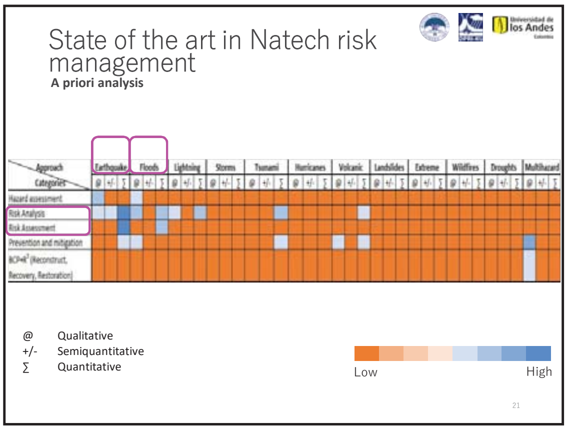
A priori analysis

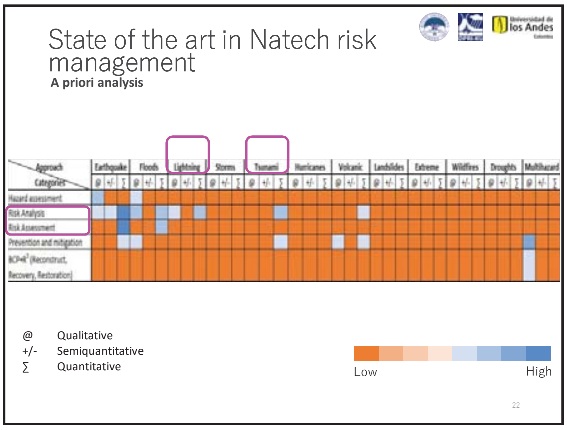
Methods and methodologies	Hazard / Approach	Earthquake	Floods	Lightning	Storms	Tsunami	Hurricanes	Volcanic eruptions	Landslides	Extreme Temp.	Wildfires	Droughts	Multihazard and crosscutting
	Qualitative												
	Semiquantitative												
	Quantitative			10%				10%					

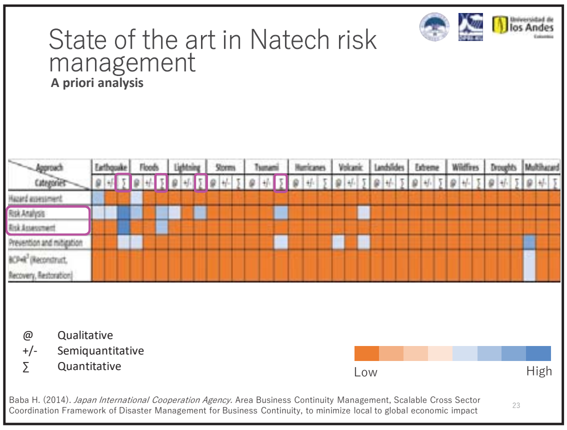
Low High

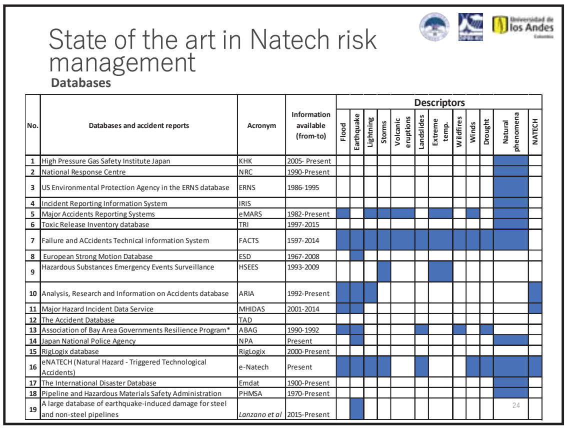












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7	Failure and ACcidents Technical information System	FACTS	1597-2014
8	European Strong Motion Database	ESD	1967-2008
9	Hazardous Substances Emergency Events Surveillance	HSEES	1993-2009
10	Analysis, Research and Information on Accidents database	ARIA	1992-Present
11	Major Hazard Incident Data Service	MHIDAS	2001-2014
12	The Accident Database	TAD	
13	Association of Bay Area Governments Resilience Program*	ABAG	1990-1992
14	Japan National Police Agency	NPA	Present
15	RigLogix database	RigLogix	2000-Present
16	eNATECH (Natural Hazard - Triggered Technological Accidents)	e-Natech	Present
17	The International Disaster Database	Emdat	1900-Present
18	Pipeline and Hazardous Materials Safety Administration	PHMSA	1970-Present
19	A large database of earthquake-induced damage for steel and non-steel pipelines	*Lanzano et al*	2015-Present

State of the art in Natech risk management
Databases

No.	Databases and accident reports	Acronym	Information available (from-to)	Flood	Earthquake	Lightning	Storms	Volcanic eruptions	Landslides	Extreme temp.	Wildfires	Winds	Drought	Natural phenomena	NATECH
1	High Pressure Gas Safety Institute Japan	KHK	2005- Present											■	
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7	Failure and ACcidents Technical information System	FACTS	1597-2014	■	■	■	■	■	■	■	■	■	■	■	
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11	Major Hazard Incident Data Service	MHIDAS	2001-2014	■	■										■
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State of the art in Natech risk management
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State of the art in Natech risk management
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State of the art in Natech risk management
Natech Tools

To complete the analysis, some available tools for:

- Natech risk assessment.
- Risk mitigation.
- Emergency operations planning .

For various types of natural hazards were included.

State of the art in Natech risk management
Tools (Natech + Others)

27 Tools included

- Risk communication tools.
- Preparedness tools
- Emergency response tools
- Modeling and simulation tools

Developed to support needs and close gaps in risk assessment, mitigation and control measures in the Natech context.

State of the art in Natech risk management

Natech Tools

No.	Tool name	Approach
1	Advanced Disaster Management Simulator (ADMS).	Emergency Management Simulation
2	Guardian Centers	Training in natural and manmade disasters
3	The Finding Individuals for Disaster and Emergency Response (FINDER)	Natural phenomenon (earthquakes and avalanches)
4	Climada (Catastrophe modeling)	Probabilistic multi-hazard risk assessment
5	SNOWPACK	Multi-purpose snow and land-surface model
6	RAPID-N	Natech risk mapping
7	PANR	Preliminary Assessment of Natech Risk in urban areas.
8	TRAS 310 Technical Rules on Process Safety (TRAS)	Precautions and Measures Against the Hazard Sources Precipitation and Flooding
9	TRAS 320	Precautions and Measures Against the Hazard Sources Wind, Snow Loads and Ice Loads
10	TRAT-GIS	Quantitative risk assessment computational tool applied to the land transport of dangerous goods
11	Tsunami-Induced Fire Spread Simulation	Tsunami consequences
12	Landslide and pipeline Natech Risk Assessment Tool	Quantitative-mechanistic model for assessing the probability of failure along pipelines due to their interaction with landslides
13	ARIPAR GIS - Software Tool for Area Risk Assessment and Management	Quantitative area risk assessment tool to evaluate the risk from major accidents in industrial areas where hazardous substances are stored, processed and transported.
14	Tool for Assessment of Radiation Hotspots	Assessment of radiation hot spot using Hot Spot Finder and linking it to decontamination efforts by local authority

State of the art in Natech risk management

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State of the art in Natech risk management

Other Tools

No.	Tool name	Approach
1	Global Platform for Disaster Risk Reduction	Disaster Risk Reduction
2	International Search and Rescue Advisory Group (INSARAG)	Earthquakes
3	Global Environments Network (GEN)	Seeks solutions to environmental and social problems
4	Real-Time Wireless Sensor Network for Landslide Monitoring	Landslides
5	STOP DISASTERS! Disaster simulation game.	Natural disasters
6	Nepal 2015 Earthquakes	Characterising the post-seismic behaviour of damaged slopes
7	TANAH - the tsunami and earthquake fighter	Tsunami
8	PreventionWeb - Information needs of the DRR community	Multihazard Disaster Risk Reduction
9	Flood Resilience Portal	Flood
10	Practical Action	App used as a Technical Information Service Rebuilding in the Aftermath of an Earthquake Seismic Resistant Retrofitting for Buildings
11	Missing map project	Map up of vulnerable areas before the disaster occurs
12	Flash Environmental Assessment Tool (FEAT)	First aid impact assessment and response prioritization tool, aimed to be used immediately after a chemical incident anywhere in the world.
13	The Hazard Identification Tool (HIT)	Support tool for first responders to identify and address secondary environmental risks as early as possible.

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Content

1. Introduction.
2. State of the art in Natech risk management.
3. **Conclusions.**

34

Conclusions

- This is a first approach which uses a small sample of literature to have an outlook of the state of the art in Natech Risk Management considering specific works which explicitly refer to Natechs.
- There is an increase interest of researchers and industries in understanding the dynamics and effects of storms, hurricanes, tsunamis, landslides and droughts.
- More methods that lie between the quantitative and qualitative approaches are urgently needed as they may be less time consuming and less expensive, while still providing some quantitative measure.

35

Conclusions

- This is a first approach which uses a small sample of literature to have an outlook of the state of the art in Natech Risk Management considering specific works which explicitly refer to Natechs.
- There is an increase interest of researchers and industries in understanding the dynamics and effects of storms, hurricanes, tsunamis, landslides and droughts in the industry and community.
- More methods that lie between the quantitative and qualitative approaches are urgently needed as they may be less time consuming and less expensive, while still providing some quantitative measure.
- Some available databases have started to include Natech as keyword and Natech accidents among their records.
- More area wide methodologies and tools are needed in order to address the consequences beyond the fence line, and include neighboring communities in the Natech risk management context.

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State of the art in Natech Risk Management

Workshop 2017 – Kyoto

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RAPID-N: Natech risk assessment and mapping

Serkan Girgin
Amos Necci
Elisabeth Krausmann

JRC activities

Objective:

→ Support the EU Member States and operators in the identification and reduction of Natech risk

Stakeholders:

→ EU Member States, candidate and neighbour countries, third countries; European Commission Services; OECD, UNEP/OCHA, UNISDR

Activities:

→ Accident analysis and guidance on Natech RR
→Risk analysis tools
→Training

JRC activities

Accident analysis and guidance

- Identification of vulnerable equipment *(fixed, pipelines, offshore)*, scenarios and consequences *(earthquakes, floods, lightning, hurricanes)*
- Site surveys for Natech damage assessment *(Japan, China)* & statistical analysis, lessons learning
- Natech accident database: **eNatech** http://enatech.jrc.ec.europa.eu

Risk analysis tools

- Framework for Natech risk assessment and mapping: RAPID-N http://rapidn.jrc.ec.europa.eu

Training

Natech Risk Mapping

- Natech risk maps are considered a high priority need for:
  - Identification of Natech-prone areas (land-use planning)
  - Emergency-response planning
- Hardly any Natech risk maps exist in the EU/OECD
  - Simple overlay of natural hazards and industrial facilities
  - Do not consider site-specific features
    - Expected release scenarios
    - Existing safety measures

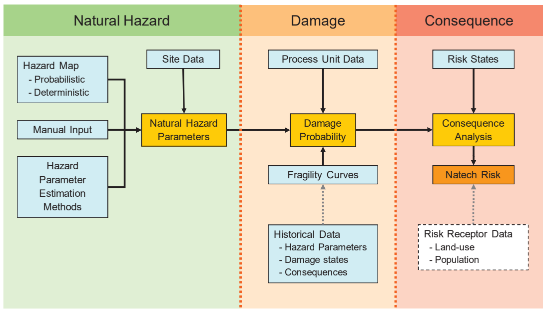
→ Development of a unified Natech risk assessment and mapping methodology and implementation as a software tool

Rapid-N Natech Risk Assessment & Mapping Framework

- Integrated methodology
  - **Natural Hazard + Accident**
- Rapid assessment
  - **Local and regional analysis**
- Publicly available
  - **Multilingual web service**
- User friendly application
  - **Easy and quick data entry**
  - **Visualization**
- Collaborative environment

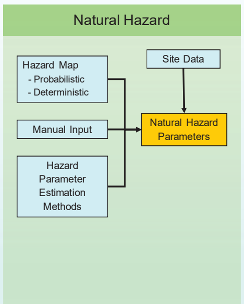
7 European Commission

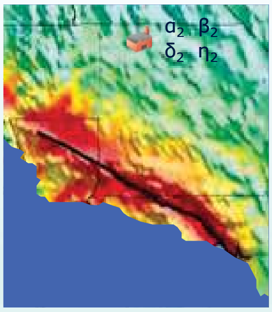
Methodology



8 European Commission

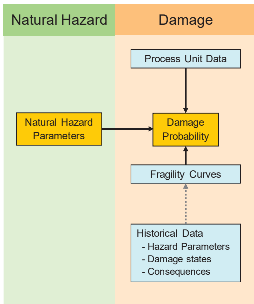
Methodology

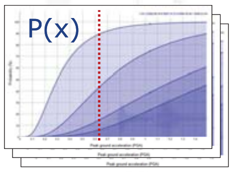




9 European Commission

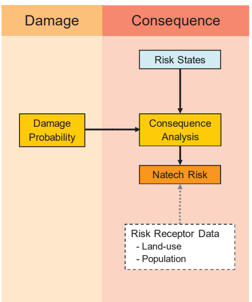
Methodology





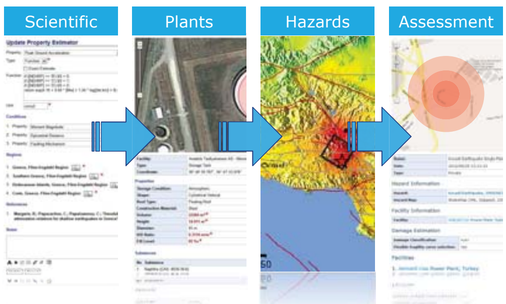
10 European Commission

Methodology



11 European Commission

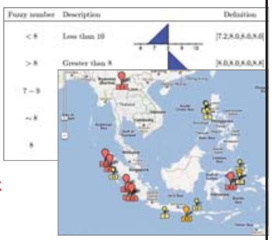
Modular Structure



12 European Commission

Scientific Tools Module

- Fuzzy arithmetic
- Automated unit conversion
- Statistics and curve-fitting
- Mapping
  - Google Maps
  - GIS analysis
- Reference management



Property Estimation Framework

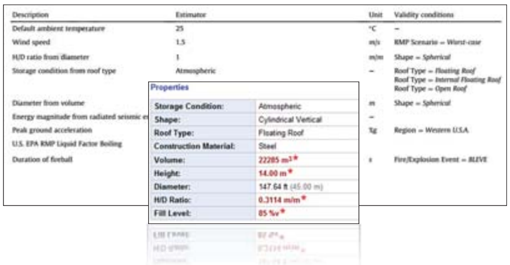
- Minimize data requirement
- Increase flexibility
  - No hard-coded functions

Property Estimation Framework

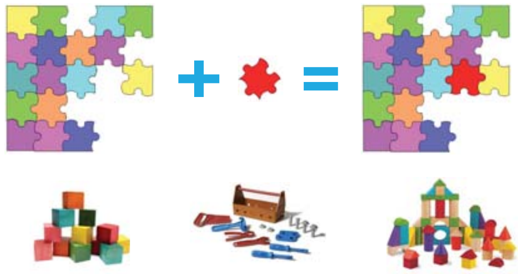
- Properties
  - **Natural hazard: e.g. PGA**
  - **Site: e.g. Soil class**
  - **Facility: e.g. Capacity**
  - **Process unit: e.g. Volume**
  - **Substance: e.g. Density**
- Data
  - **Numerical (with unit)**
    e.g. 10 m^3, 1.5 m/s
  - **Tabular**
    e.g. Atmospheric, Pressurized

Property Estimation Framework

- Property Estimators



Property Estimation Framework



Property Estimation Framework

- Minimizes data input
  - **Estimates missing data**
- Increases flexibility
  - **Dynamic model building**
- Provides extensibility
  - **Custom properties**
  - **Custom estimators**
- Selects <u>most suitable</u>
  - **Recursive**
  - **Exhaustive**

Plants Module

- Plants
  - **Industrial activity**
  - **Site properties**
- Plant Units
  - **Unit characteristics**
  - **Stored substances**
- Typical Plant Units
- Substances
  - **Identifiers**
  - **Physicochemical properties**

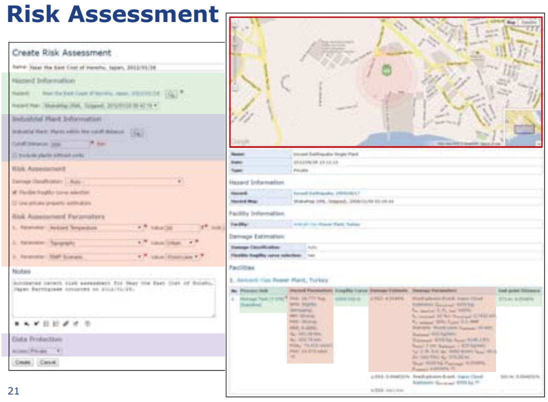
Hazards Module

- Natural Hazards
  - **Hazard parameters**
- Earthquake Catalog Data
  - **Continuous monitoring**
  - **Automated update**
- Hazard Maps
  - **Shakemaps**
- On-site Hazard Data
- Natechs
  - **Damage parameters**

Assessment Module

- Damage Classifications
- Fragility Curves
- Risk States
  - **Non-linear DS-RS relations**
  - **Damage parameters, e.g.:**
    - Natech event (e.g. BLEVE)
    - Conditional probability (e.g. 50%)
    - Volume involved (e.g. 10 %v)
  - **Validity conditions**

Risk Assessment



Status and Application

- Currently implemented for earthquakes and fixed installations and pipelines
- ~ 20,000 earthquakes (> M 5.5)
- ~ 10,000 shakemaps
- > 5,500 industrial facilities
  - Refineries
  - Power plants
- > 64,000 plant units
  - Storage tanks
- Complete implementation of U.S. EPA RMP Offsite Consequence Analysis methodology
- **Application areas:**
  - Land-use planning
  - Emergency planning
  - Preliminary Natech damage estimation
  - Early warning

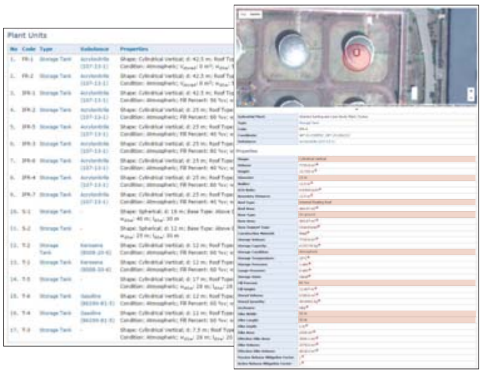
Natural Hazard

- Istanbul Earthquake
- Scenario
  - **JICA (2002) Model A**
- Epicenter
  - **40° 45.00'N 29° 24.00'E**
  - **Focal depth 10 km**
- Fault
  - **Fault length 154 km**
  - **Strike-slip**
- Magnitude
  - **Mw 7.5**

Industrial Plant

- Located in Izmit Bay
- Fiber production
- 315,000 ton/year capacity

Industrial Plant Units



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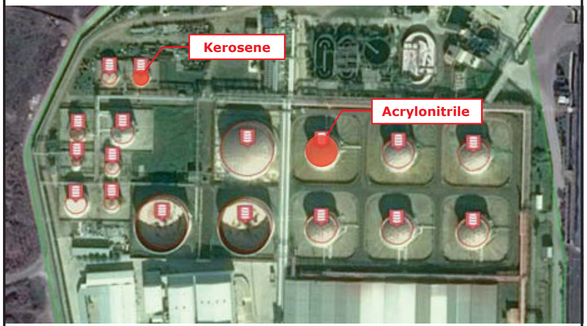
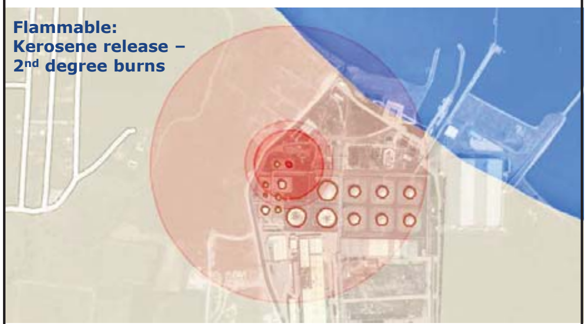


Risk Assessment – Kerosene

Consequence: Pool fire	
End-point: 2nd degree burns (40s exp.)	
DS1	No release
DS2	No release
DS3	1.24 m³ release 248 m² pool (within dike) 69 m end-point distance
DS4	619 m³ release 415 m² pool (within dike) 90 m end-point distance
DS5	1238 m³ release 8588 m² pool (dike overflow) 408 m end-point distance

d_e	6.18 km
PGA	0.7852 g
PGV	167.92 cm/s
MMI	10.07

HAZUS, 2010	
≥ 50%, Anchored	
DS1	45.00%
DS2	46.56%
DS3	5.86%
DS4	0.87%
DS5	1.72%



Risk Assessment – Acrylonitrile

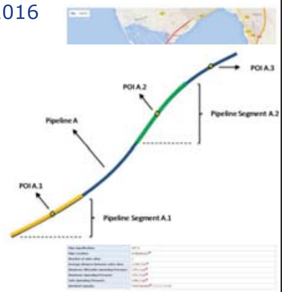
Consequence: Atmospheric dispersion	
End-point: ERPG-2 (0.076 mg/L)	
DS1	No release
DS2	No release
DS3	62 m³ release 1238 m² pool (within dike) 1.29 km end-point distance
DS4	3100 m³ release 2009 m² pool (within dike) 1.93 km end-point distance
DS5	6200 m³ release 8588 m² pool (dike overflow) 3.38 km end-point distance

d_e	6.25 km
PGA	0.7848 g
PGV	167.83 cm/s
MMI	10.06

HAZUS, 2010	
Near full, Unanchored	
DS1	0.90%
DS2	13.19%
DS3	28.34%
DS4	18.33%
DS5	39.25%

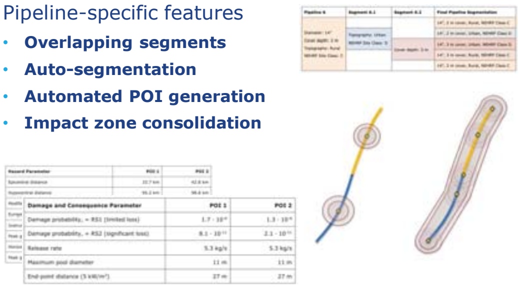
Pipeline Natech Risk Assessment

- Prototype completed in 2016
  (JRC Technical Report JRC101463)
- Pipeline-specific entities
  - **Pipeline**
  - **Pipeline Segment**
  - **Point of interest (POI)**
- Pipeline-specific data
  - **Damage states**
  - **Fragility functions**
  - **Properties**
  - **Property estimators**



Pipeline Natech Risk Assessment

- Pipeline-specific features
  - **Overlapping segments**
  - **Auto-segmentation**
  - **Automated POI generation**
  - **Impact zone consolidation**



Flood Natech Risk Assessment

- 1st Phase of the prototype is completed (MAHB-ECHO AA 2015-2016)
- Collection of scientific and technical knowledge
  - **Methodologies**
  - **Hazard data sources**
  - **Equipment vulnerability**
  - **Consequence analysis**
- Gap analysis
  - **Modifications**
  - **Further development**

Flood Natech Risk Assessment

- EFAS/RAPID-N interoperability
  (JRC Technical Report JRC105055)
- Benefits
  - **Flood hazard data for natech risk assessment**
  - **Natech risk data for emergency management**
  - **Flood forecasts → Natech Alert**
  - **Data sharing/cooperation between JRC systems**

RAPID-N: Ongoing and future research

- **Extension to other natural hazards and infrastructures**
  - Pipelines (ongoing), Floods (ongoing), Lightning (planned)
- **Automated Natech damage and consequence estimation (Alert)**
  - Reporting to interested parties and authorities
- **Cascading effects**
- **Consideration of risk receptors**

Thank you for your attention!

http://rapidn.jrc.ec.europa.eu

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Disaster Prevention Research Institute
KYOTO UNIVERSITY
Workshop on Tools for Natech Risk Management

Natech Quantitative Risk Assessment by the ARIPAR software

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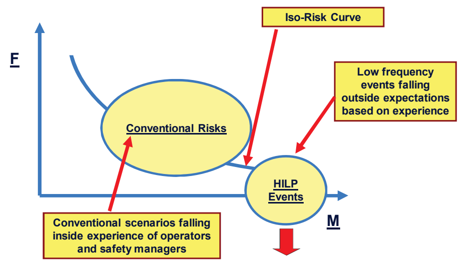
LISES - DICAM @ University of Bologna

- University of Bologna: funded in 1088: the oldest university in the western world
- 11 Schools, 33 Departments 2800 faculty members, 80000+ students
- One of the largest and best reputed Italian universities
- An international centre of competence for research in Safety of Industrial Activities
- Specific competences on external hazard factors and cascading events

Natech Events: definition

- Natural events (earthquake, floods, etc.) may cause damage to industrial installations and infrastructures
- Damage caused by natural events may start the release of hazardous substances triggering a technological accident
- These cascading events are defined "Natech" scenarios (Natural hazard triggering Technological disasters)
- NaTech scenarios are potentially high impact – low probability (HILP) events

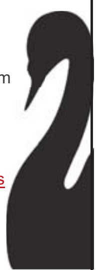
HILP (High Impact – Low Probability)



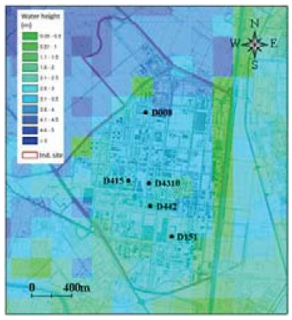
Complexity of Scenarios

- **A high number of multiple simultaneous or alternative events may result from a Natech sequence:**

1. A natural event occurs (usually impacting on a wide area)
2. At least one (possibly more than one) equipment item (storage tank, reactor, distillation column, pipe, etc.) is damaged
3. Dangerous substances (flammable, toxic, reactive with water, dangerous for environment) are released
4. Each release may result in alternative final scenarios depending on boundary conditions (ignition sources, meteo conditions, etc.)
5. Multiple simultaneous final scenario may cause further escalation (domino effects)



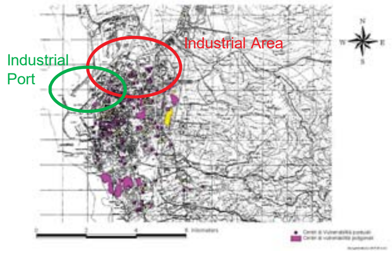
Complexity of impact vector



- Some hazards (e.g. flood) may require detailed characterization and may be strongly depending on position even in the scale of 10m

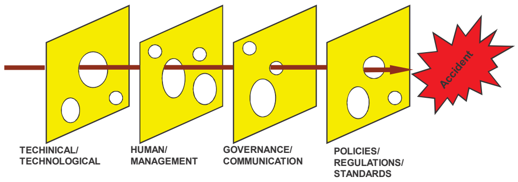
Complexity of impact area

- Residential area and industrial facilities may have limited separation distances (if any) in specific contexts



Barriers

- Barriers may be present to cascading events
- Barriers may be affected as well by the natural event (common cause failure)
- The presence of barriers as well as their possible failure needs to be taken into account in quantitative assessment of Natech scenarios



Quantitative Assessment of Natech

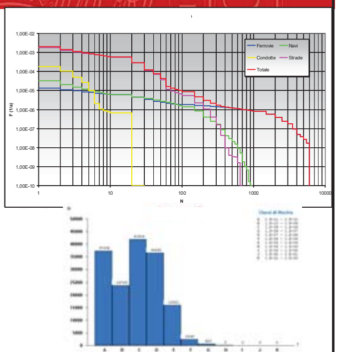
- **Quantitative assessment of Natech scenarios deals with:**
  1. HILP events - falling outside common experience of analysts and responders
  2. A high number of complex overall scenarios - simultaneous events, alternative final scenarios, escalation
  3. Complex characterization of hazard
  4. Complex description of impact area
  5. Need to include non-perfect barriers in the analysis and early warning systems
- **Quantitative Risk Assessment is usually applied to cope with a high number of scenarios having different credibility**
- **Geographical Information Systems (GIS) software is adopted to deal with the detailed characterization of complex areas**

Risk Assessment and Management:

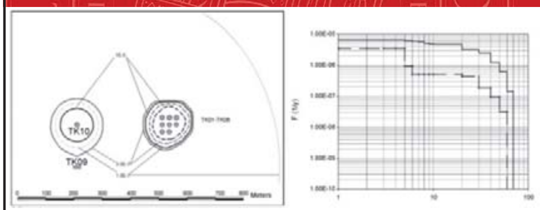
Even if QRA is a tool widely used in current practice, application to Natech is recent (2007) and still limited mostly to research

Detailed Risk Indexes

- local specific individual risk (LSIR)
- individual risk per annum (IRPA)
- Societal risk: F/N curves
- Societal risk: I-N histogram
- Societal risk: Potential Life Loss (PLL)
- Expectation value (EV)



QRA of Natech events



First complete QRA of a Natech event was published in 2007

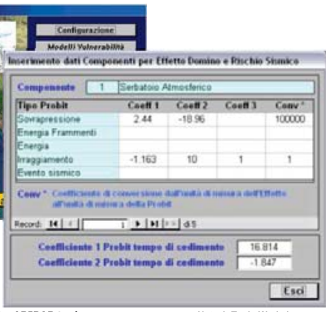
G. Antonioni, G. Spadoni, V. Cozzani: A methodology for the quantitative risk assessment of major accidents triggered by seismic events. J. Hazardous Materials 147 (2007) 48–59

Early studies date back to 2003 and 2005:

G. Fabbrocino, I. Iervolino, F. Orlando, E. Salzano: Quantitative risk analysis of oil storage facilities in seismic areas, J. Hazard. Mater. 123 (2005) 61-69

The ARIPAR-GIS software

First complete application of QRA to Natech was supported by the ARIPAR-GIS software

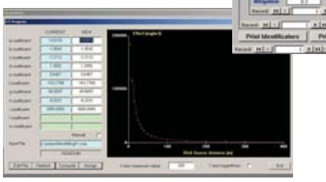


The use of a software tool is required to carry our complete calculations

The ARIPAR-GIS software

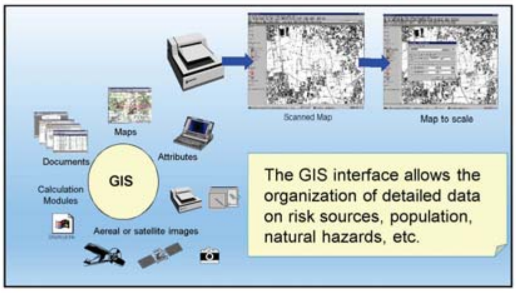
- ✓ In 1988 the ARIPAR project was launched (Analysis of Risks in the Industrial Area and Port of Ravenna - Italy)
- ✓ ARIPAR project is ambitious for the time: detailed characterization of industrial risk
- ✓ Several qualified public and private stakeholders participated: EC Joint Research Centre, University of Bologna, Civil Protection, Snamprogetti….
- ✓ 1990: ARIPAR software is launched
- ✓ 1996: first development of GIS interface
- ✓ 1996-2000: GIS interface continuously improved
- ✓ 2003: prototype for the assessment of domino effect
- ✓ 2005: prototype for the assessment of Natech events

The ARIPAR-GIS software



Main module of ARIPAR is set for the characterization of risk sources and impact areas

The ARIPAR-GIS software



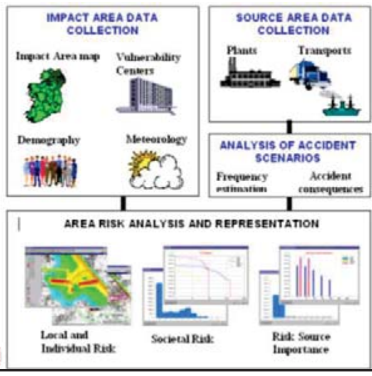
The ARIPAR-GIS software

- **ARIPAR-GIS was applied to the detailed analysis of several extended industrial areas in Italy**

Data on the main Italian area risk analysis studies performed using the ARIPAR software

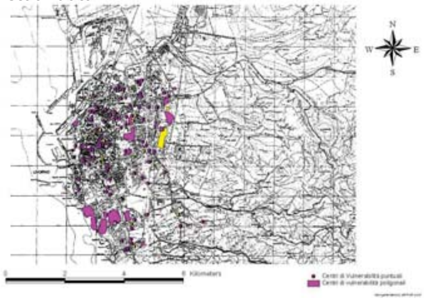
area	plants	scenarios (fixed inst.)	road, rail transport	pipeline transport	ext. (km²)	study developed by	on behalf of:
Ravenna	47	379	yes	yes	205	Snamprogetti-NIER-DAM and University of Bologna	Civil Protection Department - Emilia Romagna Region
Livorno	35	306	yes	yes	45	Snamprogetti	Local control authorities (ARPAT, Regione Toscana)
Piombino	5	46	yes	no	3	University of Pisa	Local control authorities (ARPAT, Regione Toscana)
Mantova	-	-	yes	no	25	University of Pisa	Local control authorities (Provincia di Mantova), ISS
Terni	-	-	yes	no	10	University of Bologna	Rete Ferroviaria Italiana SpA
Priolo	210	to be defined	yes	yes	>100	Snamprogetti	Ministry of the Environment
Milazzo	43	191	yes	yes	20	University of Messina	Local industry committee
Gela	4	27	yes	yes	30	University of Messina	---

The ARIPAR-GIS software



Population

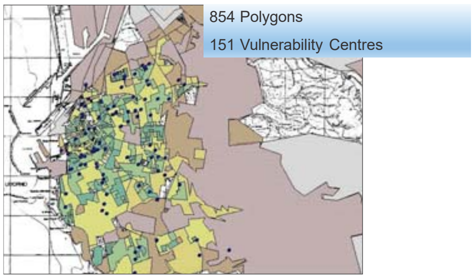
- Actual data



Natech Quantitative Assessment by ARIPAR tool
V. Cozzani, University of Bologna, Italy
Natech Tools Workshop
Kyoto, Japan, March 13, 2017

Population

- Data imported in ARIPAR-GIS



Natech Quantitative Assessment by ARIPAR tool
V. Cozzani, University of Bologna, Italy
Natech Tools Workshop
Kyoto, Japan, March 13, 2017

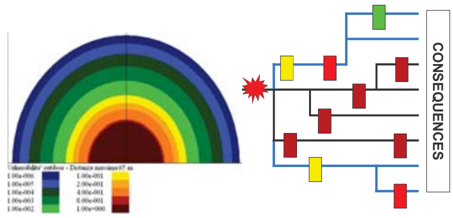
Risk Sources

- Detailed characterization of risk sources from fixed installations and transport systems

Natech Quantitative Assessment by ARIPAR tool
V. Cozzani, University of Bologna, Italy
Natech Tools Workshop
Kyoto, Japan, March 13, 2017

Risk Sources

- For each risk source an event tree and vulnerability maps of the final scenarios are managed by the software



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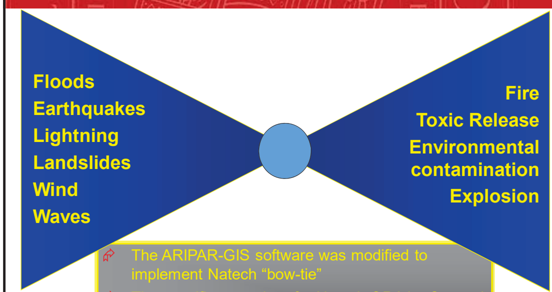
ARIPAR-GIS: Natech module



- The ARIPAR-GIS software was modified to implement Natech "bow-tie"
- The specific procedure for Natech QRA by Cozzani et al. was implemented (Cozzani et al., J. Loss Prev. Proc. Ind 28:10-22 (2014)

Natech Quantitative Assessment by ARIPAR tool
V. Cozzani, University of Bologna, Italy
Natech Tools Workshop
Kyoto, Japan, March 13, 2017

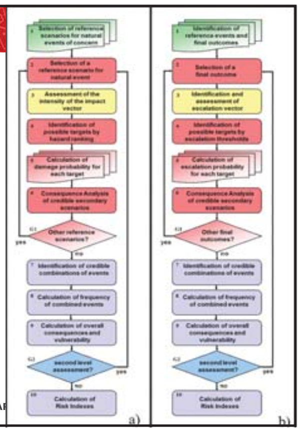
Detailed assessment

- Natech QRA was derived from that developed for domino effect assessment
- Results can be compared with those of baseline QRA
- Method is based on the use of equipment vulnerability models:

Campedel et al., Risk Analysis 28:1231-1246 (2008)

Antonioni et al., Reliability Eng.Sys.Saf. 142:334-345 (2015)

Necci et al., Reliability Eng.Sys.Saf. 154:60-72 (2016)



Natech Quantitative Assessment by ARIPAR tool
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Example of ARIPAR-GIS application: Seismic-induced accidents

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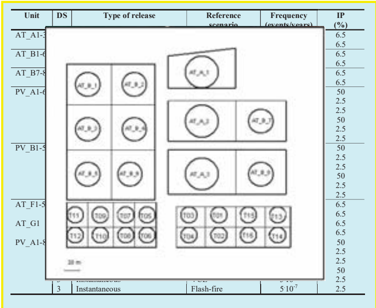

- A reference lay-out for a tank farm of an oil refinery was considered
- Reference scenarios were selected for both conventional events and LOCs induced by earthquakes

Example 1: Seismic-induced accidents

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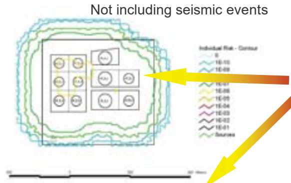
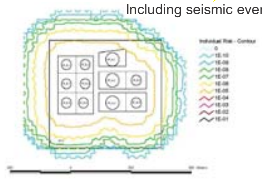
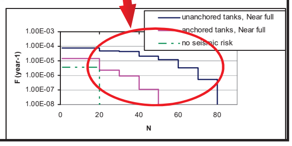
Not including seismic events



- Increase of 1 to 2 orders of magnitude of individual risk
- Strong increase in societal risk (in particular for high N values)

Including seismic events





Case-Study 1: Romenia, seismic

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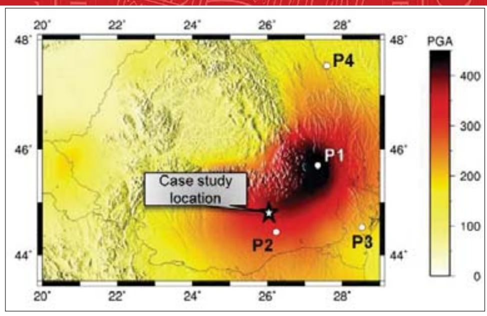

Probabilistic hazard map – 475 years recurrence period (Sokolov et al., 2007)

Tanks considered in the study (yellow) and the residential area (red)

Results and discussions

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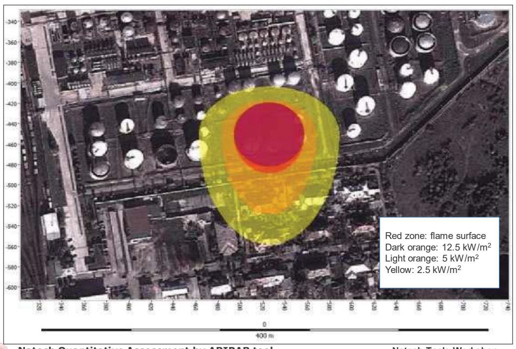

Individual Risk

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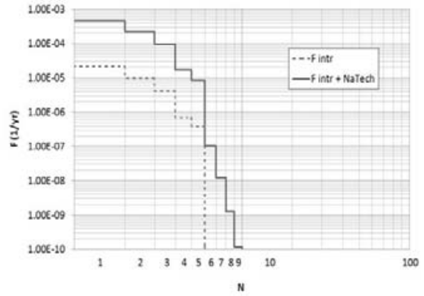
Local-specific Individual Risk comparison

a) IR considering only internal technological causes

b) Total IR considering internal technological causes and Natech event

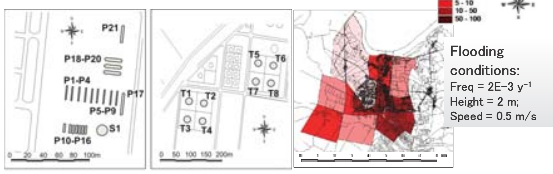
Societal risk

Societal Risk: F-N curves



Case Study 3: Italy, Flood

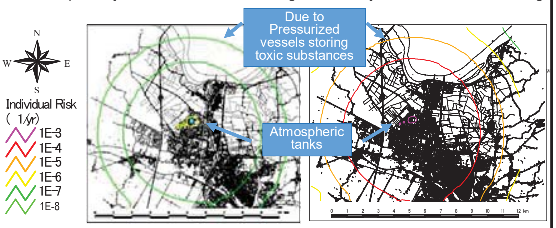
- Pressurized and atmospheric tank farm



Vessel features	Pressurized vessels					Atmospheric vessels		
	P1 to P9	P10 to P16	P17	P18 to P20	P21 to P23	S1	T1-T4	T5-T8
Nominal capacity (m^3)	50	30	115	150	100	3179	6511	6511
Substance contained	Propylene	Propane	LPG	Ammonia	Chlorine	Organic solvent	Gasoline	Benzene
Physical state	Liquefied gas	Liquefied gas	Liquefied gas	Liquefied gas	Liquefied gas	Liquid	Liquid	Liquid
Inventory (metric ton)	32	12	59	84	140	1550	3656	4275

Individual Risk

- LSIR profile increases up to three order of magnitude with respect to the QRA with conventional scenarios
- Frequency increment due to high severity of selected flooding

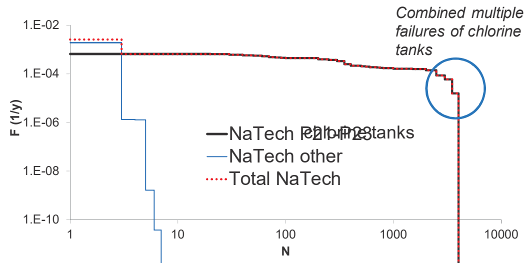


Conventional QRA

QRA and NaTech scenarios

Societal Risk: F-N Curve

- Pressurized vessels have a higher impact on the overall risk: relevant severity of toxic releases



Conclusions /1

- ARIPAR-GIS software proved to be a robust tool to support Natech QRA
- Results obtained by the approach from different applications in Europe seem coherent
- The results provide a detailed quantification of Natech risk even for complex impact areas and complex scenarios
- Quantitative assessment of Natech risk supports decision making and captures the effect of safety barriers

Conclusions /2

- ARIPAR-GIS addresses detailed risk assessment: it is not a screening tool
- QRA requires expert users and a deep knowledge of models, in particular when addressing consequence analysis
- Uncertainty needs to be managed when detailed approaches are developed
- Risk results are highly dependent on natural hazard characterization
- Equipment vulnerability model are the key element required for the implementation of the approach

Acknowledgements

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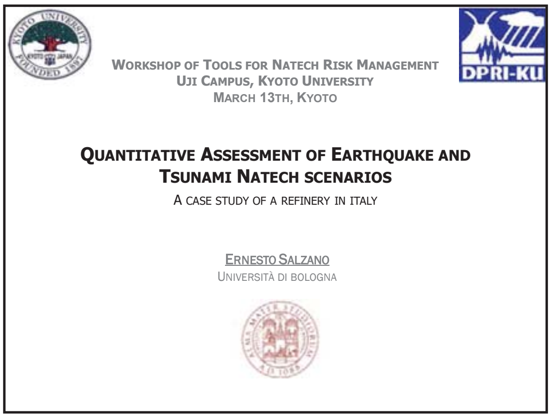
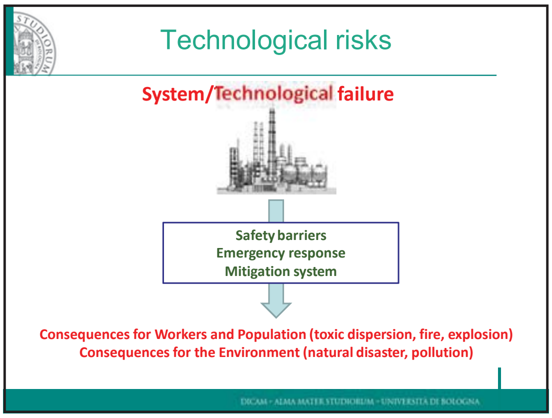
- All members of LISES - Laboratory of Industrial Safety and Environmental Sustainability at DICAM - UniBO: *Giacomo Antonioni, Sarah Bonvicini, Gigliola Spadoni, Alessandro Tugnoli*
- Gabriele Landucci, Università di Pisa, Italy
- Amos Necci, currently at EC JRC, Ispra site, Italy

The development of some NaTech assessment tools has been part of a specific task of iNTeg-Risk project, funded by the European Commission under FP7: www.integrisk.eu-vri.eu

iNTeg-Risk


Workshop of Tools for Natech Risk Management
Uji Campus, Kyoto University
March 13th, Kyoto
DPRI-KU
Quantitative Assessment of Earthquake and Tsunami Natech scenarios
A case study of a refinery in Italy
Ernesto Salzano
Università di Bologna


Technological risks
System/Technological failure
Safety barriers
Emergency response
Mitigation system
Consequences for Workers and Population (toxic dispersion, fire, explosion)
Consequences for the Environment (natural disaster, pollution)
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Technological risks
Deepwater Horizon: after burning for 36 hours
the rig sank on April 22, 2010
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Technological risks
The pipe that channeled oil 1,400 metres up from the sea floor spewed out in 5 million barrels of oil (twice as big as the largest oil spill event ever) in 3 months
A continuous plume of oil, more than 35 kilometers in length
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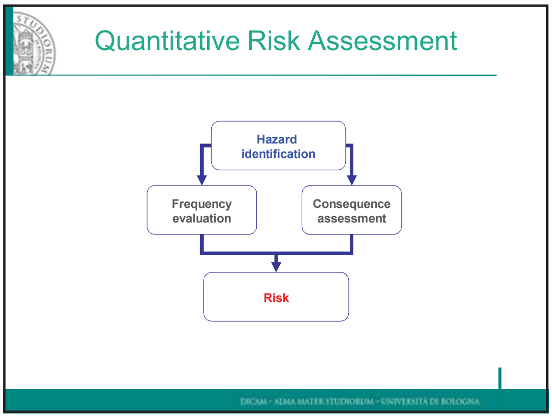
Quantitative Risk Assessment
Hazard identification
Frequency evaluation
Consequence assessment
Risk
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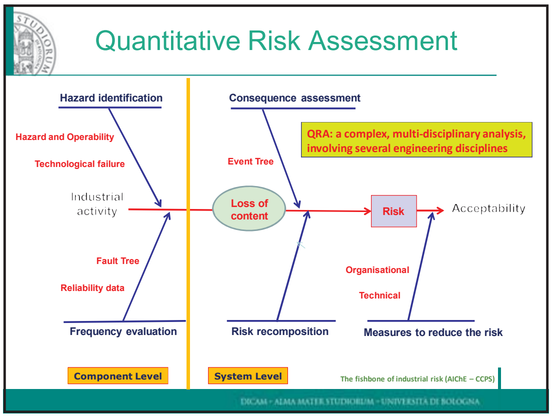
Quantitative Risk Assessment
Hazard identification
Consequence assessment
QRA: a complex, multi-disciplinary analysis, involving several engineering disciplines
Hazard and Operability
Technological failure
Event Tree
Industrial activity
Loss of content
Risk
Acceptability
Fault Tree
Reliability data
Organisational
Technical
Frequency evaluation
Risk recomposition
Measures to reduce the risk
Component Level
System Level
The fishbone of industrial risk (AIChE – CCPS)
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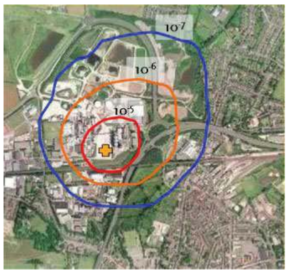
Quantitative Risk Assessment

The Aripar flowsheet for QRA, with domino effects

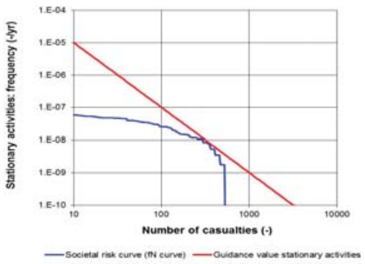
The RiskCurves/Effects flowsheet for QRA

Quantitative Risk Assessment



LOCAL, INDIVIDUAL OR LOCATIONAL RISK: Isorisk curves giving the annual risk of death or serious injury to which specific individuals are exposed

Quantitative Risk Assessment



SOCIETAL RISK (F/N Curves): The cumulative frequency (F) of incidents which can lead, on the whole impact area, to a number of fatalities higher than the given value N

Natural-Technological risks

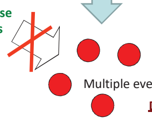
Natural disaster (earthquake, flooding, tsunami,..)

Total or partial unavailability of:

- *Utilities: electric power, cooling water, ..*
- *Safety barriers: firefighting water, ..*
- *Overloading of emergency services*

Early Warning
Emergency Shut-off

Emergency response
Mitigation systems



Multiple event

Domino effects

Consequences for Workers and Population (toxic dispersion, fire, explosion)

Consequences for the Environment (natural disaster, pollution)

Natural-Technological risks

Earthquake/Tsnuami Japan (2011): Ichihara – Chiba Refinery

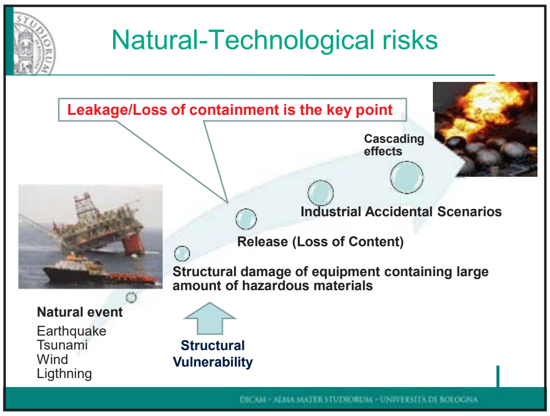
Main issues:

- Overloading of emergency system
- Fuel losses
- Post-event environmental effects

Natural-Technological risks

DOMINO EFFECTS

Emergency response in Ichihara was still able to cope with industrial accident despite earthquake and tsunami hence avoiding further consequences in the industrial area


Natural-Technological risks
Leakage/Loss of containment is the key point
Cascading effects
Industrial Accidental Scenarios
Release (Loss of Content)
Structural damage of equipment containing large amount of hazardous materials
Natural event
Earthquake
Tsunami
Wind
Ligthning
Structural Vulnerability
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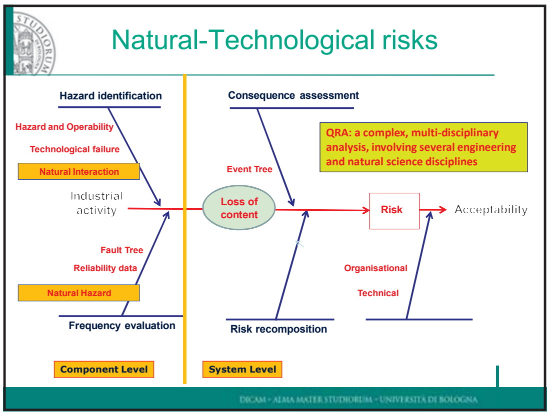
Natural-Technological risks
Hazard identification
Hazard and Operability
Technological failure
Natural Interaction
Industrial activity
Fault Tree
Reliability data
Natural Hazard
Frequency evaluation
Component Level
Consequence assessment
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Loss of content
QRA: a complex, multi-disciplinary analysis, involving several engineering and natural science disciplines
Risk
Acceptability
Organisational
Technical
Risk recomposition
System Level
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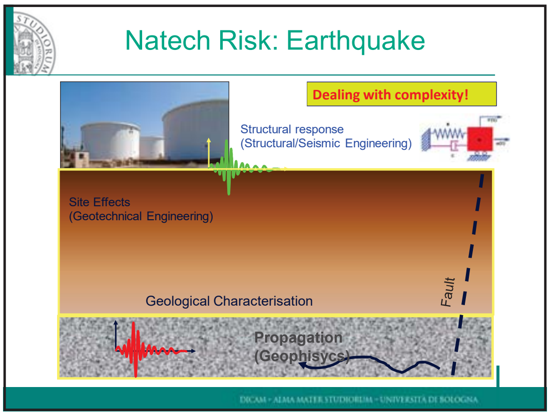
Natech Risk: Earthquake
Dealing with complexity!
Structural response
(Structural/Seismic Engineering)
Site Effects
(Geotechnical Engineering)
Geological Characterisation
Fault
Propagation
(Geophisycs)
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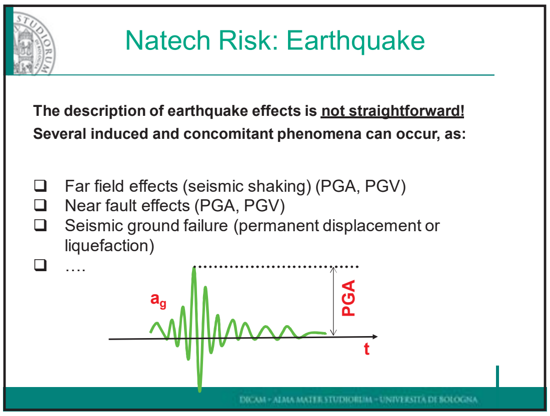
Natech Risk: Earthquake
The description of earthquake effects is not straightforward!
Several induced and concomitant phenomena can occur, as:
Far field effects (seismic shaking) (PGA, PGV)
Near fault effects (PGA, PGV)
Seismic ground failure (permanent displacement or liquefaction)
….
a g
PGA
t
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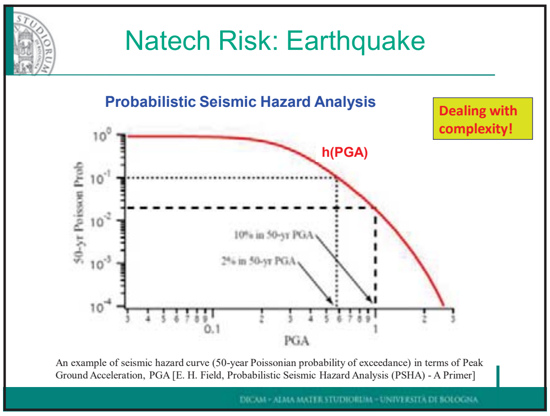
Natech Risk: Earthquake
Probabilistic Seismic Hazard Analysis
Dealing with complexity!
h(PGA)
50-yr Poisson Prob
10% in 50-yr PGA
2% in 50-yr PGA
PGA
An example of seismic hazard curve (50-year Poissonian probability of exceedance) in terms of Peak Ground Acceleration, PGA [E. H. Field, Probabilistic Seismic Hazard Analysis (PSHA) - A Primer]
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Natech Risk: Earthquake
Overturning
Sliding
EFB
Liquefaction
Uplift
Sloshing
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Natech Risk: Earthquake

Dealing with complexity!

Worldwide Standardized Design and Fabrication

Availability of Post Damage data

Natech Risk: Earthquake

Damage State (DS): Performance levels based on structural damage

- DS1 - absence of structual damage
- DS2 - slight damages to structures
- DS3 - moderate structural damages
- DS4 - Extensive damage to structures
- DS5 - total collapse of structure

Main scope:

Return-to-Service
Evaluation of post-event economical losses
Reconstruction
Repair
Upgrading

Dealing with complexity!

Natech Risk: Earthquake

Structural Vulnerability

For each Damage State (DS) for a specific structure, a structural vulnerability (**fragility function**) in terms of the standard normal cumulative distribution function for the Intensity Measure (IM) of earthquake can be defined as:

$$P[DS_i \mid IM] = \Phi\left[\frac{\ln(IM) - \ln(\overline{IM}_i)}{\beta}\right]$$

Natech Risk: Earthquake

For QRA, Performance levels based on Loss of Content are needed

Risk State (RS)

- RS3 (Minor risk): release from a 10 mm equivalent diameter
- RS2 (Severe risk): complete release of inventory in 10 min
- RS1 (Instant risk): instantaneous release of entire inventory

For each Risk State (RS) and for any specific equipment containing hazardous materials, a fragility function can be defined in terms of limit state probability as:

$$P[RS \geq RS_i \mid IM] = \Phi\left[\frac{\ln(IM) - \mu}{\beta}\right]$$

Natech Risk: Earthquake

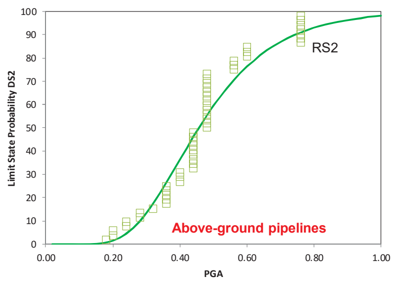
Equipment Fragility based on PGA

- Atmospheric tanks
- Pipelines
- Atmospheric equipment
- Pressurized tanks
- Pressurized equipment
- Reactors

$$P[RS \geq RS_i \mid PGA] = \Phi\left[\frac{\ln(PGA) - \mu}{\beta}\right]$$

N	RS	DS	Tank	FL	Fragility	Fragility
					μ	β
1	≥ 2	≥2	Anchored	Near Full	0,300	0,600
2	3	≥4	Anchored	Near Full	1,250	0,650
3	≥ 2	≥2	Anchored	≥ 50%	0,710	0,800
4	3	≥4	Anchored	≥ 50%	3,720	0,800
5	≥ 2	≥2	Unanchored	Near Full	0,150	0,700
6	3	≥4	Unanchored	Near Full	0,680	0,750
7	≥ 2	≥2	Unanchored	≥ 50%	0,150	0,120
8	3	≥4	Unanchored	≥ 50%	1,060	0,800

Natech Risk: Earthquake



Buried pipeline should be related to Peak Ground Velocity

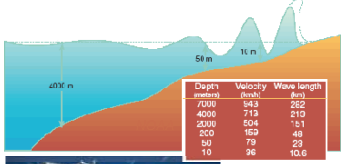
Natech Risk: Earthquake

Given a specific equipment, for each Risk State, the annual cumulative probability of Loss of Content (RS), is given by the combination of the vulnerability function and the Seismic Hazard function h(IM)

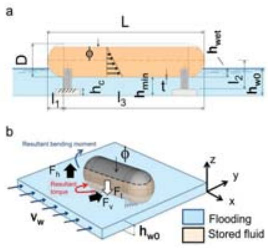
$$P[RS \geq RS_i \mid IM] = \int_{IM} P[RS \geq RS_i \mid IM] \cdot h(IM)dIM$$

Natech Risk: Tsunami

Tsunami characterisation: Water wave (velocity, inundation depth) and debris

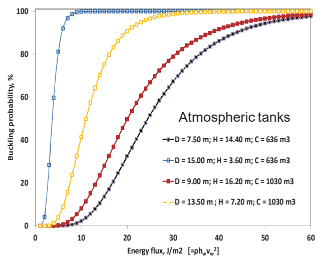


Natech Risk: Tsunami



Analogy with flooding: damage probability as function of total pressure, thus a function of water velocity and water height

Natech Risk: Tsunami



Impact as Energy Flux [J/m²]

Natech Risk: Tsunami

Depth of penetration τ by small and large fragment

$$\frac{DAMAGE}{RELEASE}: \tau > 0 \text{ (shell thickness)}$$

$$\zeta_{small} = k_s m_p^a u_o^b \qquad m_p \leq 1 \text{ kg}$$

$$\zeta_{large} = k_L \frac{m_p}{A_p} \log_{10}\left(1+5\cdot10^{-5}u_o^2\right) \qquad m_p > 1 \text{ kg}$$

m, A = mass and area of fragment
u_o = velocity of fragment

Target material	k_S	k_L	a	b
Concrete	1.8·10-5	1.0·10-3	0.4	1.5
Brickwork	2.3·10-5	2.5·10-3	0.4	1.5
Steel	6.0·10-5	5.0·10-5	0.3	1.0

Natech Risk: Tsunami

Steel Keel — Weight ≈ 100 kg, Surface = 2 m²

Tsunami Wave — Velocity = 5 m/s, Depth = 3 m

ζ_{large} = 8 mm ≈ thickness of low section of atm tanks

Natech Risk: Tsunami

Tsunami Wave damages by Johnson number

$$J = \frac{u_o^2}{\sigma_D \theta} \frac{m_p}{r_p^2}$$

$$J = \frac{\rho V_o^2}{\sigma_D} \left(\frac{L}{\theta}\right)^n \left(1 + \ln \frac{L}{L_p}\right)$$

m = mass of fragment
r = fragment characteristic dimension
u = velocity of fragment at the impact
θ = target wall thickness
σ = dynamic yield stress of target
L = characteristic lenght of target (p = partial)

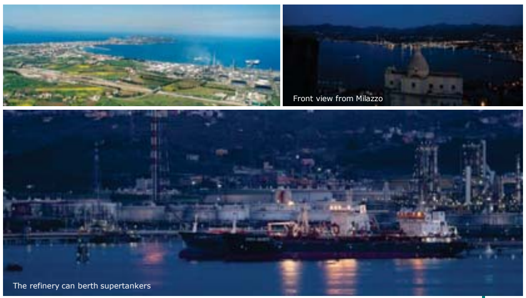
Johnson	Regime
10[illegible]	Quasi-static elastic
10[illegible]	Moderate plastic behaviour
10[illegible]	Extensive plastic deformation
10[illegible]	Hypervelocity impact

QRA Study for a refinery in Italy

Joint venture between Q8/ENI
Capacity: 8.0 million tons/y

STREST Milazzo Refinery, Sicily (Italia)

QRA Study for a refinery in Italy



QRA Study for a refinery in Italy

Flammable Gas and Liquid connection (pipework, loading arm) from the main site (storage, production) to berth

QRA Study for a refinery in Italy

QRA Study for a refinery in Italy

AREA I

QRA Study for a refinery in Italy

AREA II: Refining Units

1. Atmospheric Distillation
2. Vacuum Distillation
3. FCC (Fluid catalytic cracking)
4. Hydrocracking unit
5. LC Fining Residual Hydrocracker
6. Alkylation
7. Diesel Desulphurisation
8. Sulphur Recovery

Pressurised equipment, small scale (in terms of hazmat), safety instrumented systems for rapid shut-off


QRA Study for a refinery in Italy

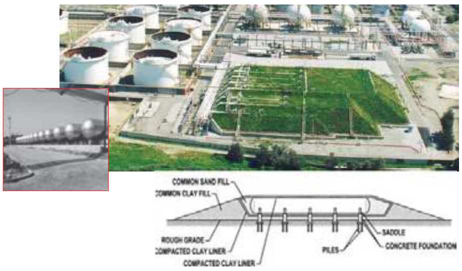
AREA III: Storage Units

170 floating roof tank: 4 million m^3

TANK PRODUCT	DIAM.	HEIGHT	CAPACITY (m3)
CRUDE	97	22	160,000
GASOIL	82.2	19	100,000
FUEL OIL	61	17	50,000
GASOLINE	61	17	50,000
NAPHTHA	24	15	7,000


QRA Study for a refinery in Italy

Area IV: Mounded Storage Unit



QRA Study for a refinery in Italy

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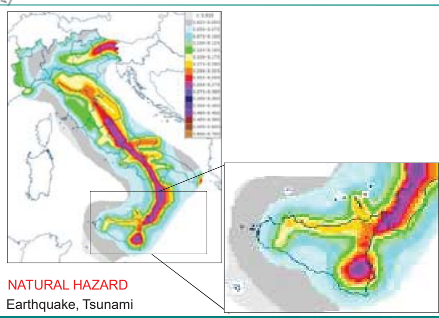
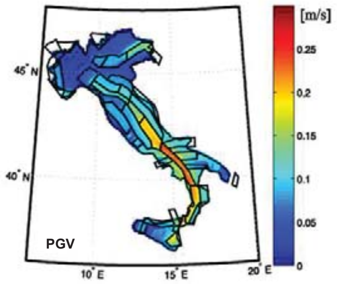


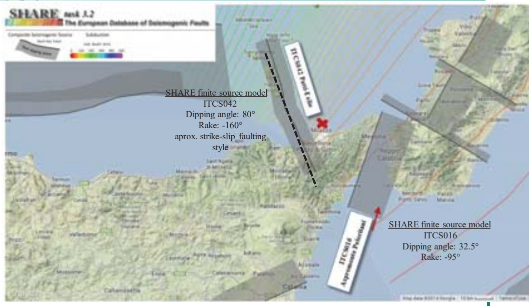
NATURAL HAZARD

Earthquake, Tsunami

QRA Study for a refinery in Italy



QRA Study for a refinery in Italy

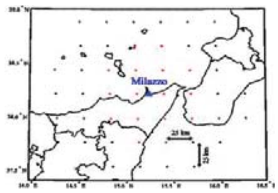


QRA Study for a refinery in Italy

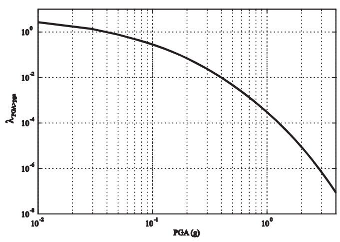
QRA Study for a refinery in Italy

Probabilistic Seismic Hazard Analysis (PSHA)

The area around Milazzo was discretized into a grid of forty-eight points (potential seismic event epicenters) with a grid spacing of approximately 25 km

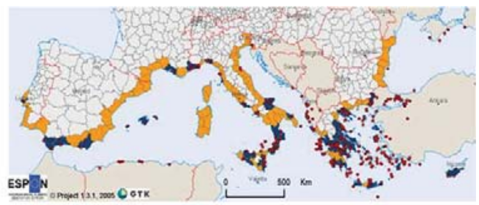


QRA Study for a refinery in Italy



Hazard curve for Milazzo in terms of PGA exceedance

QRA Study for a refinery in Italy



Historically recorded tsunami runups

Tsunami potential in coastal areas close to tectonically active zones

Regions that lie in vicinity to tectonically active zones and have experienced earthquake/volcano/landslide accociated tsunami

QRA Study for a refinery in Italy

The **1908 Messina earthquake and tsunami took about 123,000 lives**, in Sicily and Calabria, southern Italy.

…**The gazometer was destroyed, with a dramatic fire fed by furious wind**…

[CdS 29/12/1908]

NaTech

QRA Study for a refinery in Italy

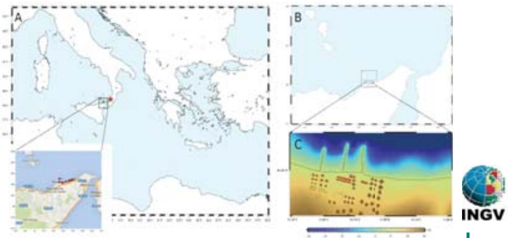
Tsunami in Sicily (Stromboli) in 2002, 30th Dec

At 13:55, two petrol ships berthed in Milazzo moved laterally (slipped) for 10m, broke their moorings (4 wires) even disconnecting the loading arm, and eventually releasing diesel oil into the sea

QRA Study for a refinery in Italy

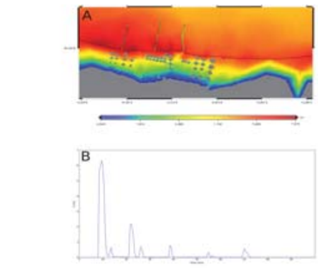
Probabilistic Tsunami Hazard Analysis (PSHA)

Numerical analysis of tsunami hazard in the area of Milazzo



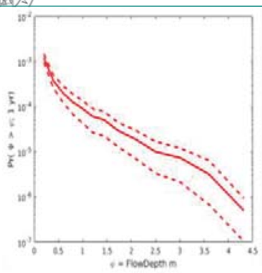
Italian National Institute of Geophysics and Volcanology

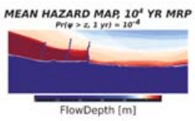
QRA Study for a refinery in Italy



A) Maximum wave height distribution originated from the crustal event indicated with the red star (M=8.0);
B) Time history of the corresponding wave height for one randomly selected receiver

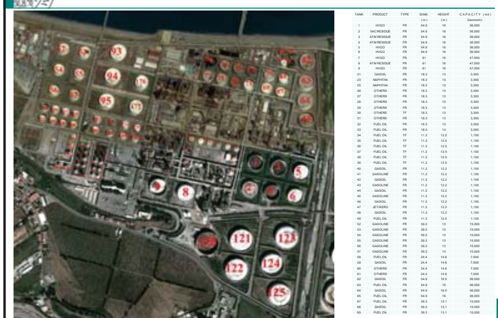
QRA Study for a refinery in Italy





Maximum flow depth distribution originated from the crustal event indicated with the red star (M=8.0)

QRA Study for a refinery in Italy



QRA Study for a refinery in Italy

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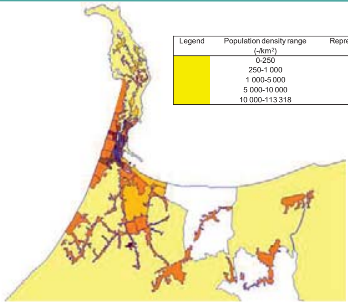

Legend	Population density range (-/km²)	Representative population density (-/km²)
	0-250	125
	250-1 000	625
	1 000-5 000	3 000
	5 000-10 000	7 500
	10 000-113 318	62 000

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Results

Results are however based on standards (coloured books): it may be only used as a comparative tool for licensing, land use planning

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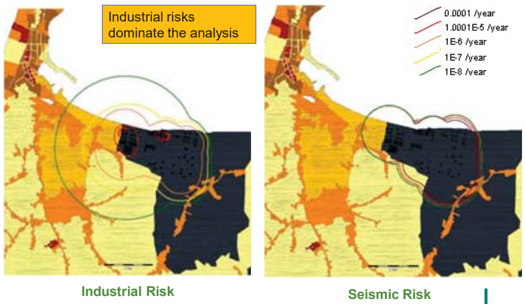
Results



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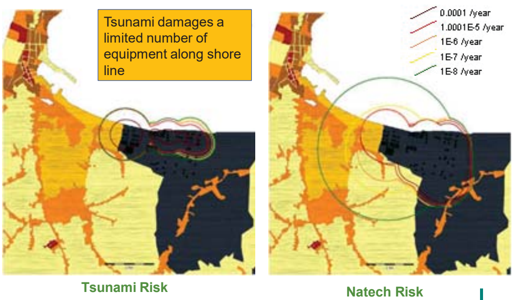
Results



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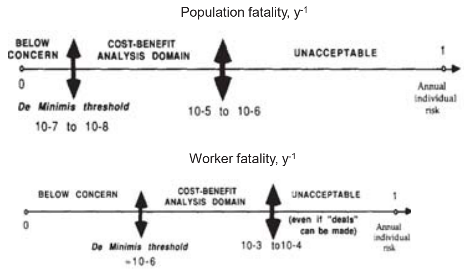
Results



Paté-Cornell, Structural Safety, 13, 145-157 (1994)

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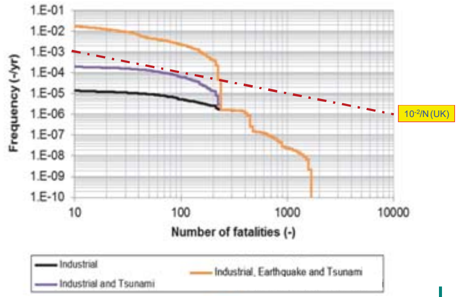
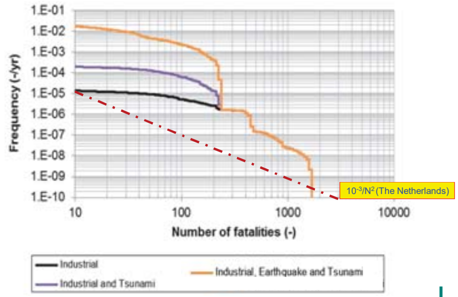
Results



Results



Conclusions

- Existing NaTech guidelines and standards concern the Return-to-Service or Serviceability Limit States (as in Hazus)
- New vulnerability functions are needed, Loss of Content being the dipendent variable
- Natech risks may weight even more than industrial-related risks, particularly for oil&gas and chemical industry
- Detailed Natech analysis needs multi-disciplinary expertise
- Acceptability criteria are the nub of the problem for industrial and NaTech risks
- For some natural disasters, early warning may be essential: emergency plan can be operating well before the occurrence of the event

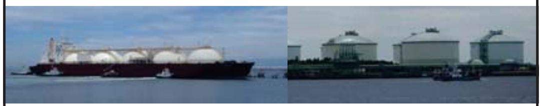
Conclusions

Thank you for your attention!

ernesto.salzano@unibo.it

Oil and gas releases during large earthquakes and tsunami

- A research initiative of Osaka University for disaster prevention in petrochemical complex -



Shin-ichi AOKI & Naomi KATO, Osaka University

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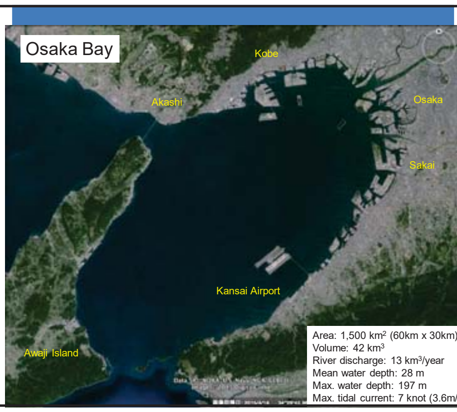
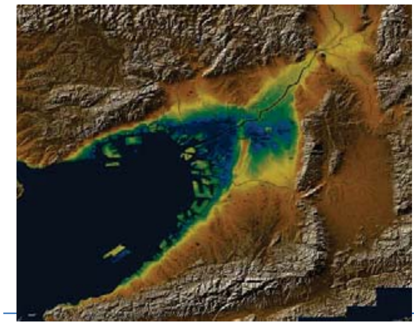


Area: 1,500 km² (60km x 30km)
Volume: 42 km³
River discharge: 13 km³/year
Mean water depth: 28 m
Max. water depth: 197 m
Max. tidal current: 7 knot (3.6m/s)

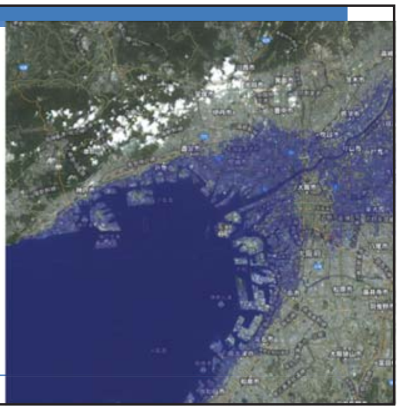
2

Topography around Osaka Bay



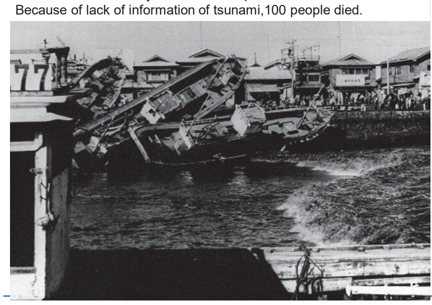
3

Inundation area in Osaka due to 5m sea level rise (w/o sea walls)



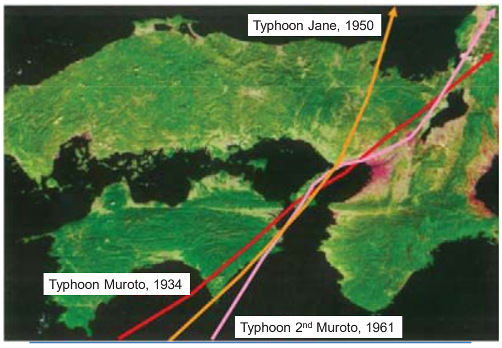
Chilean Tsunami (1960)

Tsunami came one day after the earthquake in Chili.
Because of lack of information of tsunami,100 people died.

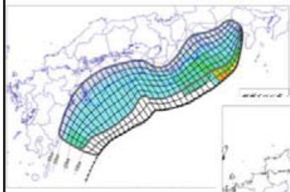


Historical Disasters by Storm Surge

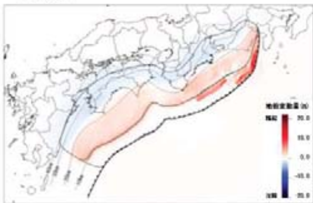
Year	Name	Location	People lost	Departure (cm)
1934. 9	Muroto	Osaka	3,036	310
1945. 9	Makurazaki	Kyushu	3,122	160
1950. 9	Jane	Osaka	534	270
1953. 9	No. 13	Ise	393	240
1959. 9	Isewan	Ise	5,098	345
1961. 9	2nd Muroto	Osaka	200	241
1970. 8	No. 10	Kochi	13	235
1991. 8	No. 19	Suo-Nada	4	310
1999. 9	No. 18	Ariake	16	180
2004. 8 10	No. 16 No. 23	Seto Kochi	45 3	134 (Kobe) 253 (Kochi)



11 cases of fault models which are supposed to be critical

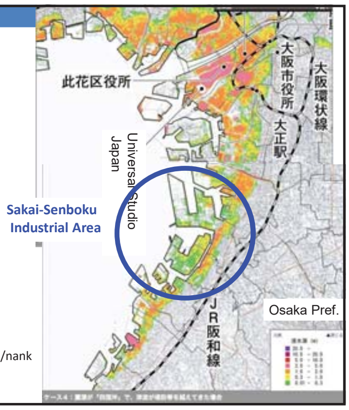


Fault model of Case-6



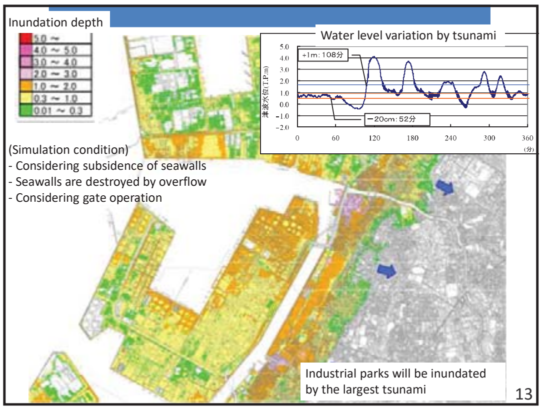
Initial rise of sea bottom of Case-6
(for simulation of tsunami propagation)

Maximum inundation depth (Case-4, high tide)



http://www.asahi.com/special/nankai_trough/

Possibility of Industrial disaster



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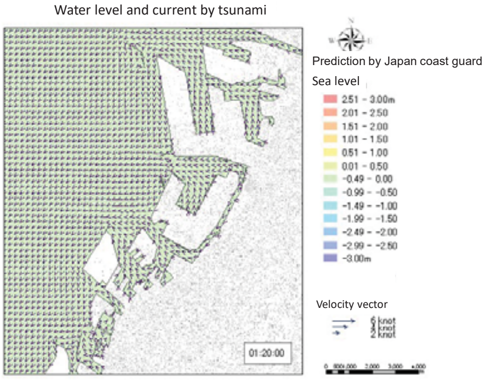
Water level and current by tsunami



Research Initiative for Disaster Prevention of Petrochemical Complex

Outbreak: Study on mechanism and model development
- Simulation of sloshing and evaluation of oil spill
- Hydrodynamic force on a tank and its failure mechanism
- Modeling fire and explosion of oil in a tank or sea surface

Inland Propagation

Offshore Propagation

Propagation: Study on process and integrated model
- Simulation of tsunami and diffusion of spilt oil
- Radiation of heat and hazardous materials
- Simulation of ship evacuation, drift, collision

Countermeasures (sea area)
- Tsunami reduction by flexible pipes
- Protection by water curtain
- Usage of dispersing agent
- Information system for spilt oil

Countermeasures (land area)
- Blocking tsunami by earth fill
- Protection by water curtain
- Prevention against failure of a tank
- Risk communication with residents

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Method of Research

- Numerical simulation using some mathematical models and CFD
  → validation of the model
- Laboratory experiments for scaled models
  → similarity, scale effect

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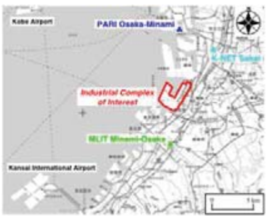
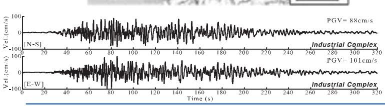
Oil spill from a storage tank by sloshing using MPS

Target area





Velocity waveform used in calculation

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Simulation of oil spill by sloshing in a storage tank

Diameter (m)	Sinkage of floating roof	Amount of overflow (kl)	Number of tanks in the industrial complex	Subtotal of amount of overflow (kl)
30 (15-44)	Yes	6.2	205	1,271
50 (45-64)	Yes	75.6	28	2,117
70 (65-84)	Yes	801.3	29	23,238
Total of outflow amount of oil from the industrial complex				**26,626**

Estimate of total oil spill in an industrial park

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Laboratory experiments on hydrodynamic forces by tsunami entering a harbor

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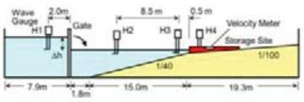
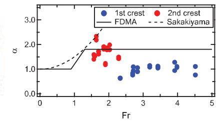
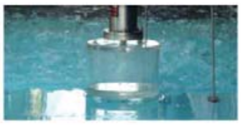
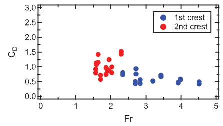
2D Experiments on a tsunami wave force acting on a tank





Inundation coef. vs. Froude number





Drag coef. vs. Froude number

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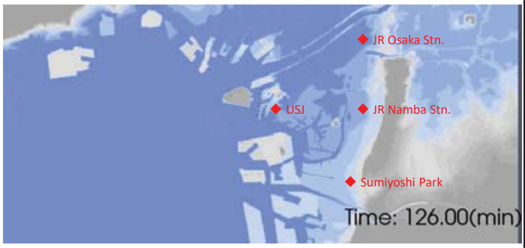
Numerical simulation of tsunami propagation and dispersion of spilt oil

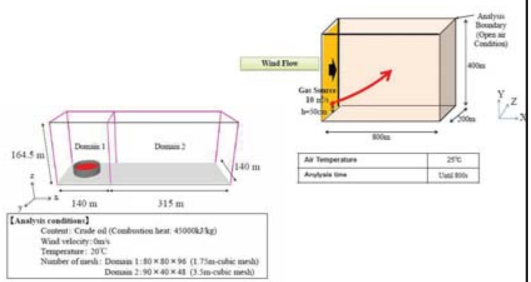
Sakai-Senboku Area

Numerical simulation of tsunami propagation and dispersion of spilt oil

Osaka Port



Numerical simulation of heat radiation and gas diffusion from a tank



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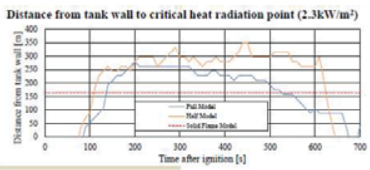
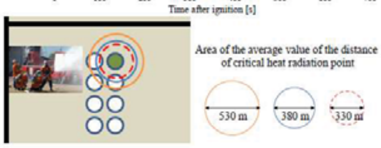
Numerical simulation of heat radiation and gas diffusion from a tank





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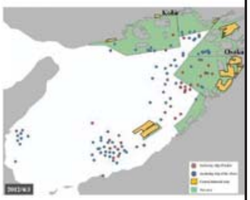
Analysis of ship behavior by AIS data

AIS: Automatic Identification System

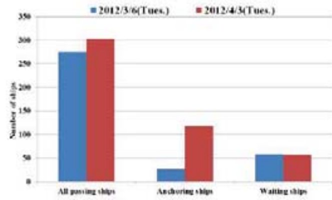


Waiting ships moored in Osaka Bay

Evacuation behavior of ships under tsunami

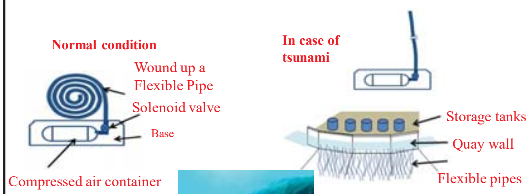
Analysis of ship behavior by AIS data

Target area: Osaka Bay
Date of investigation :
03/06/2012: no wind
04/03/2012: wind speed > 20m/s

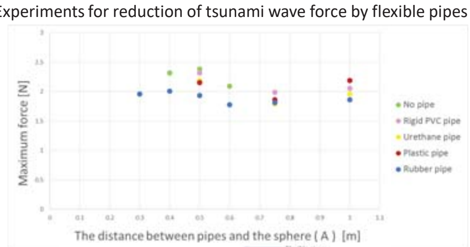


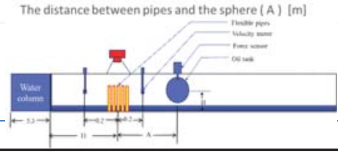
Ship condition around the industrial park

Reduction of tsunami energy by flexible pipes

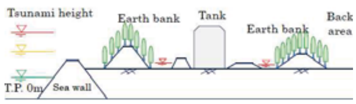


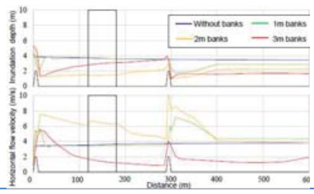
Experiments for reduction of tsunami wave force by flexible pipes





Blocking tsunami by an earth bank





Outreach activities

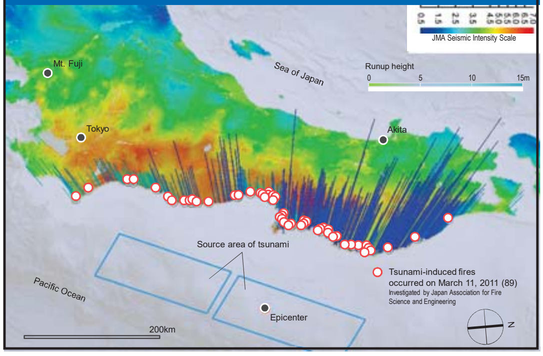
Exchange of opinions with residents near the industrial park

Development of simulation tool for fire spread on floating oil in tsunamis

Tomoaki NISHINO (Building Research Institute)

Tsunami-induced fires in the 2011 Earthquake

2



Tsunami-induced fires in the 2011 Earthquake

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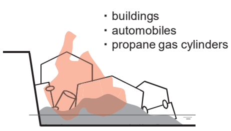
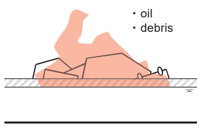
- 89 ignitions occurred in tsunami inundation areas on March 11.
- Some of fires developed to large outdoor fires spreading 67ha.

[A] Land type (accumulating combustibles)



・Yamada (17ha)
・Otsuchi (12ha)
・Ishinomaki Kadowaki (6ha)

[B] Marine type (floating combustibles)



・Kesennuma bay
(Details of fire spread are not clear)

Problems

4

- Some fires spread to tsunami refuge buildings and high grounds.
- Measures against tsunami-induced fires are not sufficient.
- There is no method for predicting tsunami-induced fires.

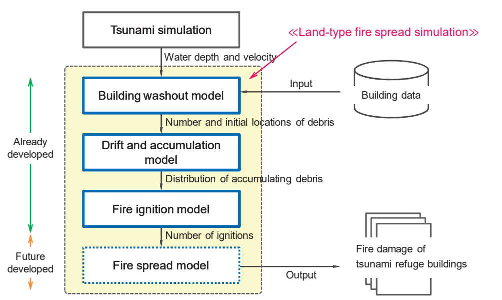

Tsunami refuge building damaged by land type fires (taken by one of the authors)


Marine type fires around the tsunami refuge building (provided by Ryosuke Onodera)

Previous development

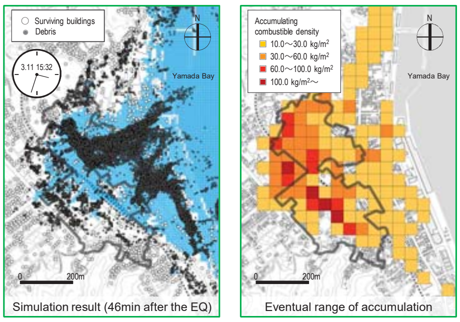
5

JSPS Grant-in-Aid for Young Scientists (A), FY2015-FY2017



Validation of drift and accumulation model

6



Simulation result (46min after the EQ) | Eventual range of accumulation

Nishino et al., Fire Technology, 2016

Validation of fire ignition model

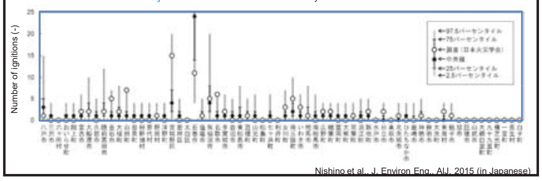
7

- Statistical model based on the ignition record in the 2011 Tsunami.
- Explanatory variables related to the spill amount of combustibles.

$$p(y_i|\lambda_i) = \frac{\lambda_i^{y_i} exp(-\lambda_i)}{y_i!}$$

$$\lambda_i = exp(-\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + r_i)$$

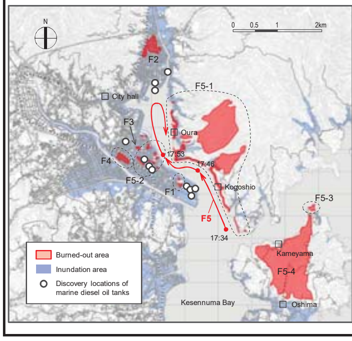
x_1 : number of automobiles carried away by tsunamis
x_2 : number of gas-cylinder use households carried away by tsunamis
x_3 : area of industrial zones inundated by tsunamis



Nishino et al., J. Environ Eng., AIJ, 2015 (in Japanese)

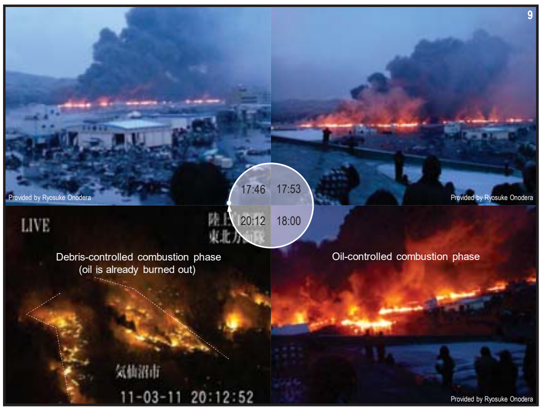
Fire damage in Kesennuma

8



F1
: Building fire (0.2ha)
F2
: Land-type tsunami-induced fire (10.2ha)
F3
: Land-type tsunami-induced fire (0.5ha)
F4
: Land-type tsunami-induced fire (3.6ha)
F5
: Marine-type tsunami-induced fire (-)
F5-1
: Forest fire (114.1ha)
- Marine type F5 spread to the forest.
F5-2
: Building fire (1.2ha)
- Marine type F5 spread to the building.
F5-3
: Ship fire (-)
- Marine type F5 spread to the ship.
F5-4
: Forest fire (117.0ha)
- Marine type F5 spread to the forest.

9



Consideration

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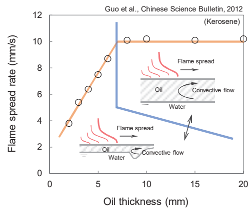
- Fire front moved 2km on Kesennuma Bay in 20min (1.7m/s).
- Water velocity in tsunamis is 1-10m/s.
- Flame spread rate over oil floating on water is up to 10mm/s.



Hypothesis

Marine-type tsunami-induced fire is regarded as the phenomenon that burning oils ignite surrounding oils in the process of being transported by tsunamis (not simple flame spread on liquid fuel).

Fire spread model on floating oil in tsunamis

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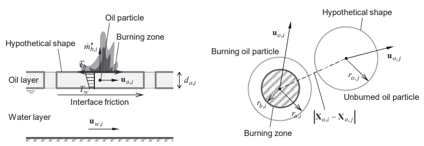
- Fires on the sea is an assembly of burning floating oil particles.
- Locations of individual particles are predicted in time series.
- Combustions of individual particles are predicted in time series.
- Overall burning zone is tracked.
- 14 assumptions are made in the model.



Assumptions

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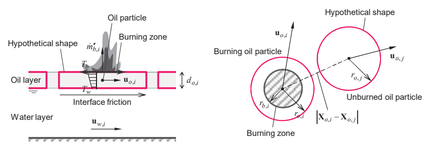
(1) Tsunami inundation flow is already known.
(2) Locations, time and rate of oil spills are already known.
(3) Oil floats on the water (oil and water are clearly separated).
(4) Oil is an assembly of disc-like particles with uniform thickness.
(5) Thickness and radius change depending on the density of particles.

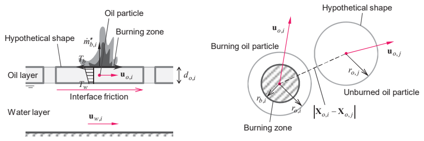


Assumptions

(6) Oil particles travel horizontally due to the interface friction and the turbulence in water flow.

$$\mathbf{X}_{o,i} = \mathbf{X}^{I}_{o,i} + \int_{t_i}^{t} \mathbf{u}_{o,i} dt + \sum_{k=m_i}^{m} \sqrt{24\boldsymbol{\kappa}_i \Delta t}\left(\xi_i - \frac{1}{2}\right)$$

$$m_{o,i}\frac{\partial \mathbf{u}_{o,i}}{\partial t} = C_f \rho_{o,i} A_{o,i}(\mathbf{u}_{w,i} - \mathbf{u}_{o,i})|\mathbf{u}_{w,i} - \mathbf{u}_{o,i}|$$



Assumptions

(7) Locations and time of first ignition is already known.

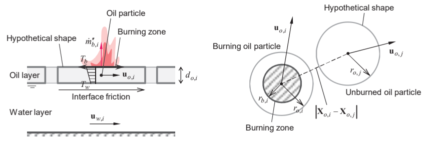
(8) Combustion continues when thickness is not smaller than 1mm.

(9) Mass loss rate due to combustion depends on the heat balance at the oil surface.

Radiation from flames   Heat loss to water

$$\rho_{o,i}\frac{\partial V_{o,i}}{\partial t} = -\pi r_b^2 \left[\frac{\sigma T_f^4 - k_o(T_b - T_w)/d_{o,i}}{c(T_b - T_0) + L_v}\right]$$

Heat of vaporization



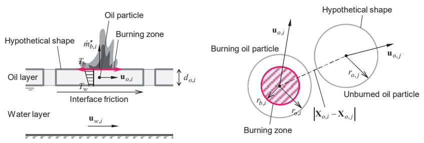
Assumptions

(10) Burning zones of particles spread in axial symmetry.

(11) Spread rate of burning zones depends on the thickness.

$$\frac{\partial r_{b,i}}{\partial t} = \begin{cases} 0 & (d_{o,i} < 0.001) \\ 1.2 d_{o,i} + 0.0016 & (0.001 \le d_{o,i} < 0.007) \\ 0.01 & (0.007 \le d_{o,i}) \end{cases}$$

The experimental data is approximated.
(Guo et al., Chinese Science Bulletin, 2012)



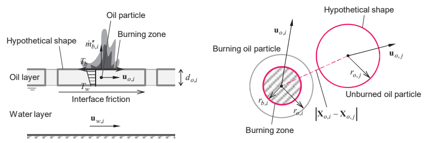
Assumptions

(12) Fire spread between particles occurs when burning zones contact with unburned particles.

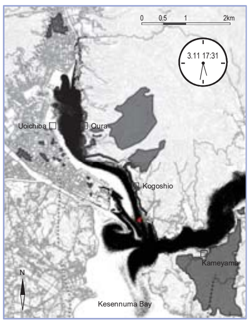
$$|\mathbf{X}_{o,i} - \mathbf{X}_{o,j}| \le r_{b,i} + r_{o,j} \quad and \quad d_{o,i} \ge 0.001 \quad and \quad d_{o,j} \ge 0.001$$

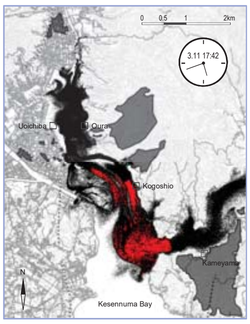
(13) Wind effect on the combustion is ignored.

(14) Emulsification is ignored.



Numerical analysis





Numerical conditions

Item		Settings
Simulation time		6h (2011.3.11 14:46-20:46)
Tsunami	Time increment	0.1s
	Mesh width	10m
	Fault model	Fujii et al., 2011
Oil (marine diesel)	Time increment	0.6s
	Initial volume of particles	0.001m³
	Number of particles	7,532,000 (=7,532kL) *
	Density of particles	814kg/m³
	Friction coefficient	0.006 (Lau et al., 1979)
	Spill locations	11 discovery points of tanks *
	Spill rate	0.2m³/s (convenient assumption)
	Start time of spills	50min after the earthquake

* Fire Departments of Kesennuma and Motoyosi, 2012 (in Japanese)

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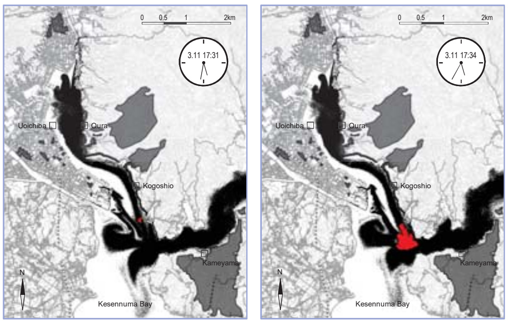
Numerical results



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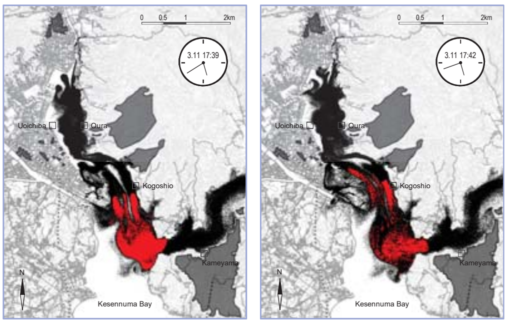
Numerical results



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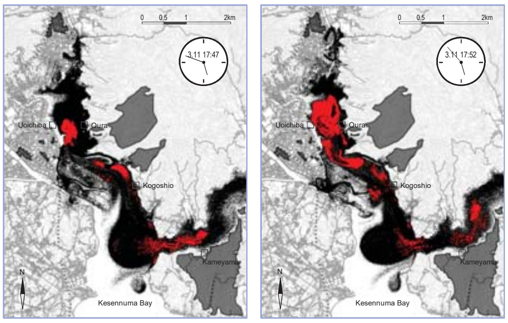
Numerical results



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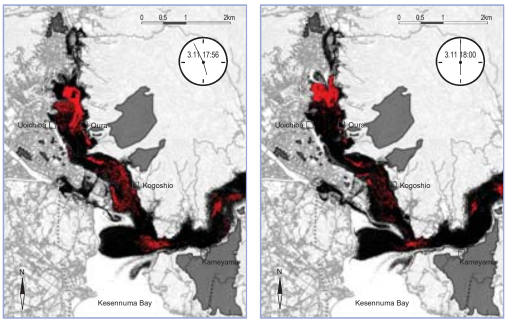
Numerical results



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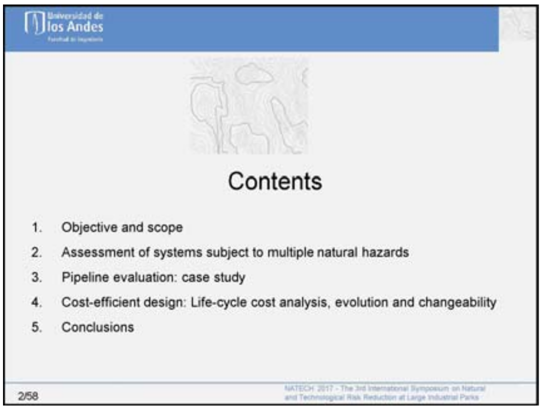
Summary

- Modeling of fire spread on floating oil in tsunamis.
- Numerical analysis of tsunami-induced fire spread in Kesennuma.
- Qualitative trend of fire spread was well predicted.

- Future challenges
  - Model extension including the combustion of floating debris.
  - Radiation and plume modeling
  - Fire risk assessment of ports in future tsunami.


Universidad de los Andes
Facultad de Ingeniería
Modelig the complexity of risk management in pipelines
F. Muñoz & M. Sanchez-Silva
Department of Chemical Engineering &
Department of Civil and Environmental Engineering
School of Engineering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2. Assessment of systems subject to multiple natural hazards
3. Pipeline evaluation: case study
4. Cost-efficient design: Life-cycle cost analysis, evolution and changeability
5. Conclusions
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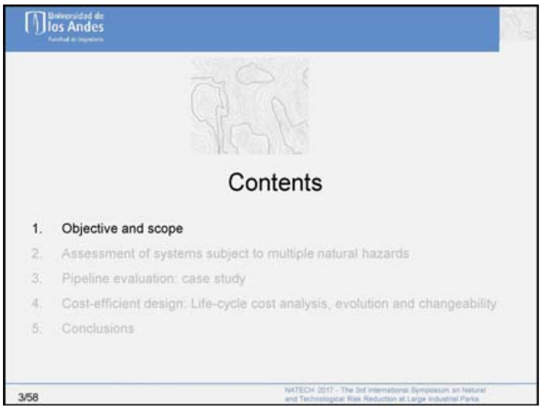
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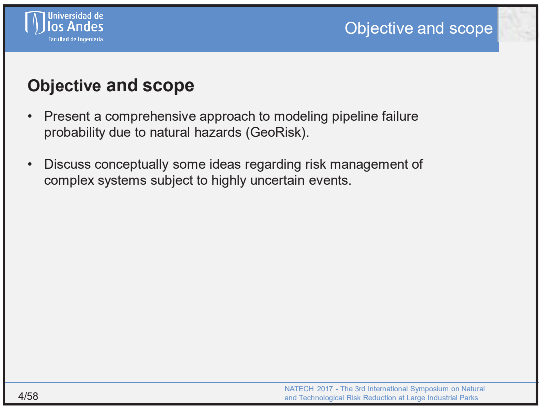
Universidad de los Andes
Objective and scope
Objective and scope
• Present a comprehensive approach to modeling pipeline failure probability due to natural hazards (GeoRisk).
• Discuss conceptually some ideas regarding risk management of complex systems subject to highly uncertain events.
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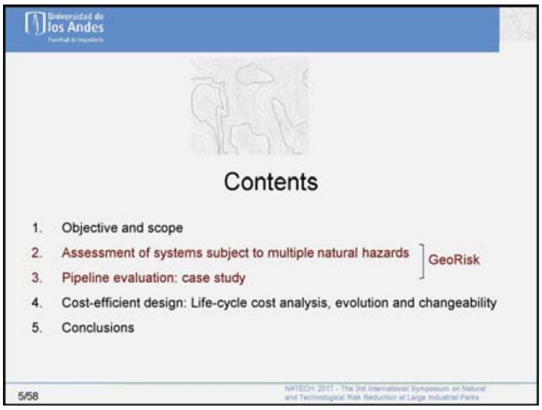
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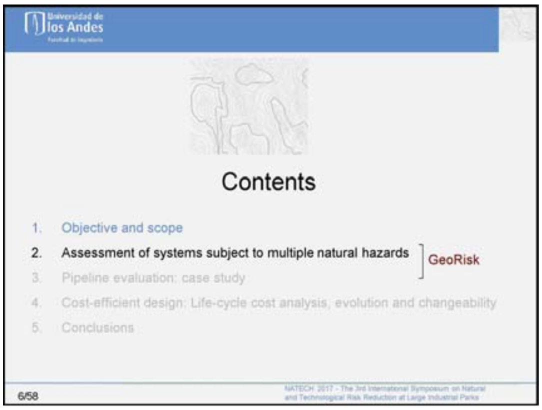
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Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

Dimensionality of events & decision criteria

Definition of the decision space: $\Omega = \{\mathcal{V}, \mathcal{D}, \mathcal{M}\}$

- Definition of the state variables (space):
  $\mathcal{V} = \{n, t, s\}$
- Managing problem complexity:
  - Nature and scope of the decision
    $\mathcal{D} = \{d_1, d_2, \cdots, d_m\}$
  - Precision and relevance of the model
    $\mathcal{M} = f(X_1, X_2, \cdots, X_k)$

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Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

Dimensionality of events

Definition of the state variables $\{n, t, s\}$

Physical nature of event, *n*.

Antropic:
- Deficient operation
- Poor maintenance
- Terrorist atacks…

Natural origin:
- Seismic events (Peak Ground acceleration/displacement/velocity)
- Flooding (Water level and flow rate)
- Landslides (volume and mass displaced)
- Volcanic activity (seismic activity, piroclastic flux, emissions)…

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Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

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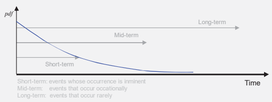
- Landslides (volume and mass displaced)
- Volcanic activity (seismic activity, piroclastic flux, emissions)…

Temporal dimensionality, *t*.

Long-term (events that occur rarely):
- Large magnitude earthquakes
- Volcanic activity

Mid-term (occational events):
- Flooding
- Landslides

Local (inmminent or high frequent events):
- Temperature variations
- Changes in the environment



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Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

Dimensionality of events

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- Volcanic activity

Mid-term (occational events):
- Flooding
- Landslides

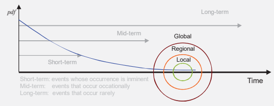
Local (inmminent or high frequent events):
- Temperature variations
- Changes in the environment

Size and spatial dimensionality, *s*.

Global (cover a large area):
- Seismic events
- Troppical storms and hurricanes

Regional (localized within a well defined area):
- Flooding
- Landslides (volume and mass displaced)

Local:
- Subsidence
- Structural failure



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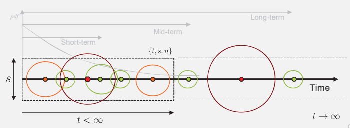
Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

Dimensionality & decision criteria

Definition of state variables (space) $\{n, t, s\}$

The scope of every study is defined within a space $\{t, s, n\}$ such that
$t \in \mathcal{T}; \quad s \in \mathcal{S}; \quad \text{and} \quad n \in \mathcal{N}$

$\mathcal{T}$: Time dimensionality
$\mathcal{S}$; Space dimensionality
$\mathcal{N}$; Nature of the event



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Universidad de los Andes, Facultad de Ingeniería — Approach to modeling multiple hazards

Dimensionality of events & decision criteria

- Definition of the state variables (space) $\{t, s, n\}$
- Managing problem complexity

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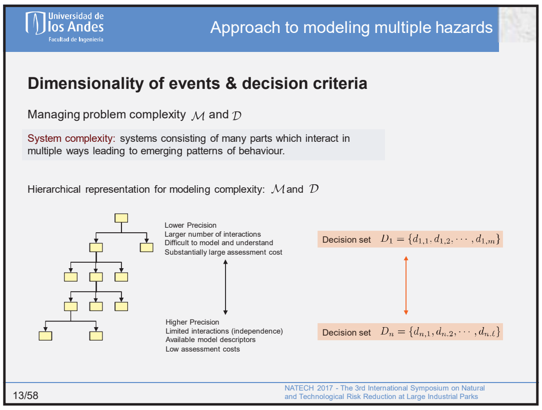
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Approach to modeling multiple hazards
Dimensionality of events & decision criteria
Managing problem complexity $\mathcal{M}$ and $\mathcal{D}$
System complexity: systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.
Hierarchical representation for modeling complexity: $\mathcal{M}$ and $\mathcal{D}$
Lower Precision
Larger number of interactions
Difficult to model and understand
Substantially large assessment cost
Higher Precision
Limited interactions (independence)
Available model descriptors
Low assessment costs
Decision set $D_1 = \{d_{1,1}, d_{1,2}, \cdots, d_{1,m}\}$
Decision set $D_n = \{d_{n,1}, d_{n,2}, \cdots, d_{n,\ell}\}$
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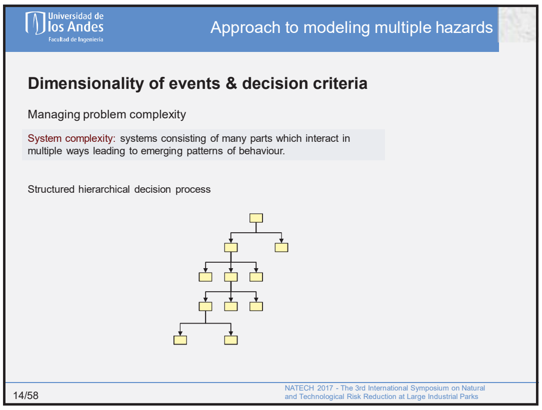
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Approach to modeling multiple hazards
Dimensionality of events & decision criteria
Managing problem complexity
System complexity: systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.
Structured hierarchical decision process
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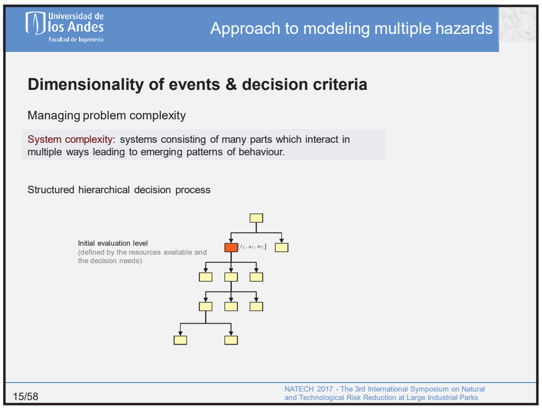
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Approach to modeling multiple hazards
Dimensionality of events & decision criteria
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System complexity: systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.
Structured hierarchical decision process
Initial evaluation level
(defined by the resources available and the decision needs)
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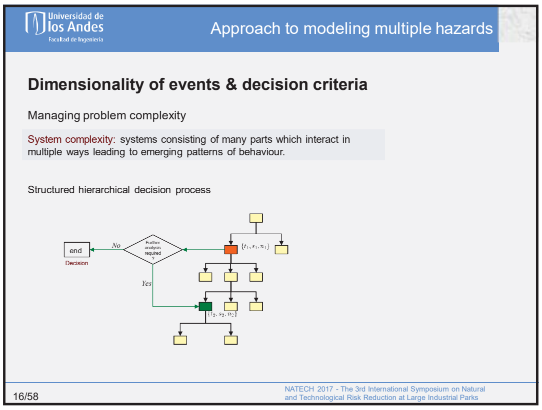
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Approach to modeling multiple hazards
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Managing problem complexity
System complexity: systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.
Structured hierarchical decision process
end
Decision
No
Yes
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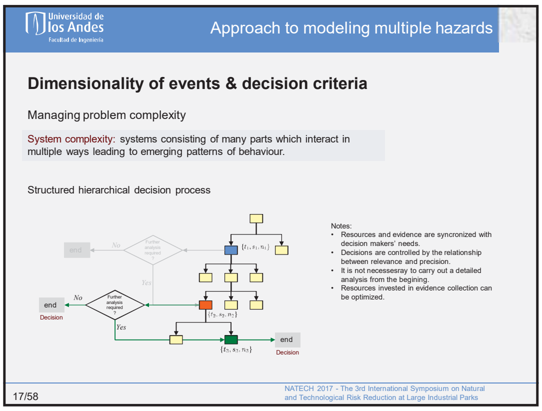
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Approach to modeling multiple hazards
Dimensionality of events & decision criteria
Managing problem complexity
System complexity: systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.
Structured hierarchical decision process
Notes:
• Resources and evidence are syncronized with decision makers' needs.
• Decisions are controlled by the relationship between relevance and precision.
• It is not necessesray to carry out a detailed analysis from the begining.
• Resources invested in evidence collection can be optimized.
end
Decision
No
Yes
end
Decision
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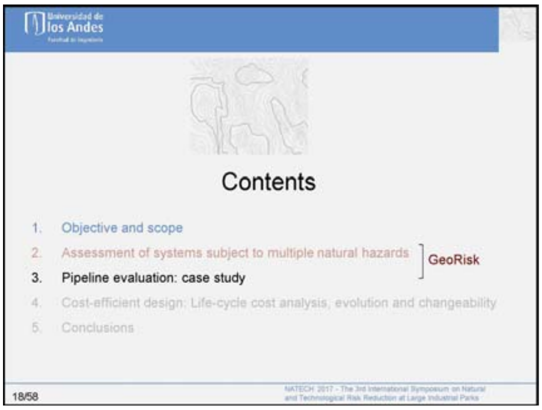
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Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards (GeoRisk).

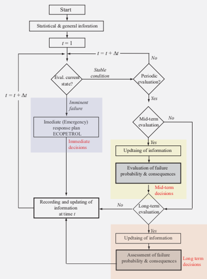
Project funded by ECOPETROL (Colombian Oil Company)

Main Research team:
Asc. Professor Felipe Muñoz, PhD
Asc. Professor Nicolás Estrada, PhD
Asc. Professor Luis A. Camacho, PhD
Professor Bernanrdo Caicedo, PhD
Professor Mauricio Sánchez-Silva, PhD

Local Experts:
Professor Manuel García Universidad Nacional de Colombia
Professor Jaime I. Ordoñez, Universidad Nacional de Colombia

International Experts:
Professor KK Phoon (NUS-Singapore)
Professor Joaquim Casal (UPB- Barcelona, Spain)
Professor Emeritus Willy Alvarenga (Federal University of Rio de Janeiro)

Overall evaluation strategy



Notes:
- all three analysis are associated to different decision needs;
- the tools requiered in every case may be different;
- their evaluation does not occur necessarely at the same time.
- …

Dimensionality of events & decision criteria

Pipeline evaluation model and case study

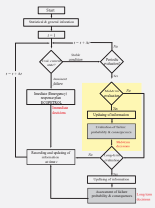
	immediate evaluation	periodic evaluation	sporadic evaluations
Time span	Short-term	Mid-term	Long-term
	days	*months*	*years*
Examples	Pipe failure	Potential landslide	Erosion
	Active landslide	Local scour	Climate change
	Existing flooding		Seismic activity
			Volcanic activity
Nature and scope of decision	Decisions focused on emergency response.	Decisions based on approximate physical models.	Long term strategic decisions.
Consequences	Direct (immediate) costs Brand impact	Impact on system operation; and stable state revenew.	Ctastrophic damage High impact/low probability

Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards.

Decision & evaluation space $\{n, t, s\}$

1. Nature of the event (n) – Landslides; i.e., soil mass movement that might cause a break-up of the pipeline.
   (scour and flooding were also studied)
2. Time window (t) – events observed within a five-year period;
3. Spatial characterization (s):
   - sector Medellín-Cartago (Col), length: 240 km
   - localized landslide events controlled by variations in the climatic conditions.



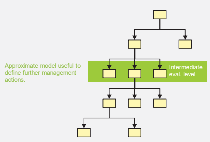
Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards.

Structured hierarchical decision process

1. Decisions to be made: $\mathcal{D}$
   i) identify critical regions;
   ii) preliminary estimative of failure probability;
   iii) define inspection needs; and
   iv) define further evaluation requirements.

1. The analysis is limited to landslides and scour problems (inhere we present only the landslide model). $\mathcal{M}$



Pipeline evaluation model and case study

Required information:

1. Topography.
2. Geotechnical information.
3. Hydrology.
4. Pipeline information.

Analysis and results:

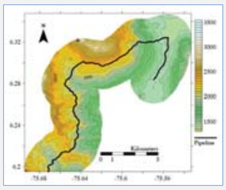
1. Landslide probability
2. Pipeline failure probability

Pipeline evaluation: case study

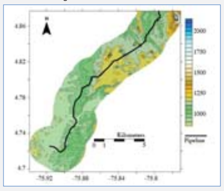
Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.

40 km - Medellín



40 km - Cartago



Pipeline evaluation: case study

Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.
2. Geotechnical information: spatial distribution, thickness, soil type mechanical and hydraulic properties.

Definition of the soil type from a set of specified points

Pipeline evaluation: case study

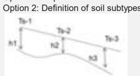
Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.
2. Geotechnical information: spatial distribution, thickness, soil type mechanical and hydraulic properties.

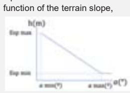
Soil thickness alternative models:

Option 1: Map of soil thickness

Option 2: Definition of soil subtypes



Opción 3: Calculate the soil thickness as a function of the terrain slope,



Pipeline evaluation: case study

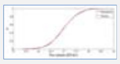
Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.
2. Geotechnical information: spatial distribution, thickness, soil type mechanical and hydraulic properties.

Mechanical and hydraulic properties:

- Cohesion: c (kPa)
- Internal friction angle: ϕ (°)
- Hydraulic conductivity: T (m^2/h)
- Rate of change of the conductivity with depth: m (-)
- Initial storage in the roots zone: S_{r0} (m)
- Maximum storage in the roots zone: S_{rmax} (m)
- Speed of water through the main channel: V_r (m/h)

The mechanical and hydraulic parameters can be specified as constant values or as probability distributions.



Pipeline evaluation: case study

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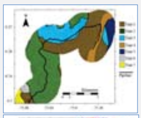
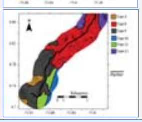




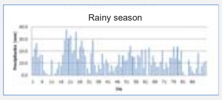
Unit	μ_γ (KN/m³)	COV %	μ_c (KPa)	COV %	μ_ϕ (°)	COV %	h_{max} (m)
1	17	2	15	20	30	10	20
2	19	5	25	15	32.5	10	20
3	18.5	5	15	15	30	10	15
4	17	2	15	20	30	10	20
5	19	5	25	15	32.5	10	20
6	18.5	5	15	15	30	10	15
7	19	5	25	15	32.5	10	20
8	17	4	7.5	20	20	5	15
9	17	4	7.5	20	20	5	15
10	19	5	12.5	15	30	10	12
11	19	5	25	15	32.5	10	20
12	19	5	25	15	32.5	10	20

Pipeline evaluation: case study

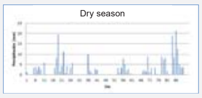
Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.
2. Geotechnical information: spatial distribution, thickness, soil type mechanical and hydraulic properties.
3. Hydrology: Dairy rain records for rainy, average, and dry seasons, and probability transition matrix between these seasons.

Rainy season



Dry season



Transition probability matrix: probability of moving from one season to another (defined based on historic records)

$$T = \begin{bmatrix} p_{1,1} & p_{1,2} & p_{1,3} \\ p_{2,1} & p_{2,2} & p_{2,3} \\ p_{3,1} & p_{3,2} & p_{3,3} \end{bmatrix}$$

The analysis was carried out for a period of 5 years during whicha train of alternative rainy and dry conditions were combined according to the transition probability matrix.

The water table depth is calculated using the semi-distributed hydrology-topography model (Topmodel).

(Beven, 2001; Romanowiczet al., 1993, 1994; Beven et al., 1995).

Pipeline evaluation: case study

Pipeline evaluation model and case study

1. Topography: Set of spacial positions of the nodes.
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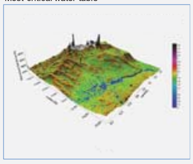
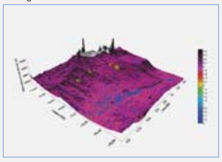
Most critical water table



Average water table



Pipeline evaluation: case study

Pipeline evaluation model and case study

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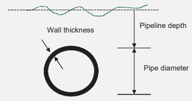
2. Geotechnical information: spatial distribution, thickness, soil type mechanical and hydraulic properties.
3. Hydrology: Dairy rain records for rainy, average, and dry seasons, and probability transition matrix between these seasons.
4. Pipeline information: depth of burial, diameter, wall thickness, material, etc.

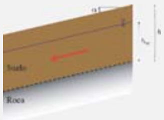


Pipeline evaluation: case study

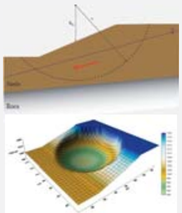
Analysis & results

Computing the probability of landslide

1. Planar failure surface: stability analysis performed for every node.



2. Rotational failure surface: stability analysis performed for for nodes whose thickness is above a certain threshold.

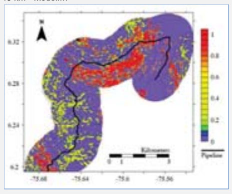


Pipeline evaluation: case study

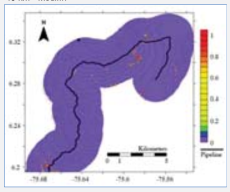
Analysis & results

Computing the probability of landslide

Heavy rainfall scenario
40 km - Medellín



Dry scenario
40 km - Medellín



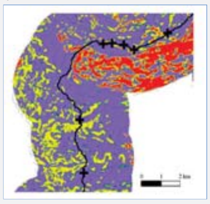
Pipeline evaluation: case study

Analysis and results

Computing the probability of landslide

Heavy rainfall scenario – correspondance with observed landslides

40 km - Medellín

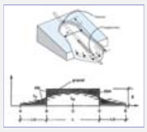


Pipeline evaluation: case study

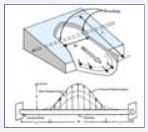
Analysis and results

Pipeline failure probability

1. Transversal alignment



2. Longitudinal alignment



Maximum strains applied:
(O'Rourke 1997)

$$\epsilon_t = \frac{F_t D_d^2}{3\pi t E D_t^2} \qquad \epsilon_l = \frac{F_l D_d}{2\pi t E D_t}$$

Maximum possible strain:

$$\epsilon_{max} = \epsilon_t |\sin\theta| + \epsilon_l |\cos\theta|$$

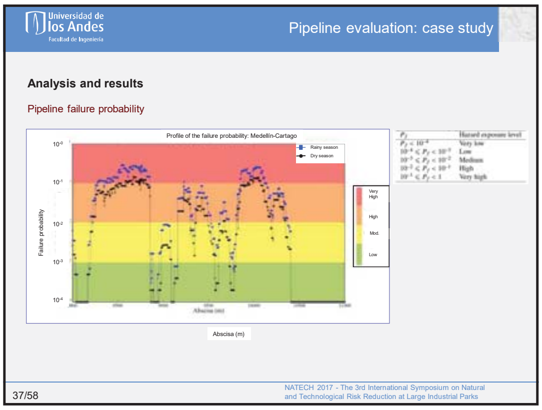
where:

- F_l or F_t : force per unit length (transverse or longitudinal
- D_d is the landslide diameter,
- t is the pipeline wall thickness,
- E is its Young modulus and D_t is its diameter.
- θ is the angular difference between between the orienta of the landslide and that of the pipeline.

Strain capacity in *tension*: $\epsilon_y = \frac{\sigma_y}{E}$

Strain capacity in *compresion*: $\epsilon_y = \frac{0,175 t}{D_t/2}$

Failure occurs when: $\epsilon_y - \epsilon_{max} < 0$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Pipeline evaluation: case study
Analysis and results
Pipeline failure probability
Profile of the failure probability: Medellín-Cartago
Rainy season
Dry season
Failure probability
Abscisa (m)
Very High
High
Mod.
Low
Hazard exposure level
Very low
Low
Medium
High
Very high
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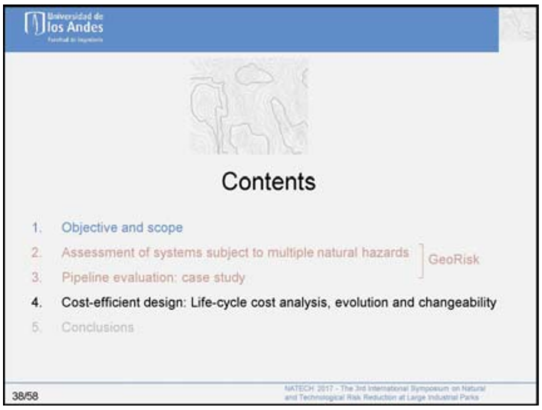
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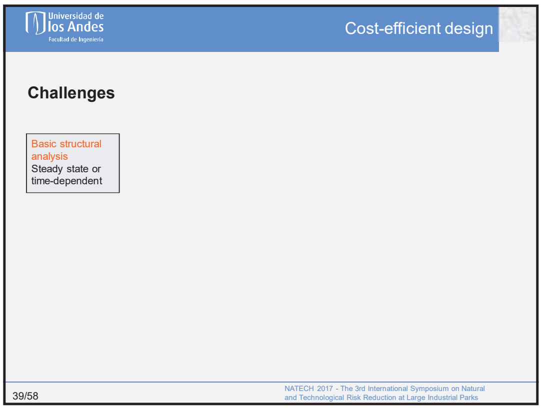
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Cost-efficient design
Challenges
Basic structural analysis
Steady state or time-dependent
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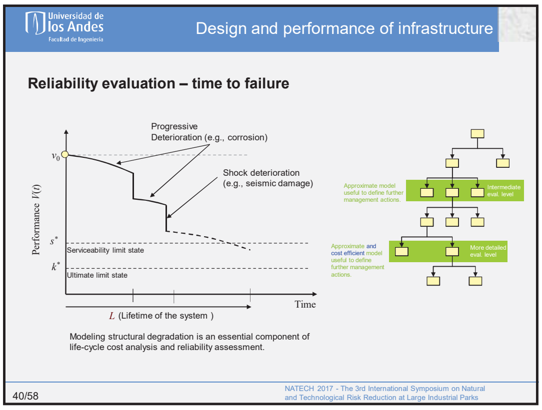
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Design and performance of infrastructure
Reliability evaluation – time to failure
Progressive Deterioration (e.g., corrosion)
Shock deterioration (e.g., seismic damage)
Performance V(t)
Serviceability limit state
Ultimate limit state
Time
L (Lifetime of the system)
Approximate model useful to define further management actions.
Intermediate eval. level
More detailed eval. level
Modeling structural degradation is an essential component of life-cycle cost analysis and reliability assessment.
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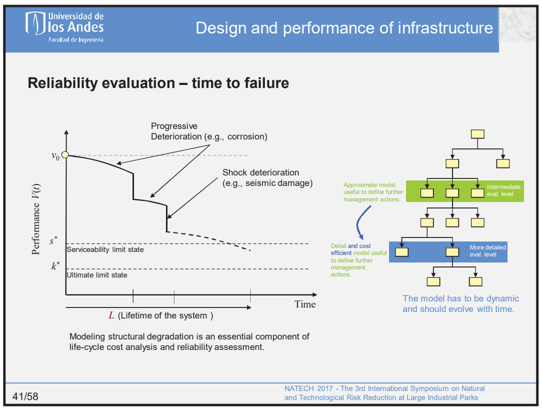
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Design and performance of infrastructure
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Progressive Deterioration (e.g., corrosion)
Shock deterioration (e.g., seismic damage)
Performance V(t)
Serviceability limit state
Ultimate limit state
Time
L (Lifetime of the system)
Approximate model useful to define further management actions.
Intermediate eval. level
More detailed eval. level
The model has to be dynamic and should evolve with time.
Modeling structural degradation is an essential component of life-cycle cost analysis and reliability assessment.
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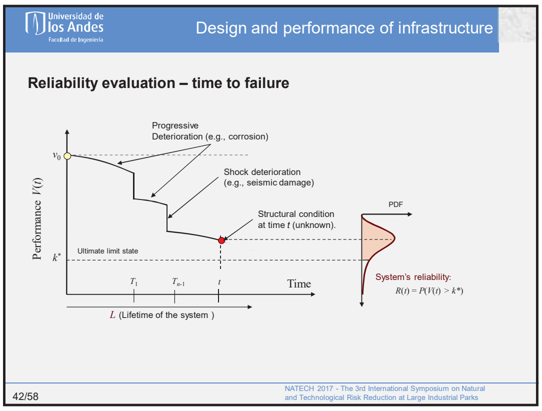
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Design and performance of infrastructure
Reliability evaluation – time to failure
Progressive Deterioration (e.g., corrosion)
Shock deterioration (e.g., seismic damage)
Structural condition at time t (unknown).
PDF
Performance V(t)
Ultimate limit state
Time
L (Lifetime of the system)
System's reliability:
R(t) = P(V(t) > k*)
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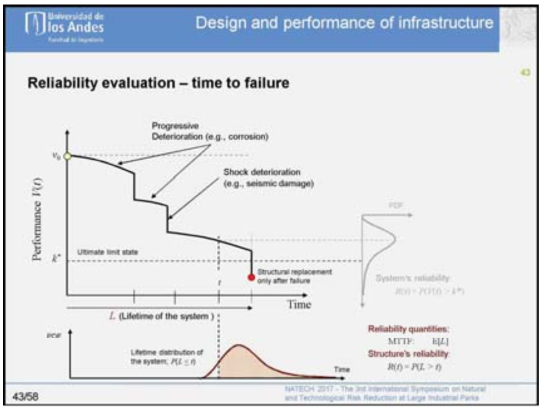
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Design and performance of infrastructure
Reliability evaluation – time to failure
Progressive Deterioration (e.g., corrosion)
Shock deterioration (e.g., seismic damage)
Performance V(t)
Ultimate limit state
Structural replacement only after failure
Time
L (Lifetime of the system)
Lifetime distribution of the system; P(L ≤ t)
Reliability quantities:
MTTF: E[L]
Structure's reliability:
R(t) = P(L > t)
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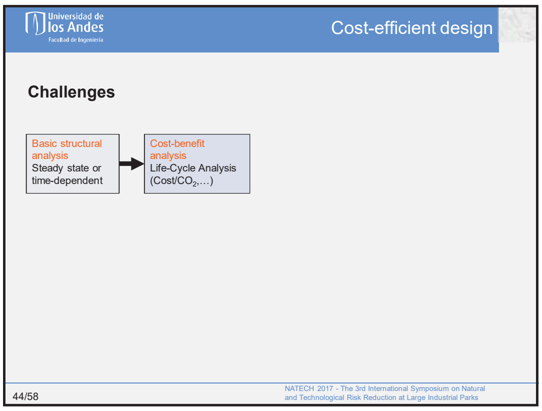
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Cost-efficient design
Challenges
Basic structural analysis
Steady state or time-dependent
Cost-benefit analysis
Life-Cycle Analysis
(Cost/CO2,…)
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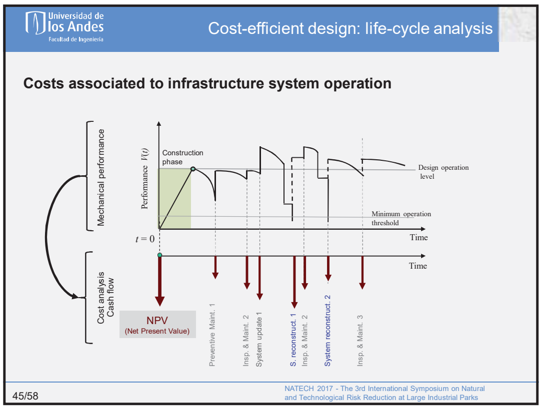
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Cost-efficient design: life-cycle analysis
Costs associated to infrastructure system operation
Mechanical performance
Cost analysis
Cash flow
Performance V(t)
Construction phase
Design operation level
Minimum operation threshold
t = 0
Time
Time
NPV
(Net Present Value)
Preventive Maint. 1
Insp. & Maint. 2
System update 1
S. reconstruct. 1
Insp. & Maint. 2
System reconstruct. 2
Insp. & Maint. 3
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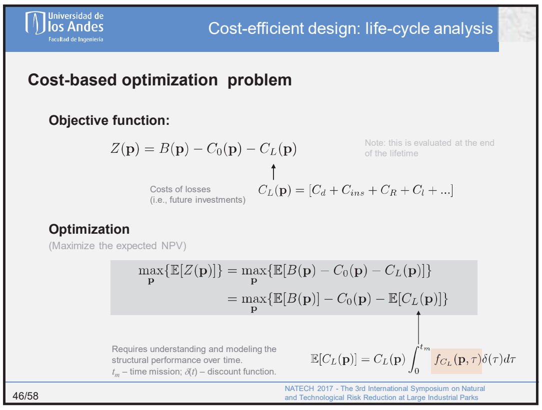
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Cost-efficient design: life-cycle analysis
Cost-based optimization problem
Objective function:
$Z(\mathbf{p}) = B(\mathbf{p}) - C_0(\mathbf{p}) - C_L(\mathbf{p})$
Note: this is evaluated at the end of the lifetime
Costs of losses
(i.e., future investments)
$C_L(\mathbf{p}) = [C_d + C_{ins} + C_R + C_l + ...]$
Optimization
(Maximize the expected NPV)
$\max_{\mathbf{p}}\{\mathbb{E}[Z(\mathbf{p})]\} = \max_{\mathbf{p}}\{\mathbb{E}[B(\mathbf{p}) - C_0(\mathbf{p}) - C_L(\mathbf{p})]\}$
$= \max_{\mathbf{p}}\{\mathbb{E}[B(\mathbf{p})] - C_0(\mathbf{p}) - \mathbb{E}[C_L(\mathbf{p})]\}$
Requires understanding and modeling the structural performance over time.
t_m – time mission; $\delta(t)$ – discount function.
$\mathbb{E}[C_L(\mathbf{p})] = C_L(\mathbf{p}) \int_0^{t_m} f_{C_L}(\mathbf{p}, \tau)\delta(\tau)d\tau$
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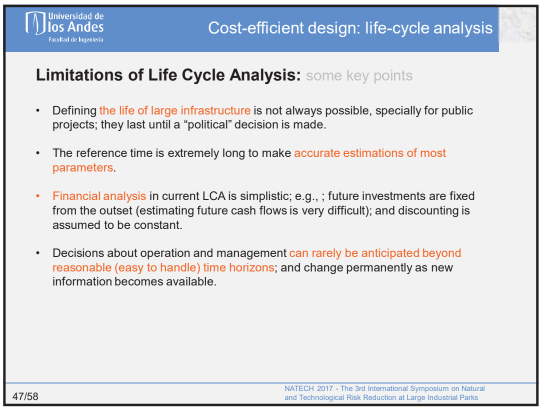
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Cost-efficient design: life-cycle analysis
Limitations of Life Cycle Analysis: some key points
• Defining the life of large infrastructure is not always possible, specially for public projects; they last until a "political" decision is made.
• The reference time is extremely long to make accurate estimations of most parameters.
• Financial analysis in current LCA is simplistic; e.g., ; future investments are fixed from the outset (estimating future cash flows is very difficult); and discounting is assumed to be constant.
• Decisions about operation and management can rarely be anticipated beyond reasonable (easy to handle) time horizons; and change permanently as new information becomes available.
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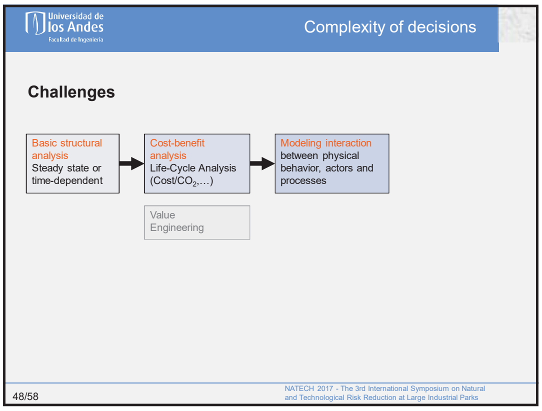
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Complexity of decisions
Challenges
Basic structural analysis
Steady state or time-dependent
Cost-benefit analysis
Life-Cycle Analysis
(Cost/CO2,…)
Modeling interaction between physical behavior, actors and processes
Value Engineering
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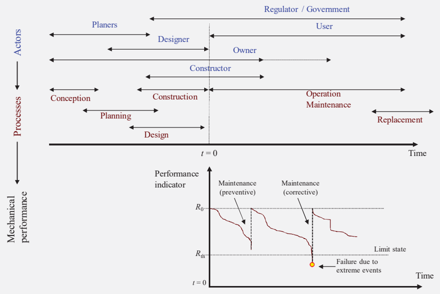
Complexity of decisions

Complexity of infrastructure management



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Complexity of decisions

Important aspects in modeling the complexity of interactions

(ideas for discussion)

i) Decisions on infrastructure operation are made based on a combination of short, mid and long term reference time frames.

i) There are many actors whose decisions, cannot be anticipated.

ii) Maintaining and providing value to the system depends highly on the perception and interests of stakeholders.

iii) Large engineering projects need to be modeled as multi-objective problems where different dimensions and metrics need to be evaluated simultaneously.

iv) ....

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Complexity of decisions

Challenges

Basic structural analysis Steady state or time-dependent → Cost-benefit analysis Life-Cycle Analysis (Cost/CO_2,...) → Modeling interactions between physical behavior, actors and processes → Flexibility, adaptation and evolution to handle unforeseen events

Value Engineering

Future design and operation

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Evolution of Design and LCA models

Key terms related to changeability

Concept	Definition	Ref.
Changeability	the ability to change, alter, or modify the system configuration with or without external influence after the system has been put in operation (deployed).	[18, 43]
Redesign	the process of evaluating and updating the system characteristics regularly to meet the changes in the demand or the environment.	[18, 34]
Adaptability	the system's ability to reconfigure itself after it has been put in operation (deployed), without external intervention.	[21, 43]
Flexibility	the system's ability (physically or managerially) to cope with uncertainty and change once it is in operation.	[44, 47, 52]
Resilience	the ability of a system to overcome undesirable events to continue operating with an acceptable (required) level of performance.	[6, 32]
Robustness	the ability of a system to withstand events without being damaged to a level that is disproportionate to the original cause.	[12, 14].

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Complexity of decisions

Adaptability/flexibility: a perspective from Biology

- Live beings have survived for millions of years despite their limited mid and long term capacity for making predictions.
- Live beings can manage unplanned events and challenges depending only on their flexibility and ability to modify its structure.
- Adaptability (i.e., evolution) is designed to be in-effective in a short run (i.e. introducing mutations very often will only take you out of the current-local optimality);
- Evolution is effective in a long-run (explores the solution space and allows for the features that will be helpful if the environment changes). Note that adaptability of species occurs mostly across and not within generations.

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Complexity of decisions

Adaptability/flexibility within the engineering context

Adaptability/flexibility will include new objectives in the design and operation of engineering systems; for instance, it will aim at (for discussion):

1. Differing unnecessary initial provisions, with the respective costs; thus, reducing the uncertainty associated to decisions;
2. Having the flexibility (physical and managerial) required to cope with unknown scenarios more effectively.
1. Avoiding the concept of optimality in the traditional sense; aiming only at best decisions (adding or preserving value) with the information available at every decision point.
2. Modifying its structure and management strategies based on the experiences and knowledge acquired over time.
3. ...

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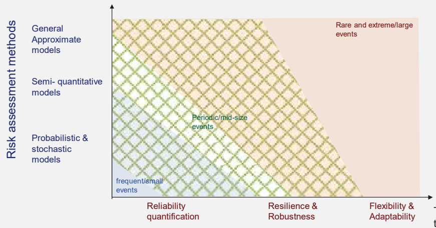
Cost-efficient design: life-cycle analysis

Criteria and tools for risk management in context



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Conclusions

Conclusions

1. GeoRisk is a tool that provides both a technical and conceptual framework to manage a diverse number of *Natech* problems.

1. The design and operation of industrial infrastructure goes beyond technical issues. It is not possible to build efficient infrastructure without a broader approach to the problem.

2. Any system (engineered or not) may not be able to fulfilling its purpose if it does not improve its ability to cope with new information (e.g., new demands), learn and improve its capabilities, and adapt its structure to be more efficient.

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Thanks!

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Pipeline evaluation: case study

Scope of event decisions

Temporal dimensionality

Description	time	Event	Approach
Frequent events	$t = 0$	$t \in \mathcal{T}_1$	Reliability based
Rare events		$t \in \{\mathcal{T}_2 \setminus \mathcal{T}_1\}$	Resilience/ Robustness
Extreme events	$t \to \infty$	$t \in \{\mathcal{T}_3 \setminus \mathcal{T}_2\}$	Flexibility/Adaptability

Mechanistic & prob. approach

↓

Stochastic & Managerial approach

Long-term $\mathcal{T}_3$
Mid-term $\mathcal{T}_2$
Short-term $\mathcal{T}_1$
Time

Radiation Measurement for Protection of Children in Fukushima

Takeshi Komino

General Secretary, CWS Japan
SG/Executive Committee, Asian Disaster Reduction and Response Network
Regional Steering Group, World Humanitarian Summit Asia
Co-Chair, Humanitarian Policy and Practice Advisory Group at ACT Alliance
Board Member, Core Humanitarian Standard
Secretariat, Japan CSO Coalition for DRR

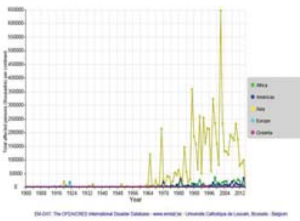
ADRRN | JCC-DRR Japan CSO Coalition for Disaster Risk Reduction | CWS JAPAN | actalliance

CWS Japan Operation Pillars

Disaster Trends

From UNISDR…

1. ***Downward trend in mortality risk*** due to enhanced capacities in early warning, preparedness and response.
2. ***Upward trend in economic loss and damage*** due to increase in exposure and vulnerability to natural hazards.
3. ***No sufficient attention, capacity and investment to address underlying risk drivers*** (unequal economic development, poorly managed urbanization, climate change)



Sendai Framework for DRR 2015-2030

- **<u>1.5 billion people</u>** were affected by disasters in various ways.
- At Technical Hazard working session at WCDRR, participants called for proactive risk assessment, and **<u>transparent disclosure of risks</u>**.
- Sendai Framework's priority of areas:
  - 1. Understanding disaster risk;
  - 2. Strengthening disaster risk governance to manage disaster risk;
  - 3. Investing in disaster risk reduction for resilience;
  - 4. Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.
- Clear focus on **<u>risk identification and mitigation</u>**.

Experience from Japan

- **<u>Nuclear power plant meltdown</u>** at Fukushima Daiichi Nuclear Power Plant
- **<u>Many lessons</u>** are drawn including:
  - Safety myth
  - Emergency evacuation
  - Information management
  - Critical infrastructure such as hospitals
- How are these lessons mitigating the **<u>future risks</u>**?

Sharing Lessons and Protecting the Vulnerable

Contamination Level

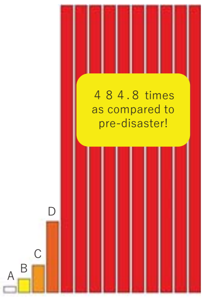
A　Air contamination level before the accident in Fukushima city　**0．0５ μSv/h**

B　International standard on exposure limit
１mSv/y＝0．１１４ μSv/h

C　Ministry of Environment's target after decontamination　**0．２３ μSv/h**
（１６ hours inside, 8 hours outside）

D　Designated high-radiation area
1.3mSv/3 months＝0．６μSv/h

E　The highest figure after the accident in the city
２４．２４ μSv/h

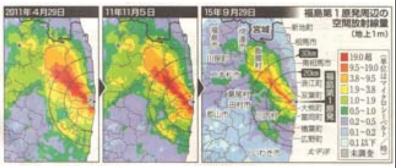


Decontamination in Fukushima City 2016.10

How Contamination is Measured

2,700 units placed in Fukushima prefecture
(in the city, 368 units)

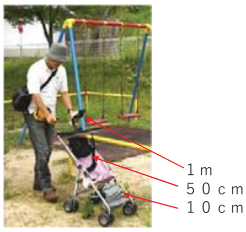
Does this help to protect the future generation?



Thinking about Well-being of Children

In 2014, Fukushima Prefecture saw limitation in promoting the health of children only with exercise inside (e.g. rise in obesity rate), so outside activities have started to be promoted.

Measurement for Protection of Children



Concrete roads – contaminated particles are washed away by rain, so lower figures

Lower than Ministry of Env. Standard 0.23 μ Sv/h

Soft-surfaced sidewalk – contaminated rain is soaked inside, thus higher figures

Higher than designated high-radiation area 0.60 μ Sv/h

It's not possible to use high-pressure decontamination for high contaminated rubber sidewalks.

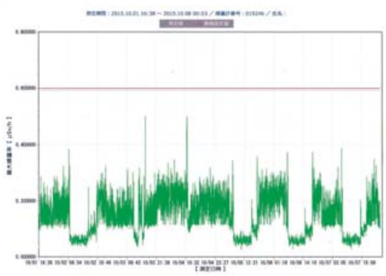
Measuring your Exposure

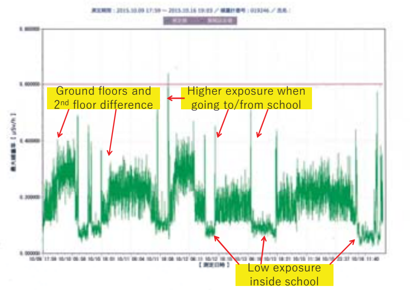
Glass Badge

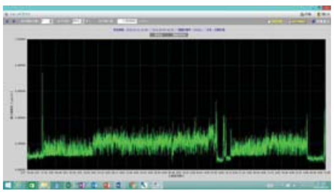
Local government lend to interested citizens. Then notifies accumulated exposure within 3 months period.

DOSE e NANO

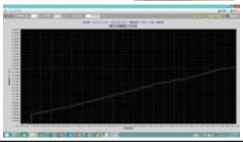
Provided by Shalom for interested citizens. Measured every minute, results are presented as accumulated figures in 6.25 days).







Decreasing exposure depends on accurate measurement！
↓
Average results don't give you any action tips…



Summary

- Many lessons – not political, it's linked to human lives
- Protection can only take place with human centered approach (limitation to one size fits all approach by the government)
- Protection by the people, for the people

Annex 4:

Number of Participants per Country

and Participant Affiliations

Country	No.	Participants	Affiliation
Afghanistan	1	Marina Hamidzada	DPRI
Bulgaria	1	Toma Stoyanov	Kyoto University
China	1	Liuyi Zhang	DPRI
Colombia	4	Jaime Pacheco	First Secretary of the Colombian Embassy in Japan
		Felipe Muñoz	Universidad de los Andes
		Mauricio Sánchez	Universidad de los Andes
		María Camila Suarez Paba	DPRI
Egypt	2	Ahmed Ibrahim	Kyoto University
		Mohamed Abdel	DPRI
Germany	1	Uta Reichardt	DPRI
India	1	Sandhya Babel	Thammasat University
Italy	4	Valerio Cozzani	Università di Bologna
		Ernesto Salzano	Università di Bologna
		Elizabeth Krausmann	Joint Research Center, European Commission
		Giuseppe Aliperti	DPRI
Japan	16	Kaoru Takara	DPRI
		Ana Maria Cruz	DPRI
		Shin-Ichi Aoki	Osaka University
		Naomi Kato	Osaka University
		Daniel Cardoso	Osaka University
		Tomoaki Nishino	Building Research Institute
		Takeshi Komino	CWS
		Hirokazu Tatano	DPRI
		Takashi Kumagai	DPRI
		Kazuyoshi Nishijima	DPRI
		Alexander Guzman	Ritsumeikan University
		Atsushi Aoyama	Ritsumeikan University
		Dewi Dimyati	Kyoto University
		Kaori Horikomi	DPRI
		Sasha Yoshioka	Kyoto University
		Hitomu Kotani	DPRI
Mexico	1	Irasema Alcantara-Ayala	National Autonomous University of Mexico (UNAM)
Philippines	1	Angelica Baylon	MAAP
South Korea	1	BonJun Koo	DPRI

This publication is the multi-perspective contributions and international experiences presented at Kyoto University, Uji Campus, in March 2017, within the framework of the Workshop on Tools for Natech Risk Management. The organizer of the workshop was the Disaster Prevention Research Institute (DPRI), Kyoto University.

WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

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