Mutual Joint Visit Workshop for Seveso Inspections on External Emergency Planning
Ravenna, 17 October 2024



16 ottobre 2024 Prefettura di Ravenna

17 ottobre 2024 Chemical Hub of Ravenna

18 ottobre 2024 Palazzo Rasponi dalle Teste www.comune.ra.it

Natech Risk Management in Complex Industrial Areas

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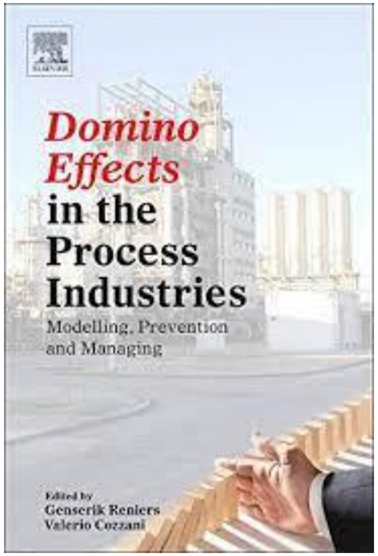
Presentation of the speaker

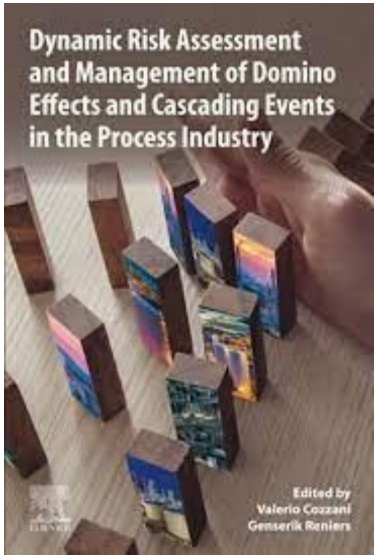
- Professor of Chemical Engineering at University of Bologna, Italy
- Ph.D. in Chemical Engineering
- Member of Italian National Committee for Civil Protection (Commissione Grandi Rischi)
- Deputy Member of Italian Central Technical Committee for Fire Prevention (Comitato Centrale Tecnico-Scientifico Prevenzione Incendi)
- Member of the Working Party on Loss Prevention in the Process Industry of the European Federation of Chemical Engineering
- Chair of the Technical Committee on Chemical and Process Industry of the European Safety and Reliability Association

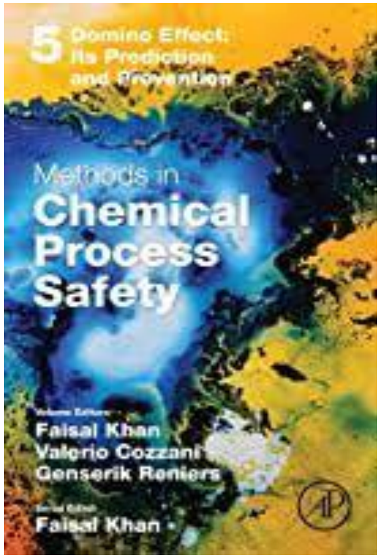
Presentation of the speaker

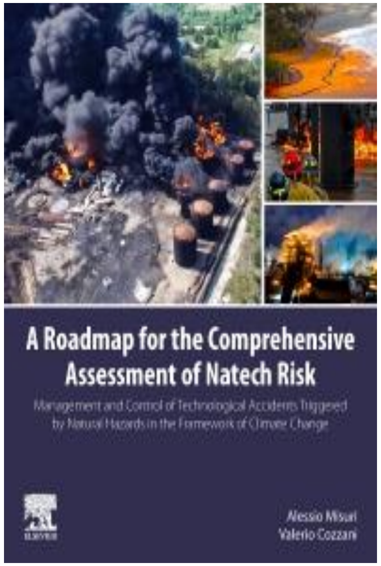
Authored books on Natech and Cascading Events:

- https://www.sciencedirect.com/book/9780444543233/domino-effects-in-the-process-industries
- https://www.sciencedirect.com/book/9780081028384/dynamic-risk-assessment-and-management-of-domino-effects-and-cascading-events-in-the-process-industry
- https://www.sciencedirect.com/bookseries/methods-in-chemical-process-safety/vol/5/suppl/C
- https://www.sciencedirect.com/book/9780443153907/a-roadmap-for-the-comprehensive-assessment-of-natech-risk









Outline

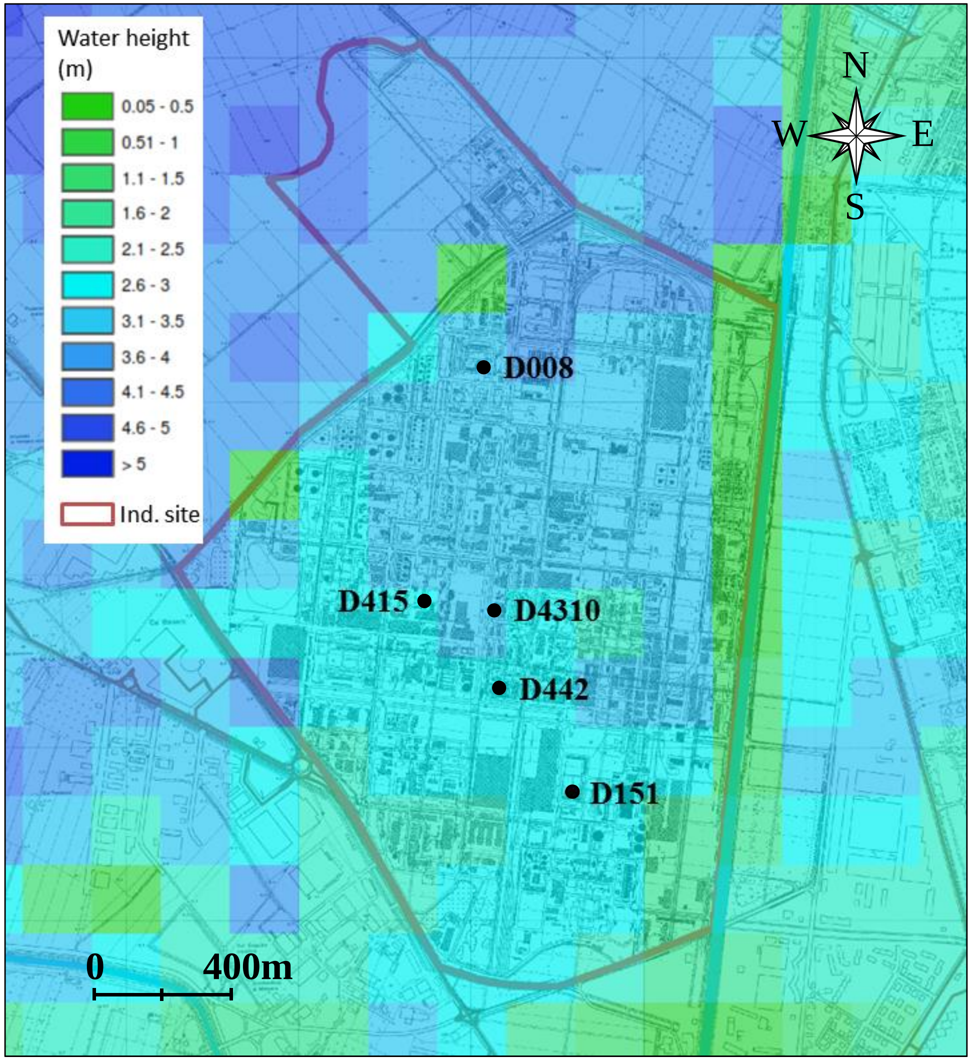
1. **Natech scenarios: a complex issue**
2. **The influence of Safety Barriers**
3. **Assessing Emergency response in complex Natech Scenarios**

Part 1 –
Natech scenarios: a complex issue

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)

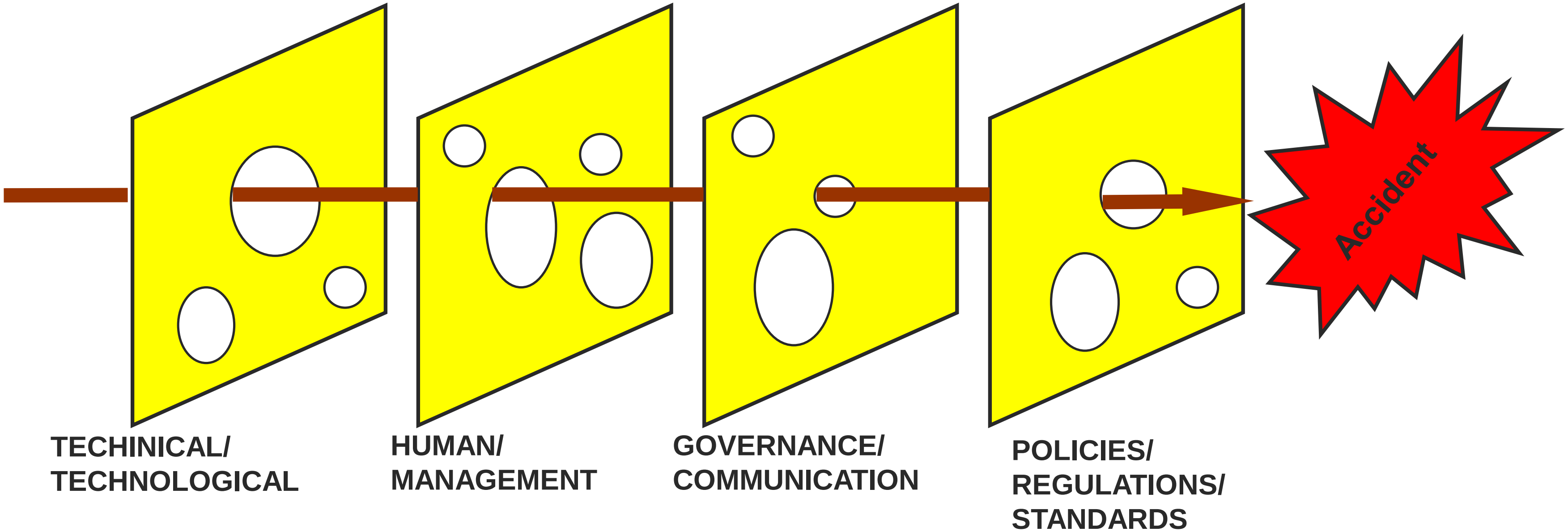
Complexity of impact vector



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

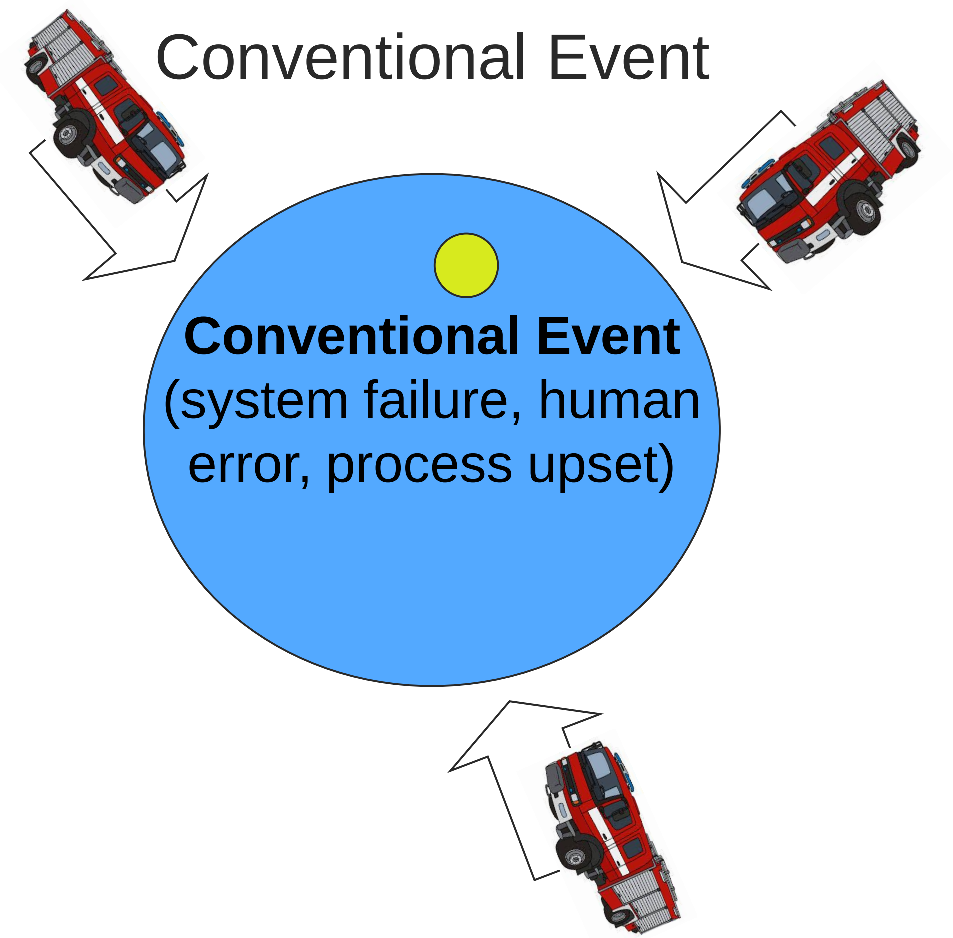
Complex Performance of Safety Barriers

- 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

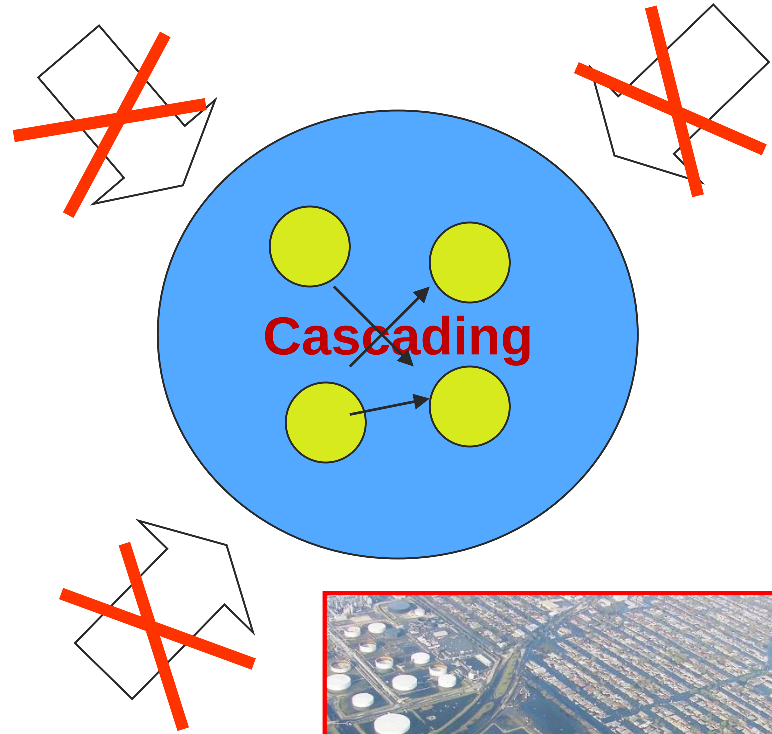


Complexity of Emergency Response

Conventional Event

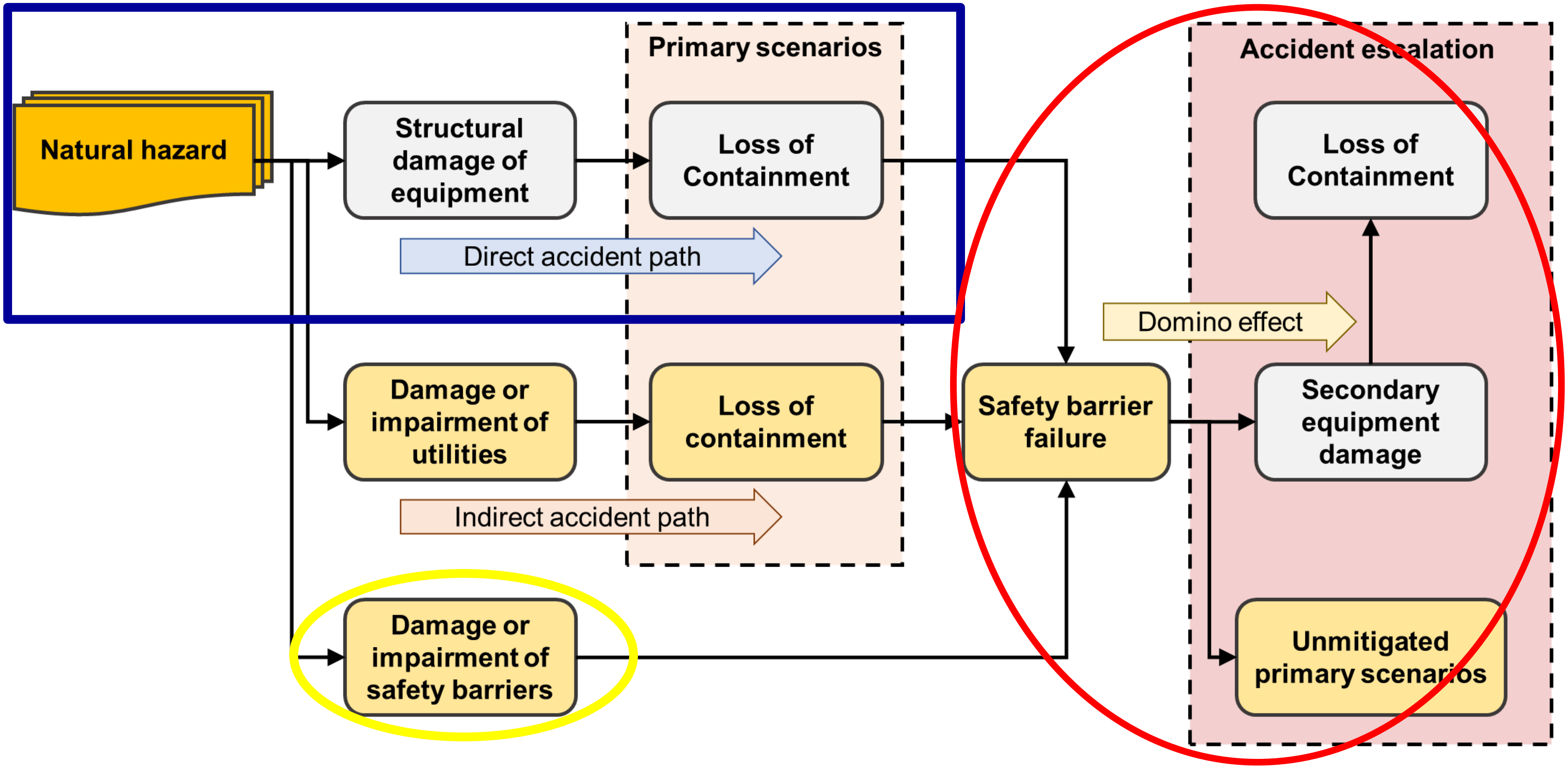


Cascading (Natech) Event



External emergency teams first response

Natech assessment: a complex task

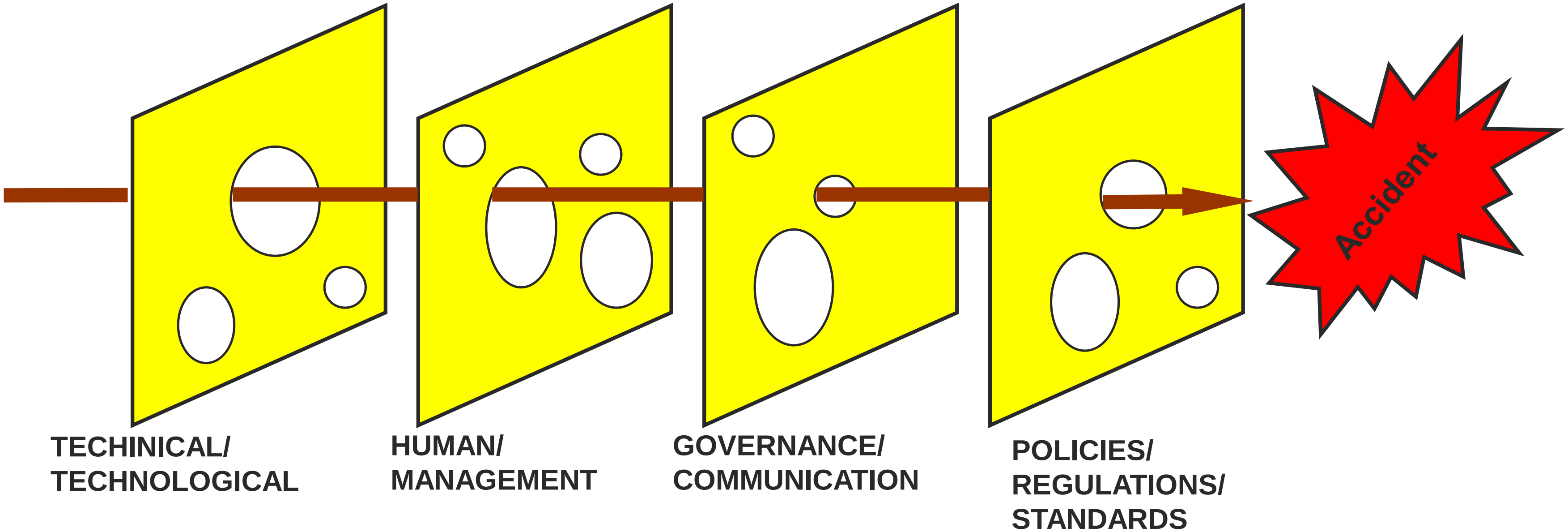


- Safety barrier impairment or degradation may cause both **unmitigated primary scenarios** and **unmitigated escalation scenarios**
- **Impairment or Degradation of First Response may contribute to accident escalation**

Part 2 –
The influence of Safety Barriers

Safety Barriers

- Safety barriers are applied as a standard measure to **prevent and mitigate** accidents, as well as to **support emergency management**
- Safety barriers may be affected as well by the natural event (common cause failure)
- **The possible degradation or failure of safety barriers needs to be taken into account in emergency planning**



Barrier failure in Natech events

Hurricane Harvey (Texas, 2017)

- About 100 chemical releases. **Power outage** was experienced in many cases. Massive release from shutdown and emergency flaring. (*Misuri et al., 2019*)*
- Arkema peroxide plant was flooded. **Power outage** interrupted the refrigeration units. **Inert gas system not available**. **Backup generators submerged.** Violent explosions. **Emergency intervention was hindered by floodwater**. *(CSB)*

Vltava River Flood (Czech Republic, 2002)

- Electrolysis plant was flooded. **Emergency retention sumps were flooded**. 80000t of chlorine were released in air and water. *(eMars)*

Hurricane Katrina (Louisiana, 2005)

- At Murphy Oil, one crude oil tank (95m diameter) was dislodged (*Godoy, 2007*), spilling more than 3000m3 of oil. **Containment dikes were submerged and damaged**. Part of oil spread in residential area. (*NOAA*)

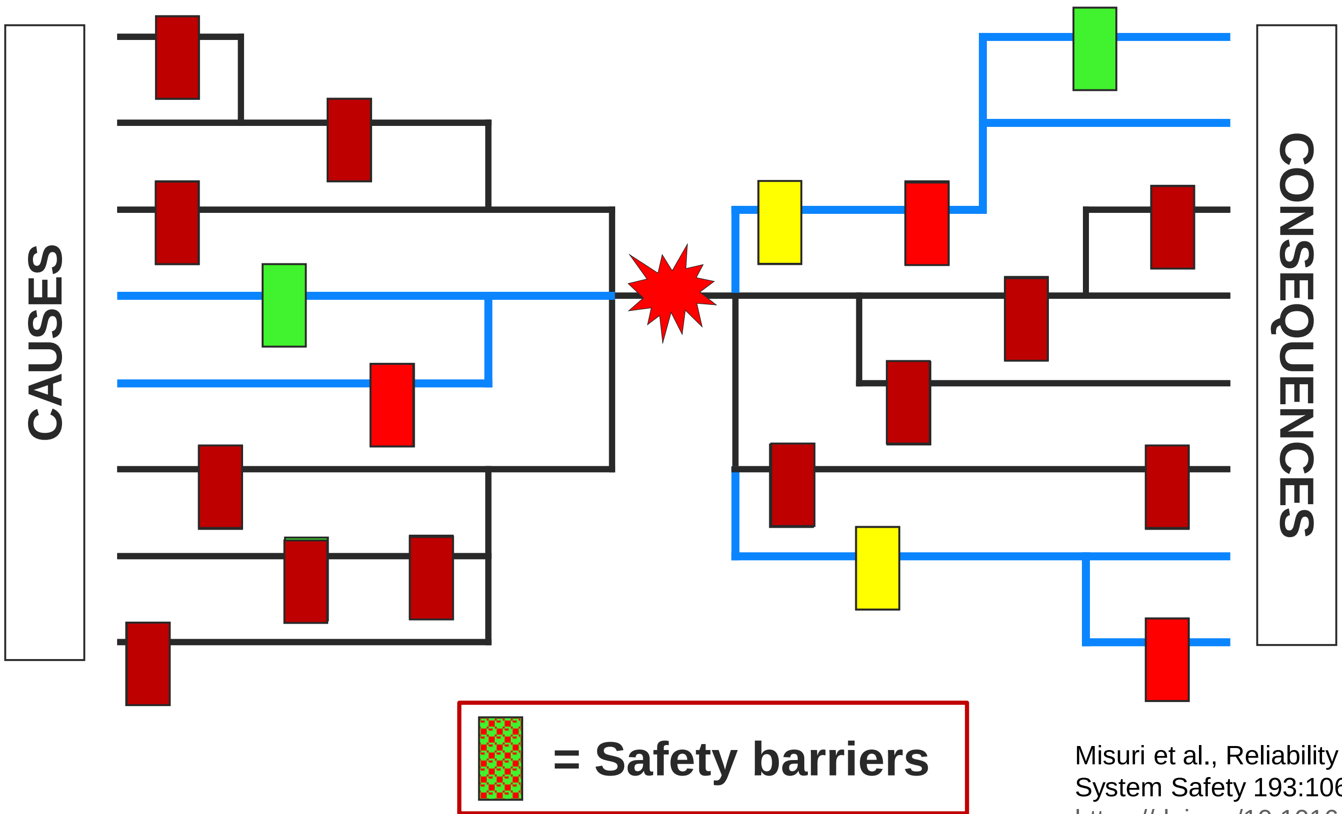
San Jacinto River Flood (Texas, 1994)

- During flooding, 8 hydrocarbon pipelines ruptured (other 29 were undermined), releasing LPG, gasoline, crude oil, diesel fuel and natural gas. Fire developed in multiple areas. 545 injuries by smoke. **Manual interruption valves were submerged**. **Operator intervention hampered**. *(NTSB)*

Misuri et al., Reliability Engineering and System Safety 193:106597 (2020)
https://doi.org/10.1016/j.ress.2019.106597

Barrier failure in Natech events

- The impact of natural hazards may hinder or deplete safety barrier action



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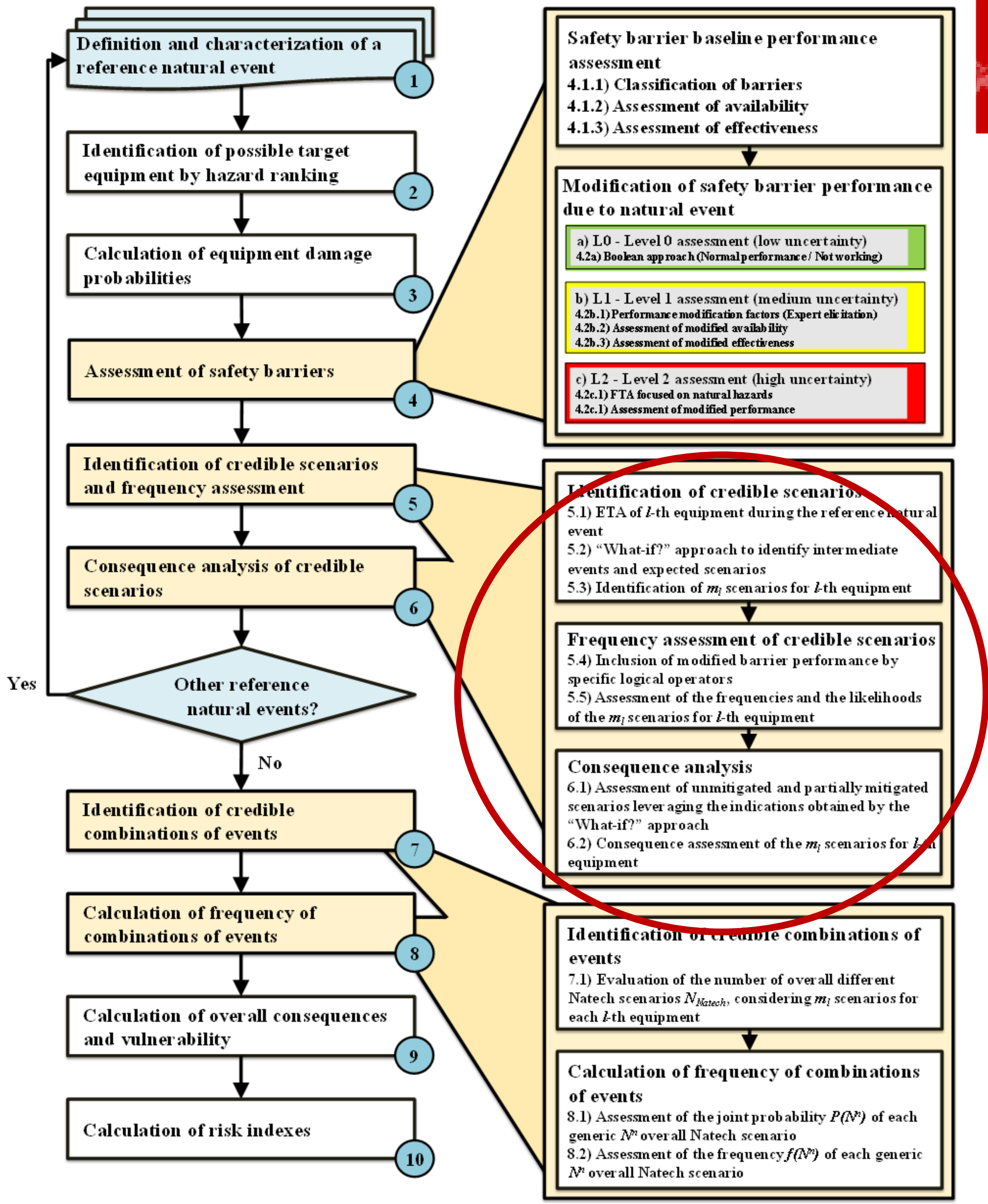
Safety Barriers Performance Modification

Safety barrier	ϕ_f	$[Q_1, Q_3]_f$	ϕ_e	$[Q_1, Q_3]_e$
Inert-gas blanketing system	**0.5**	[0.25, 0.75]	**0.625**	[0.5, 0.85]
Automatic rim-seal fire extinguishers	**0.15**	[0.15, 0.25]	**0.5**	[0.25, 0.75]
Fixed / Semi-fixed foam systems	**0.375**	[0.25,0.50]	**0.5**	[0.5, 0.75]
WDS / Water Curtains / Sprinklers	**0.375**	[0.18, 0.75]	**0.75**	[0.5, 0.85]
Hydrants	**0.5**	[0.25, 0.75]	**0.5**	[0.25, 0.75]
Fire activated valves	**0.5**	[0.25, 0.50]	**0.375**	[0.25, 0.69]
Fire and gas detectors	**0.5**	[0.25, 0.75]	**0.5**	[0.25, 0.75]
Shut down valves	**0.25**	[0.15, 0.50]	**0.5**	[0.25, 0.50]
Blow down valves	**0.25**	[0.15, 0.50]	**0.25**	[0.15, 0.50]
Fire walls	**0.2**	[0.15, 0.25]	**0.5**	[0.25, 0.75]
Blast walls	**0.15**	[0.15, 0.75]	**0.25**	[0.25, 0.50]
Fireproofing	**0.15**	[0.15, 0.25]	**0.25**	[0.15, 0.44]

(Misuri et al., Reliability Engineering System Safety (2020), https://doi.org/10.1016/j.ress.2020.107278)

Primary Scenarios

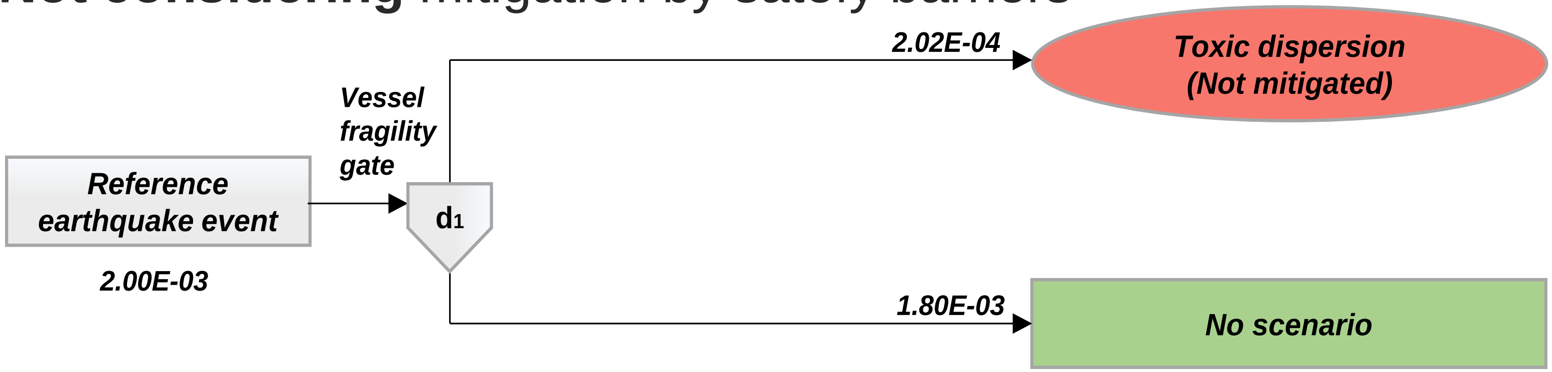


- A specific procedure was developed to identify and assess unmitigated and partially mitigated primary scenarios arising from barrier failure
- The procedure addresses both the frequencies and the consequences of **unmitigated primary scenarios**

Misuri et al., Rel.Eng.Sys.Saf. 235:109272 (2023). https://doi.org/10.1016/j.ress.2023.109272

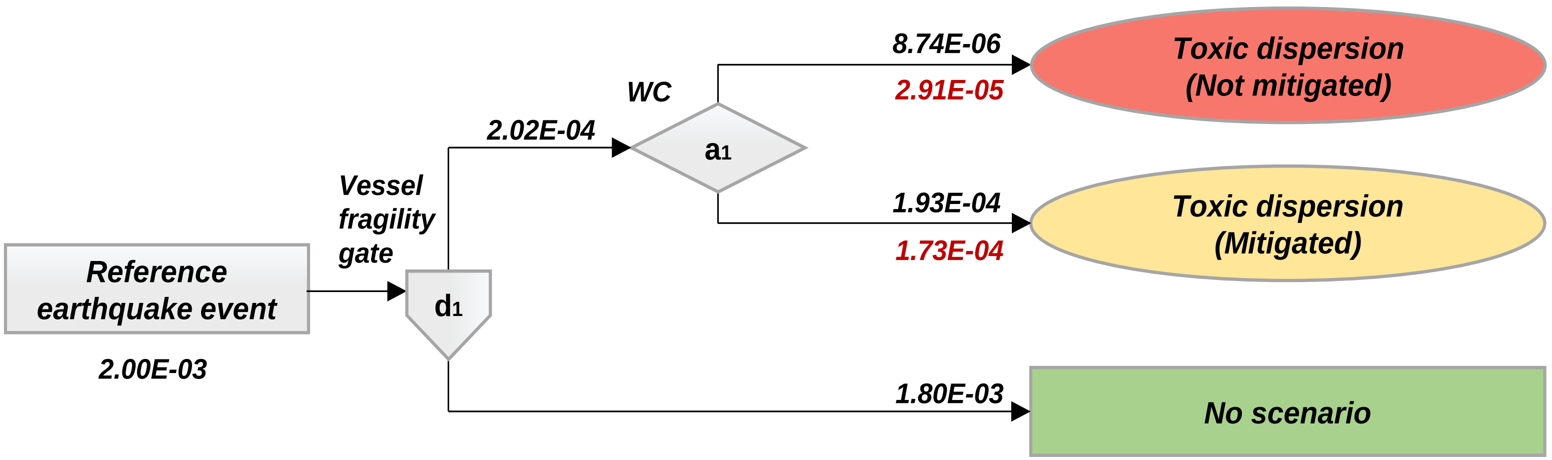
Example - Primary Scenarios

a) **Not considering** mitigation by satefy barriers



~~Considering **mitigation by safety barriers**~~

b) Considering **depleted safety barriers** in **Natech scenarios**



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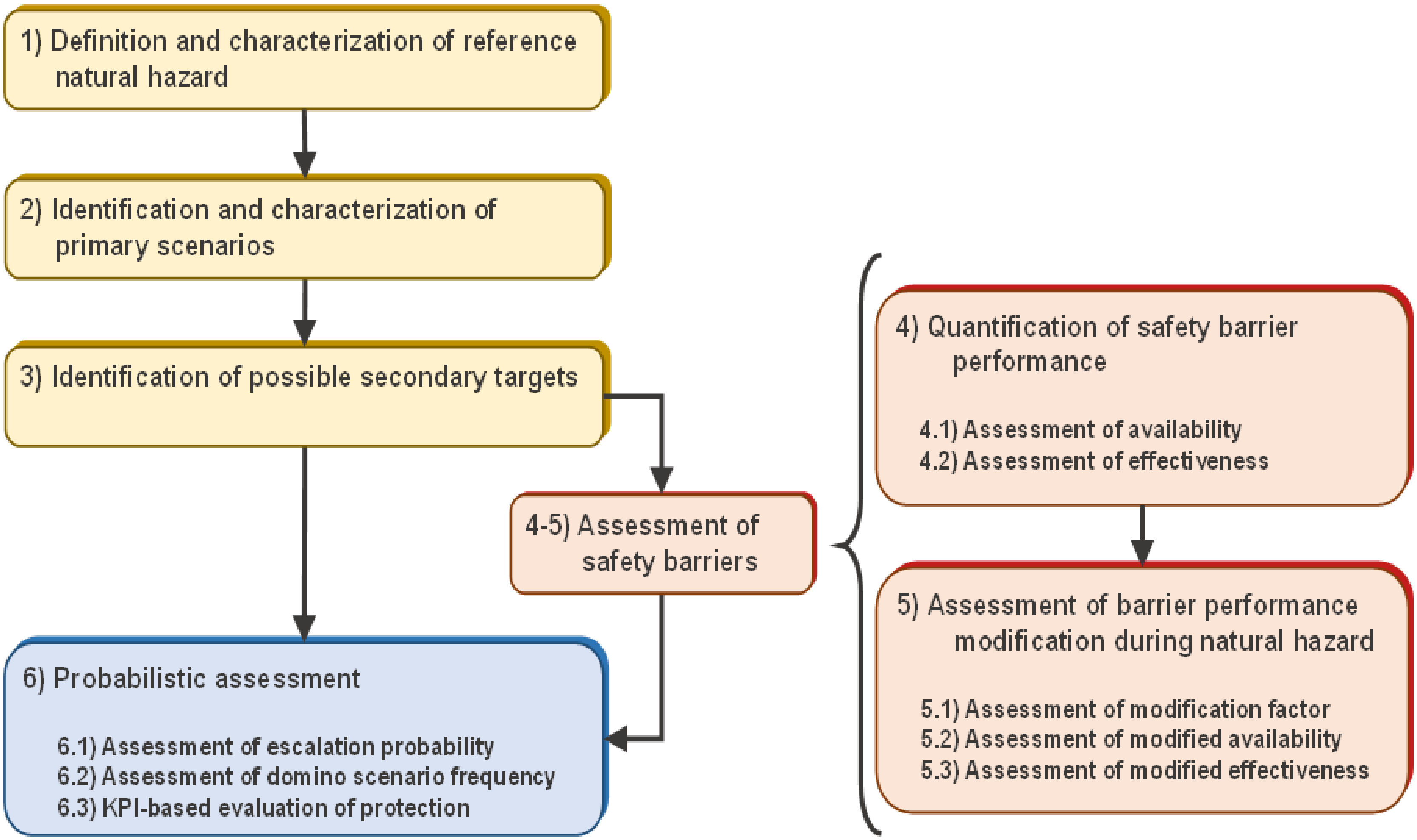
Unmitigated Escalation Scenarios



Misuri et al., Reliability Engineering System Safety (2020), https://doi.org/10.1016/j.ress.2020.107278

Part 3 –

Assessing Emergency Response in complex Natech scenarios

Impact of Natural Hazards on Emergency Response

Several factors may affect emergency response in the case of Natech:

- First responders may not be able to access the area of the site
- Utilities and safety systems may be damaged by the natural event
- Emergency safety barriers may be affected by the natural event
- High likelihood of an overload of emergency response

Is it possible to assess the different performance expected from emergency response?

Assessing Emergency Response

1. **DEFINITION** OF THE **EMERGENCY RESPONSE PHASES**
2. **DEFINITION** OF THE **EMERGENCY RESPONSE FACTORS**
3. **CHARACTERIZATION** OF **PHASES AND FACTORS**
4. **ANALYSIS** OF THE **EMERGENCY RESPONSE PERFORMANCE**
5. **ANALYSIS** OF THE **EMERGENCY RESPONSE TIME**

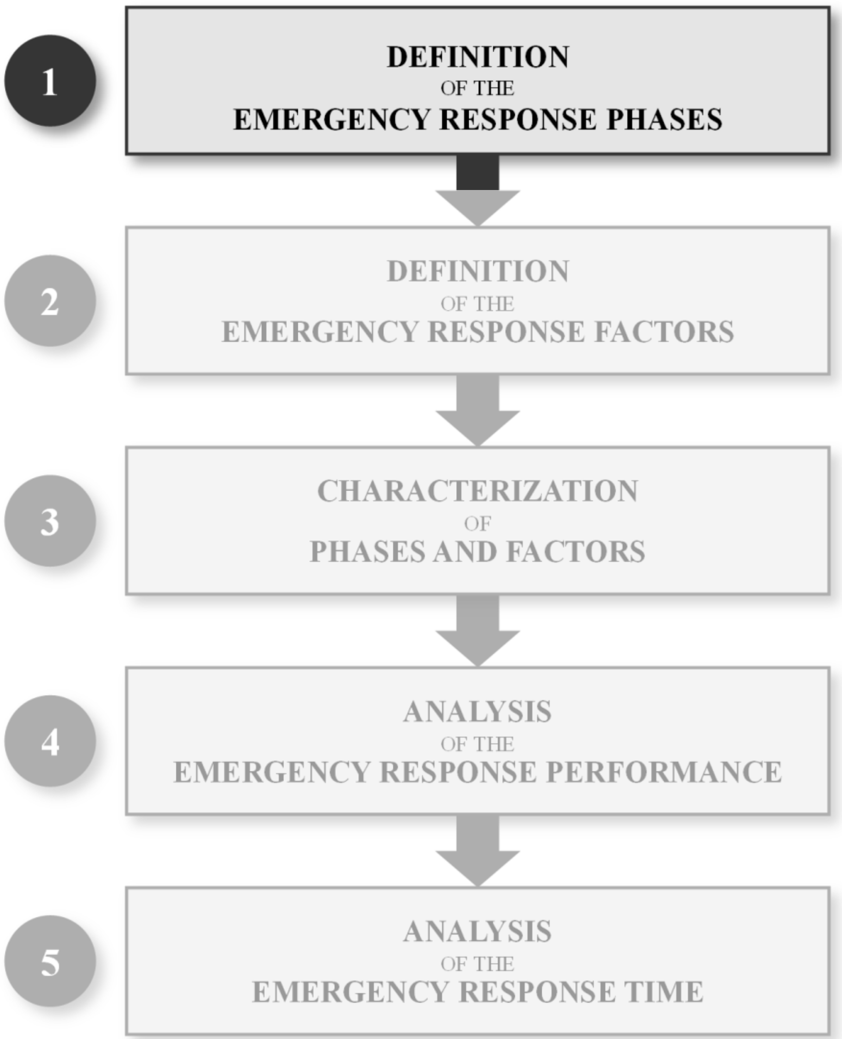
A methodology was developed to:

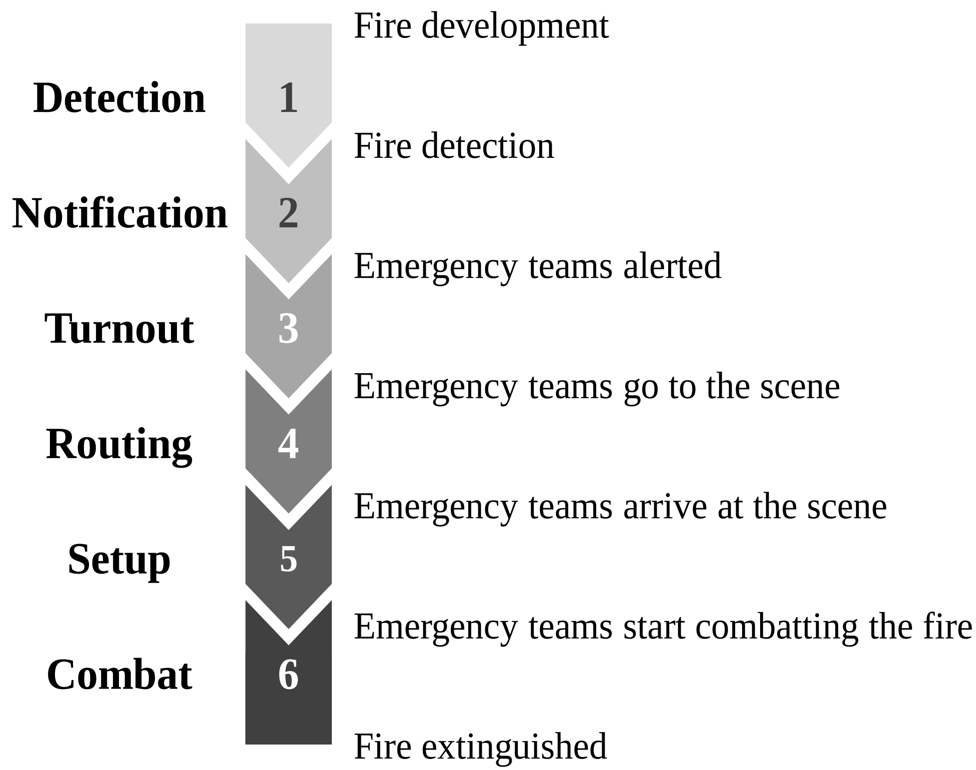
- Assess the **performance** of emergency response (% of successful deployment of first response)
- Assess the **time** required for the deployment of first response

Ricci F., Yang M., Reniers G., Cozzani V. ***The Role of Emergency Response in Risk Management of Cascading Events Caused by Natech Accidents****, 2022, Chemical Engineering Transactions, 91, pp. 361-366.*

Ricci F., Yang M., Reniers G., Cozzani V. ***Emergency Response in Cascading Sequences Triggered by Natural Events****, 2024, Reliability Engineering and System Safety, 243, 109820 https://doi.org/10.1016/j.ress.2023.109820.*

Assessing Emergency Response





Ricci F., Yang M., Reniers G., Cozzani V. ***Emergency Response in Cascading Sequences Triggered by Natural Events***, *2024, Reliability Engineering and System Safety, 243, 109820*

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Assessing Emergency Response

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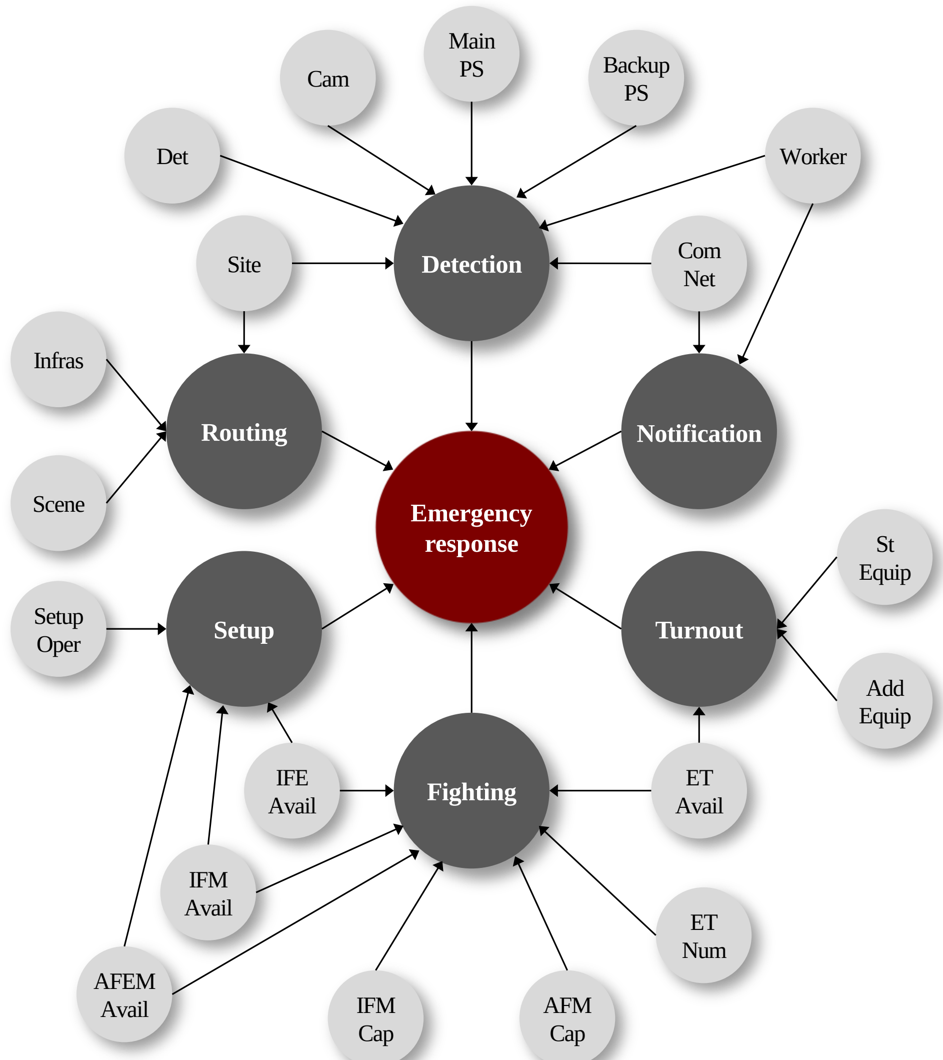
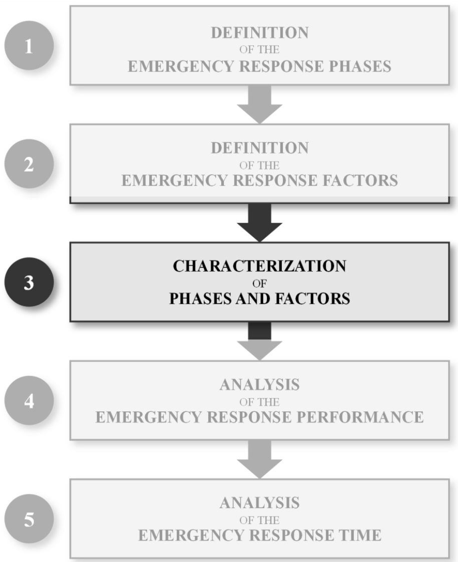
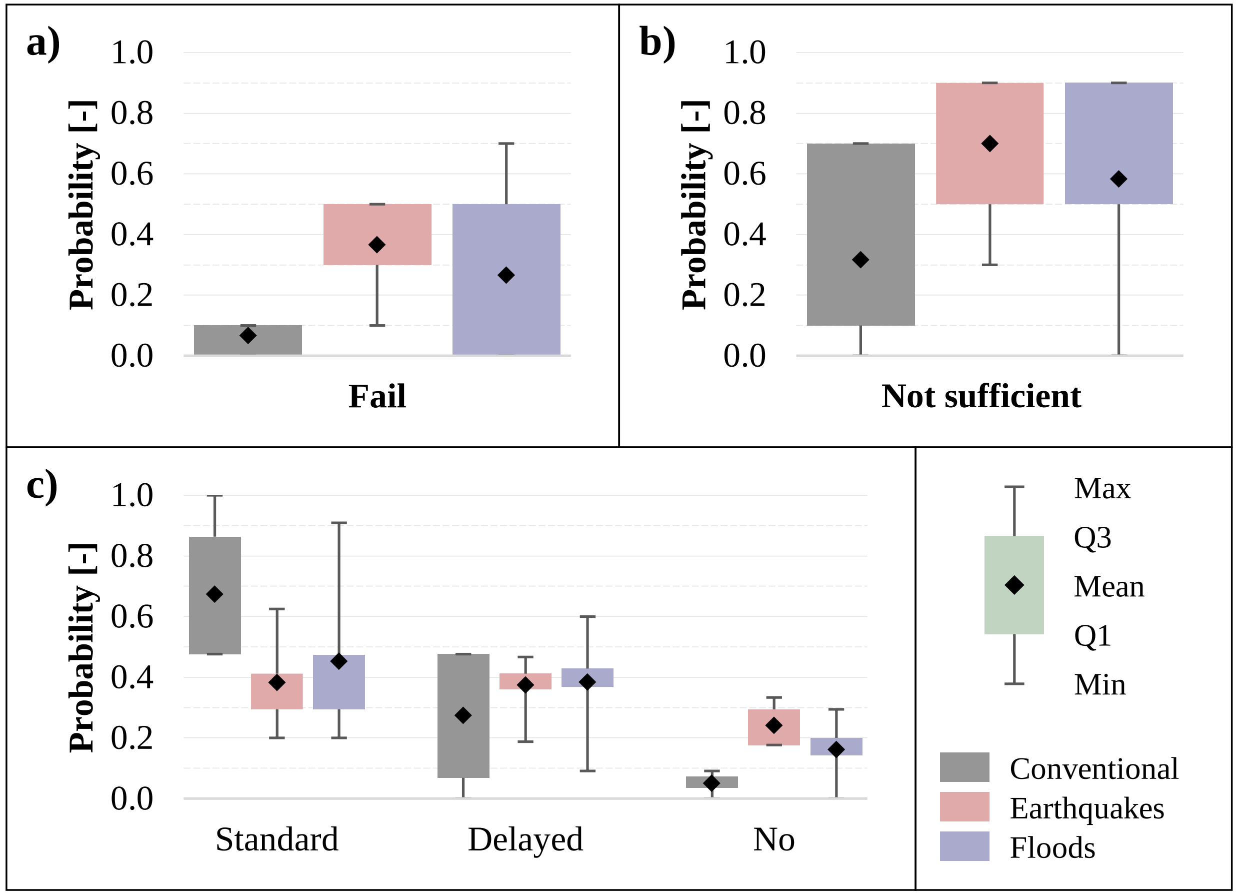


Assessing Emergency Response

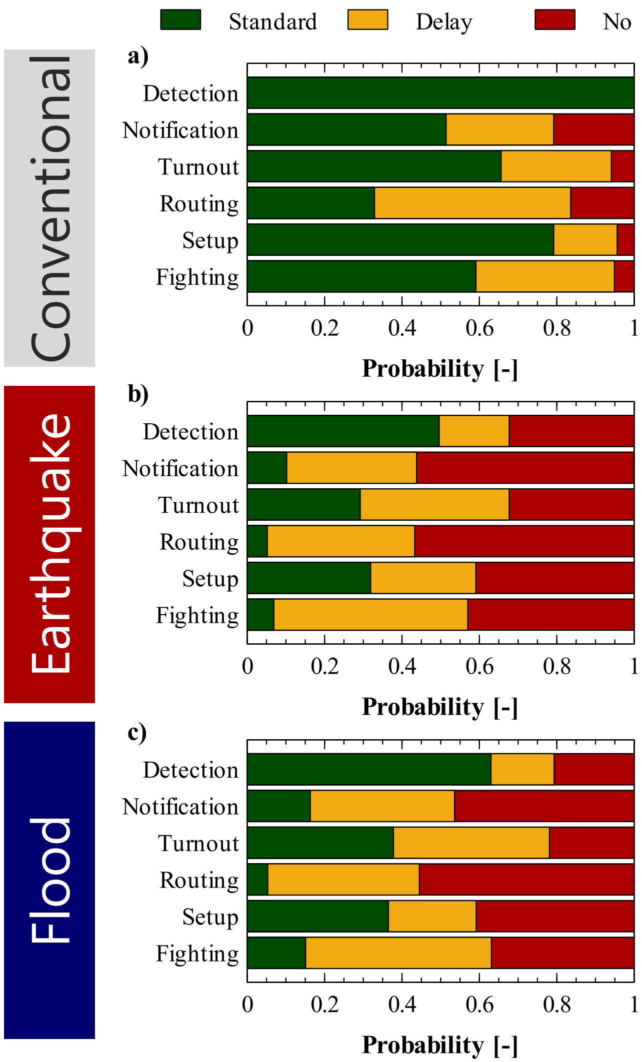


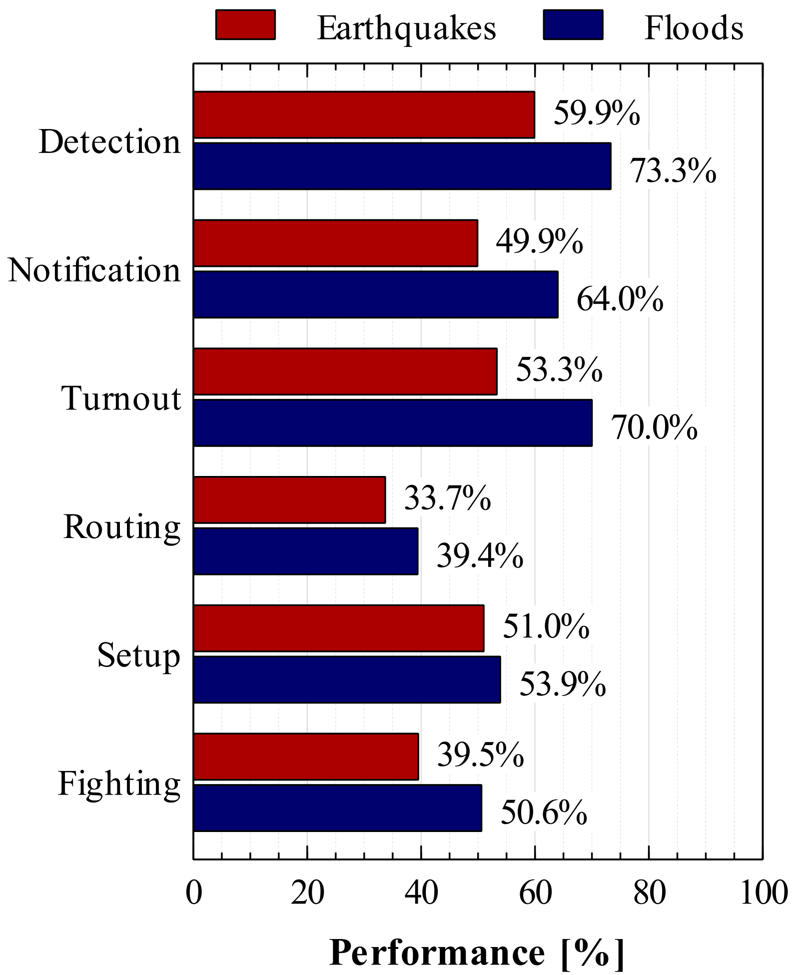
Expert survey for the characterization of factors modification



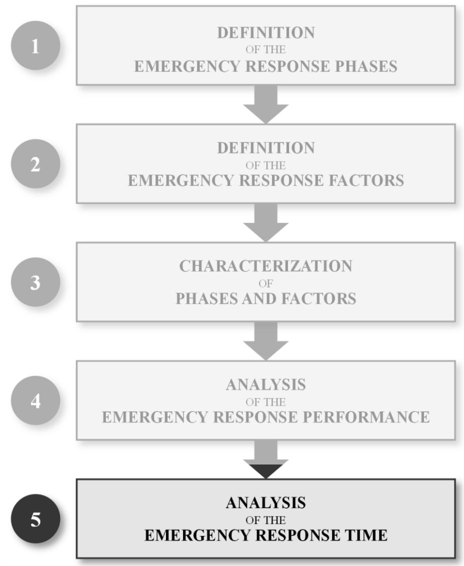
A **survey** was carried out involving Dutch firemen services responsible of emergency planning in an industrial port area

Assessing Emergency Response: Results

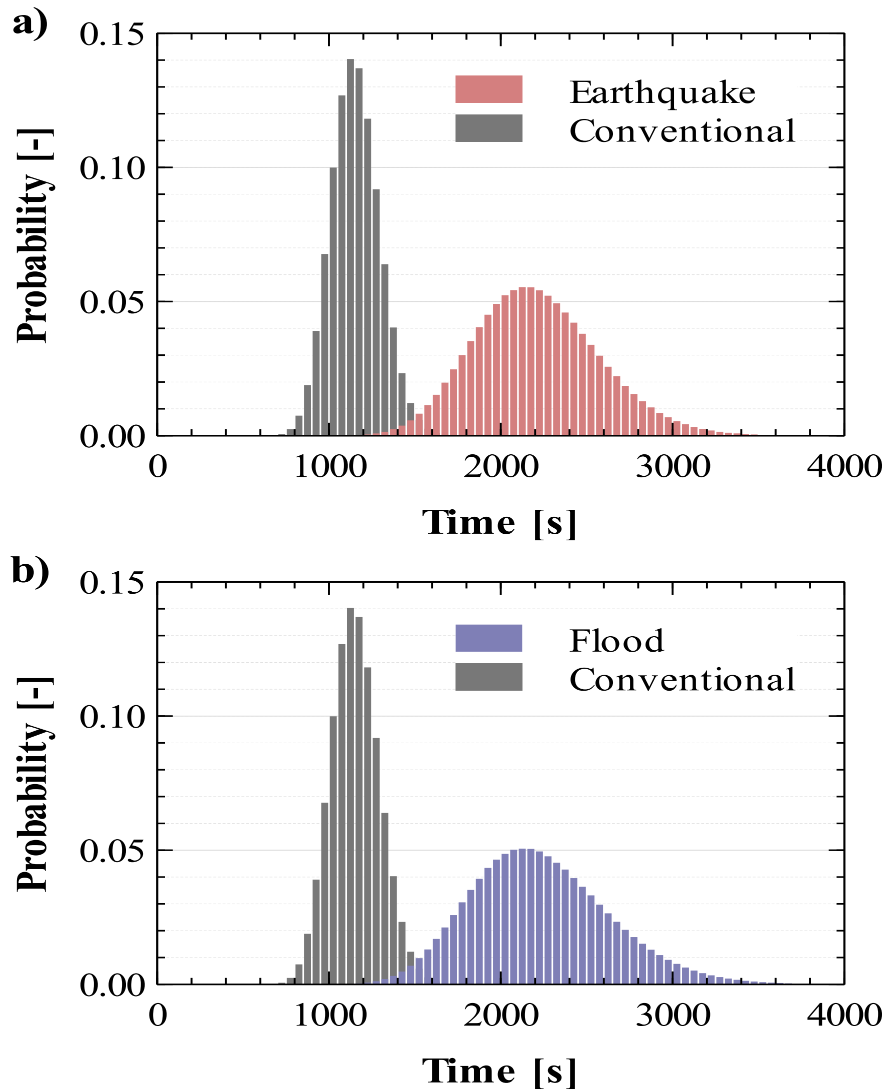




Assessing Emergency Response: Results



A distribution was also calculated for the **time required for successful deployment of emergency response** in the case of Natech



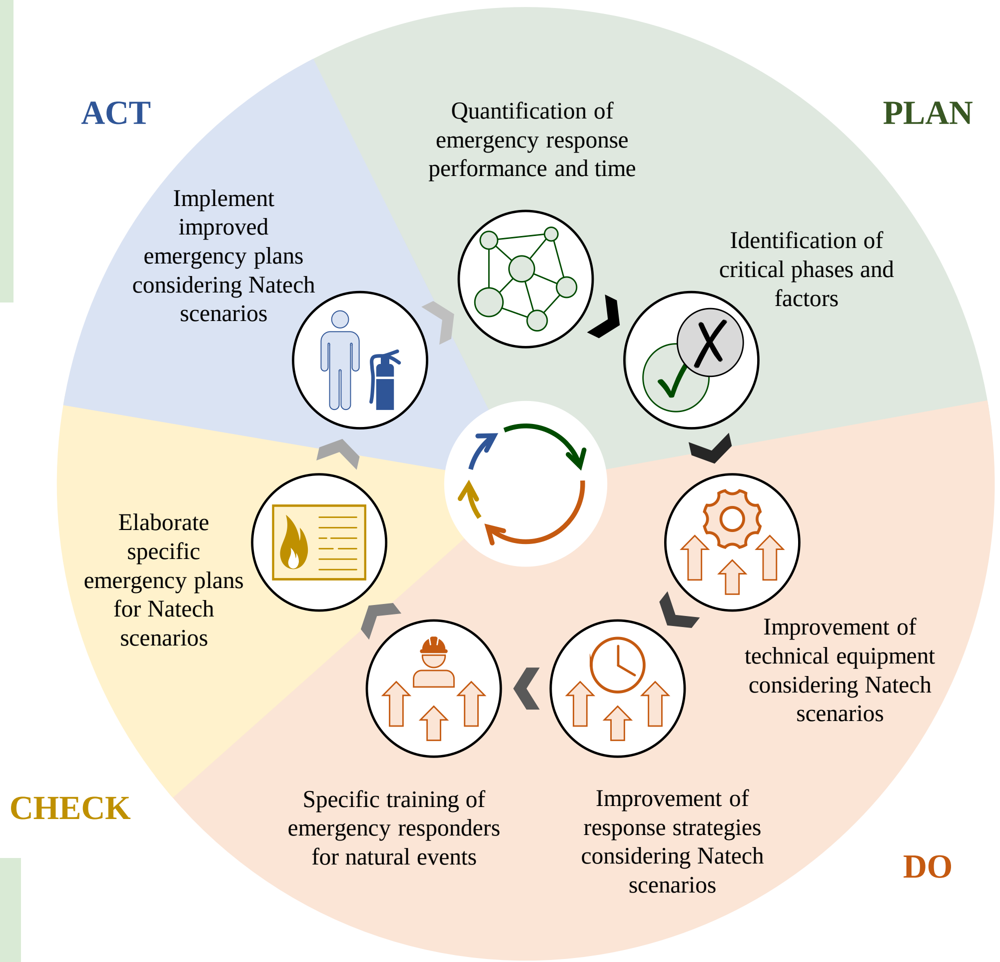
An approach to improve Emergency Management

The model developed represents a valuable tool to improve the emergency management of Natech scenarios, for instance by applying a Plan-Do-Check-Act (PDCA) cycle.

The quantification of the emergency response performance and time represent the starting point of the PDCA

The model allows the identification of critical phases and factors.

A PDCA-based modelling is a simple tool easily integrated in the safety management systems of Seveso sites



Conclusions

- The role of emergency response in risk management is paramount
- Emergency Management and Emergency Planning in Natech scenarios is appropriately assessed only if safety barrier performance degradation is considered
- A framework for the quantification of emergency response performance and time in cascading sequences caused by natural hazards was defined.
- The assessment is able to provide site-specific performance and time required for emergency response in Natech scenarios based on expert surveys
- The method may support the implementation of a structured specific approach to emergency management in the case of Natech events

Thank you for attending!

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Recent publications on the topic

- *Cozzani et al., 2014, Quantitative assessment of domino and NaTech scenarios in complex industrial areas, Journal of Loss Prevention in the Process Industries, 28:10-22.*
- *Misuri et al., 2019, Lessons learnt from the impact of hurricane Harvey on the Chemical and Process Industry, Reliability Engineering and System Safety, 190:106521.*
- *Misuri et al., 2020, Assessment of safety barrier performance in Natech scenarios, Reliability Engineering and System Safety, 193:106597. https://doi.org/10.1016/j.ress.2020.107278*
- *Misuri et al., 2020, Quantitative risk assessment of domino effect in Natech scenarios triggered by lightning, Journal of Loss Prevention in the Process Industries, 64:104095.*
- *Ricci et al., 2021, A comprehensive analysis of the occurrence of Natech events in the process industry, Proc. Saf. Env. Prot., 147, 703–713, 2021*
- *Misuri et al., 2021, Assessment of safety barrier performance in the mitigation of domino scenarios from Natech events, Reliability Engineering and System Safety, 205:107278.*
- *Ricci et al., 2021, Safety distances for storage tanks to prevent fire damage in wildland-industrial interface. Process Safety and Environmental Protection, 147:693–702, https://doi.org/10.1016/j.psep.2021.01.002.*
- *Misuri et al., 2021, Assessment of risk modification due to safety barrier performance degradation in Natech events, Reliability Engineering and System Safety, 212:107634.*
- *Misuri and Cozzani, 2021, A paradigm shift in the assessment of Natech scenarios in chemical and process facilities, Process Safety and Environmental Protection, 152:338-351. https://doi.org/10.1016/j.psep.2021.06.018*
- *Ricci et al., 2023, Natech accidents triggered by cold waves, Process Safety and Environmental Protection 173:106–119. https://doi.org/10.1016/j.psep.2023.03.022*
- *Ricci et al., 2023, Natech Accidents Triggered by Heat Waves, Safety 9:33. https://doi.org/10.3390/safety9020033*
- *Ricci et al., 2024, Vulnerability Assessment of Industrial Sites to Interface Fires and Wildfires. Reliability Engineering and System Safety 243:109895, https://doi.org/10.1016/j.ress.2023.109895*
- *Ricci et al., 2024, Emergency response in cascading scenarios triggered by natural events. Reliability Engineering and System Safety 243:109820. https://doi.org/10.1016/j.ress.2023.109820*
- *Amaducci et al., 2024, Quantitative Risk Assessment of Natech Scenarios triggered by Earthquakes involving Pipelines. Reliability Eng. System Safety 245:109993. https://doi.org/10.1016/j.ress.2024.109993*