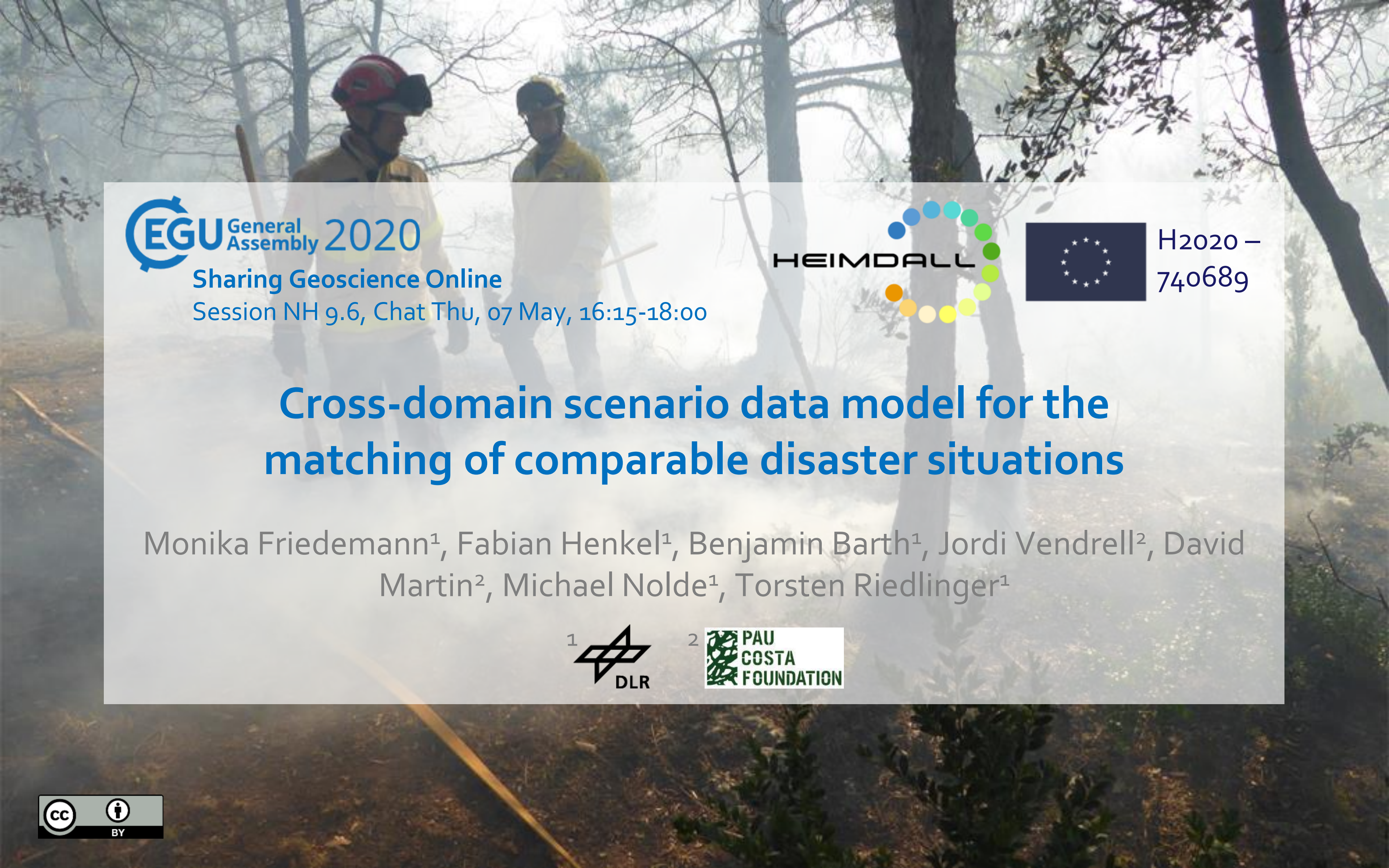

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H2020 – 740689

Cross-domain scenario data model for the matching of comparable disaster situations

Monika Friedemann[1], Fabian Henkel[1], Benjamin Barth[1], Jordi Vendrell[2], David Martin[2], Michael Nolde[1], Torsten Riedlinger[1]

1 DLR
2 PAU COSTA FOUNDATION

Motivation

- Natural and man-made disasters are becoming increasingly
  - Severe with hazard interdependencies and cascading effects and major impacts on people and property, economy and environment
  - Complex affecting Europe and beyond, cross-region, cross-country
- E.g. extreme forest fires in Sweden in 2018, Greece in 2018, France and Spain in 2012, Portugal in 2017, California in 2017 and 2018, Australia 2019/2020 ; region-wide flood events in Serbia and Croatia in 2014, Austria and the Czech Republic in 2013, Germany in 2002, 2006 and 2013

Need to improve the ability of stakeholders to monitor, anticipate, prepare for and learn from disasters (adaptive emergency management)

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Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building

H2020 Security Project
Research & Innovation (RIA)

05/2017 – 10/2020

Aims at co-designing technological solutions for an improved adaptive emergency management at local, regional, national and European level with a multi-disciplinary group of experts including firefighters, police, emergency medical services, command and control and civil protection

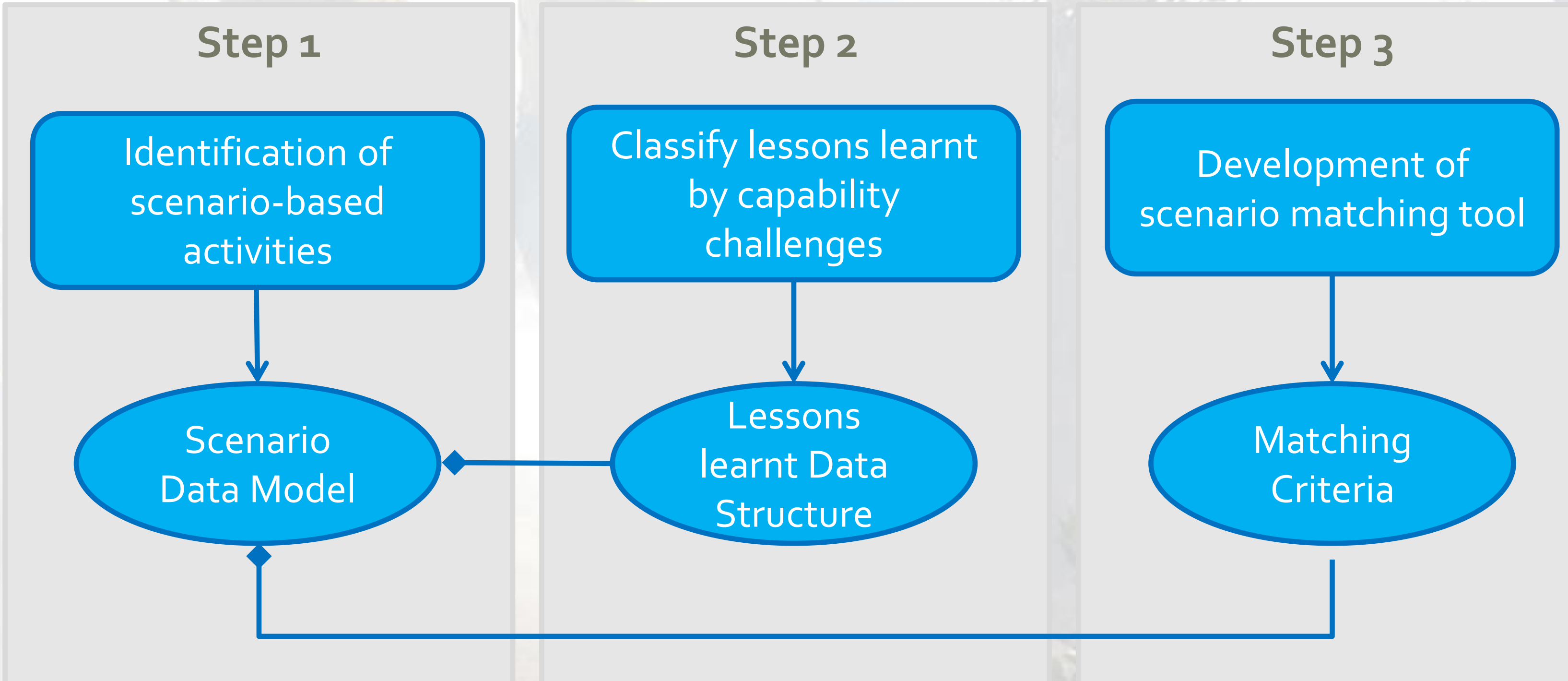
14 EU Partners (Lead: DLR) incl. 1 ELSI (Ethical, Legal, Social Issues) EBERHARD KARLS UNIVERSITÄT TÜBINGEN

and 5 End User Partners: FREDERIKSBORG BRAND & REDNING · Generalitat de Catalunya Departament d'Interior (Police & F&R) · SCOTTISH FIRE AND RESCUE SERVICE Working together for a safer Scotland · Croce Rossa Italiana

Research Focus and Approach

- How to find the most practical technical solutions for an improved adaptive emergency management that involves complex multi-hazard scenarios?
- Three-step approach:
  1) Identification of information that needs to be represented in a conceptual scenario model to improve scenario-based prevention and response planning activities;
  2) Extension by a harmonized lessons learnt data structure to capture experience of the emergency management in complex disasters;
  3) A scenario matching tool which allows users to find similar historic or fictional situations from local storage as well as shared by other organizations

Three-step Approach



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1. Scenario-based Activities and Scenario Data Model

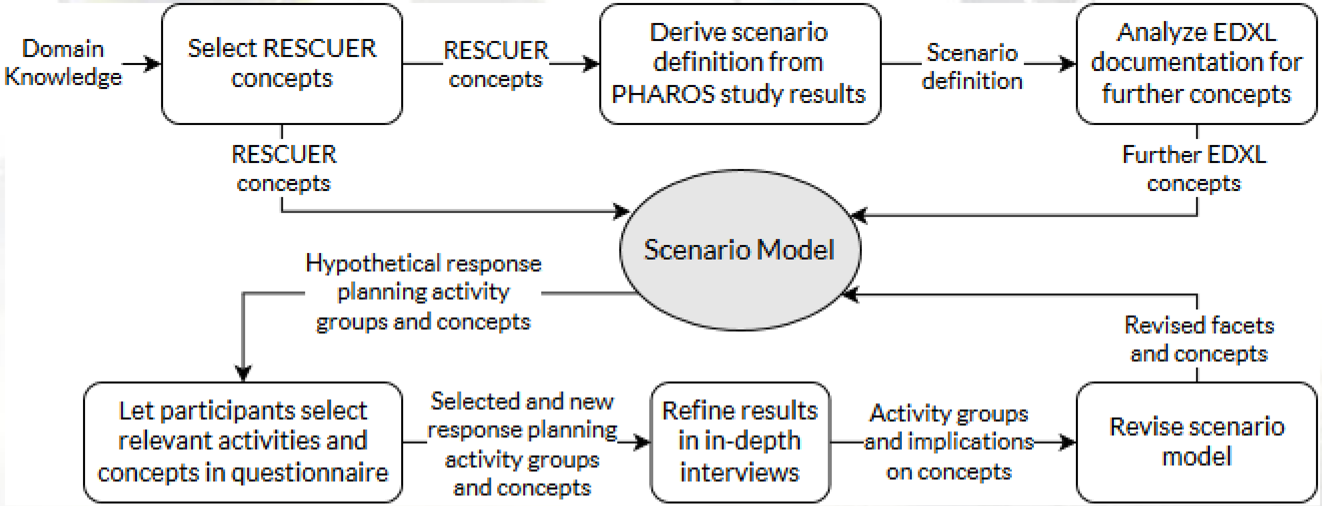
- Identification of immediate and long-term prevention and response planning activities that involve complex multi-hazard scenarios
- Identification of information that needs to be represented in a conceptual scenario model to improve these activities

1. Scenario Data Model / Related Work

- Many years of research on scenario-based strategic planning
- Projects and initiatives that combine ontologies, taxonomies or information models with emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards for improving procedural/organizational and semantic interoperability in disaster management in specific domains such as alert notifications , crowdsourcing, data model interoperability between mobile devices of field commanders and C&Cs, between civil and military organizations or between sensors

EDXL + research on process-specific knowledge to be used and adapted for scenario-based response planning process

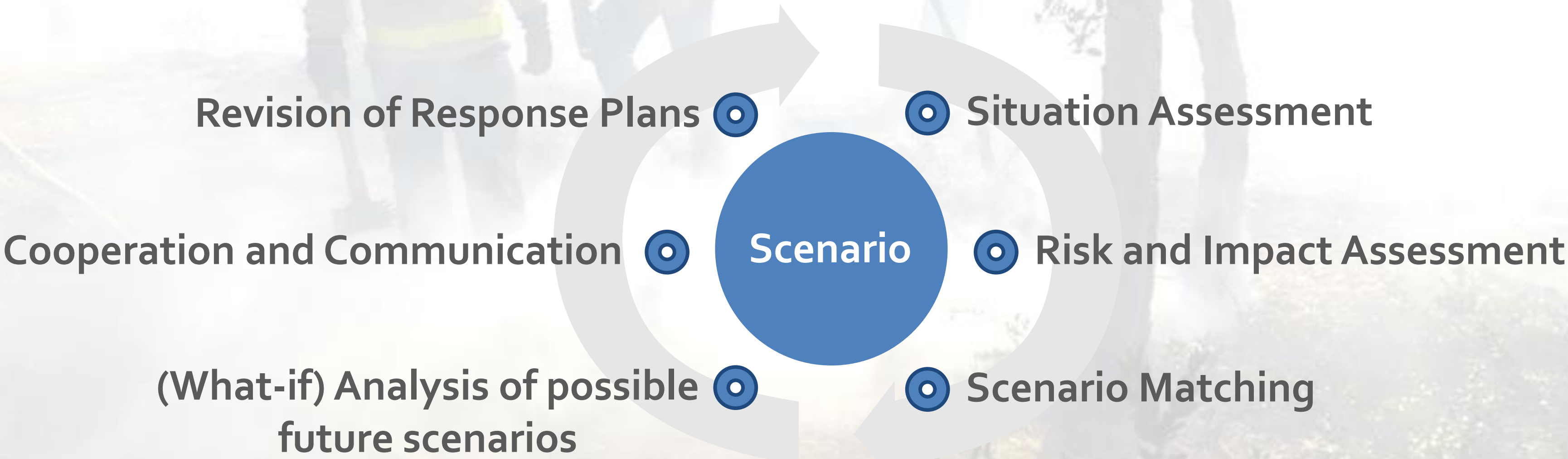
1. Scenario Data Model / Approach*



*Friedemann, M., Barth, B., Vendrell, J., Muehlbauer, M., Riedlinger, T.:
Conceptual scenario model for collaborative disaster response planning.

1. Scenario Data Model / Scenario-based Activities

- Identified scenario-based response planning activities (immediate & long-term)*



*Friedemann, M., Barth, B., Vendrell, J., Muehlbauer, M., Riedlinger, T.:
Conceptual scenario model for collaborative disaster response planning.

1. Scenario Data Model / Activities as Context for Scenarios

Implications for scenario model

Pre-defined response plans; Lessons learnt

Revision of Response Plans

Consider common vocabularies; Flexibility towards agency-specific strategic and tactical descriptions;

Cooperation and Communication

Related scenarios; simulated weather conditions,

(What-if) Analysis of possible future scenarios

situation evolutions and effects; Continencies; Credi-bility; Separation of „actual" from „fictional" scenarios

Scenario

Changing weather-related conditions, events, actions, prevention and mitigation measures and decisions; History management

Situation Assessment

Risk, damage to population and property; Impact of measures taken;

Risk and Impact Assessment

Cascading effects; interacting hazards

Scenario Matching

Similar scenarios with matching criteria, metrics and mismatch

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2. Lessons Learnt / Related Work

- Driver + Lessons Learned Framework*
  - „there exists no single and comprehensive approach to lessons learned in crisis management"
  - „As a matter of fact, there does not even exist a common understanding of the meaning and role of lessons learned and the lessons learned processes"
- No agreement so far on common structures to share lessons learnt among different organizations or even within the same organization

* Eriksson, P. and Andersson, D. (2017). **DRIVER D530. 1 - Lessons Learned Framework Concept.** Available at: https://www.driver-project.eu/wp-content/uploads/2017/11/Lessons-Learned-Framework-Concept.pdf. [Verified 23 April 2020]

2. Lessons Learnt / Approach

- Application of a generalized process to identify, discuss about, manage and disseminate lessons learnt from complex disasters
- Extension of the scenario data model by a harmonized lessons learnt data structure to capture experience of the emergency management

2. Lessons Learnt / Process

- Generalized Process*:
  1. Define case study / disaster incident / scenario
  2. Collect lessons learnt from the specific case study to identify either strategic and tactical strengths or weaknesses
  3. Review applicability of collected lessons learnt, discuss and debate on their strengths and weaknesses and translate them into recommendations for others in similar situations
  4. Manage lessons learnt using a harmonized lessons learnt data structure
  5. Disseminate and learn from lessons learnt/recommendations

* Revised based on the first release of the process in: Vendrell, J. et al. (2017). **HEIMDALL D3.4: HEIMDALL Demonstrations – Issue 1**. Available at: http://heimdall-h2020.eu/wp-content/uploads/2018/01/HEIMDALL_D3.4.PCF_.v1.0.F.pdf [Verified April 23, 2020]

2. Lessons Learnt / Data Structure (1)

- Facilitate sharing and finding of lessons learnt through a common taxonomy
- Classified using „Common Capability Challenges (CCC)“ matrix developed in the EU project FIRE-IN*
- Initially developed with and for fire and rescue services; well applicable to other organizations

The FIRE-IN Common Capability Challenges	High flow of effort in hostile environment	Low frequency, high impact	Multiagency / multileadership environment	High level of uncertainty
Incident Command Organization	Focus on sustainability of safe operations (TOP CHALLENGES)	Anticipate vulnerability, and communicate to the public (TOP CHALLENGE)	Distribute decision-making (TOP CHALLENGE)	Strategies choosing safe, resilient scenarios, and maintaining credibility
Pre-planning	Pre-plan a time-efficient, safe response, minimizing responder's engagement	Negotiate solutions with stakeholders for anticipated scenarios (TOP CHALLENGE)	Pre-plan interoperability and enhance synergies	Focus on governance and capacity building towards more resilient societies
Standardization	Establish specific procedures and guides facilitating operativity	Standardize capabilities in front of pre-established scenarios (TOP CHALLENGE)	Establish an interagency framework	Build doctrine for resilience in emergency services and societies
Knowledge cycle	Train specific roles and risks	Organizational learning focusing efforts in key risks and opportunities (TOP CHALLENGE)	Build a shared understanding of emergency and train interagency scenarios (TOP CHALLENGE)	Focus on capacity building towards more resilient societies
Information management	Information cycle	Manage key information focused on decision-making	Define common information management processes between agencies	Provide an efficient, flexible flow of information for a shared understanding
Community involvement	Develop public self-protection to minimize responders exposures (TOP CHALLENGE)	Involve communities in preparing population for the worst scenario before it happens (TOP CHALLENGE)	Not identified at this stage	Cultural changes in risk tolerance and resilience
Technology	Use technology to assess risks and minimize responder's engagement (TOP CHALLENGE)	Forecast and simulate complex scenarios	Technological tools to support data sharing	Get a clear picture of the risk evolution

?

Future research towards generalized capabilities

* EU project FIRE-IN: **Common Capability Challenges Matrix**. Available at: https://fire-in.eu/challenges-resources [last visited: 21 April, 2020]

(2) CCC Matrix

The FIRE-IN Common Capability Challenges	High flow of effort in hostile environment	Low frequency, high impact	Multiagency / multileadership environment	High level of uncertainty
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(3) CCC Matrix

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Technology	Use technology to assess risks and minimize responder's engagement (TOP CHALLENGE)	Forecast and simulate complex scenarios	Technological tools to support data sharing	Get a clear picture of the risk evolution

2. Lessons Learnt / Data Structure (4)

- Challenge: High flow of effort in hostile environments | Low frequency, high impact | Multi-agency / multi leadership environment | High level of uncertainty
- Capability: Incident Command Organization | Pre-planning | Standardization | Knowledge cycle | Information management | Community involvement | Technology
- CCC Result: Specific cell in the CCC matrix
- Evaluation: Negative/positive
- Level of Command: Strategical | tactical | operations (organization-specific)
- Lesson/Recommendation: Free text

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2. Lessons Learnt / Example

- Case Study / Scenario: Òdena Forest Fire 2015/07/26
- Challenge: High flow of effort in hostile environment
- Capability: Pre-planning
- CCC Result: Pre-plan a time-efficient, safe response, minimizing responder's engagement
- Evaluation: Positive
- Level of Command: Goo (Strategical)
- Lesson/Recommendation: The prevention works previously carried out at the Can Maçana saddle improve the response (opportunity to do technical burn at the head of the fire).

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2. Lessons Learnt / Scenario Data Model

Further Implications for scenario model

Lessons learnt data structure;
Link to measures and decisions taken

Revision of Response Plans

Situation Assessment

Sharing of lessons learnt

Cooperation and Communication

Challenges and capabilities based on
CCC matrix foster semantic interoperability

Scenario

Risk and Impact Assessment

(What-if) Analysis of possible future scenarios

Scenario Matching

Access to lessons learnt in similar incidents

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3. Scenario Matching

- Objective:
    - Development and implementation of a scenario matching tool which allows users to find situations with a similar context, environmental conditions, hazard behaviour and stressed capabilities, from local storage as well as shared by other organizations

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3. Scenario Matching

- Challenge:
  - How to define similarity of complex, multi-hazard situations which require a coordinated response planning?
    - Impact/Severity is not comparable
    - Not only similarity in hazard behavior but also similar complexity/scale with strategic implications for the involved stakeholders => cross-domain
    - Environmental conditions must be considered (synoptic situation)

Combine hazard attribution and behavior, environmental conditions and context with capability challenges concept, customized towards specific strategic goals

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3. Scenario Matching / Matching Criteria

- Ranking of scenarios based on the mutual similarity
- Distance measures are applied to individual scenario parameters used for matching, the so-called matching criteria
- Multi attribute decision making*

*Tzeng, G., Huang, J.-J., 2011. **Multiple attribute decision making: methods and applications, chapter 2: Analytic Hierarchy Process**, A Chapman & Hall book. CRC Press, Boca Raton, Fla.

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3. Scenario Matching / Matching Criteria

- Suitable matching criteria:
  - Weather conditions and synoptic situation
  - Hazard location (i.e. spatial matching)
  - Hazard type, incident status and urgency (e.g. actual vs. fictional, immediate vs. historic, training, etc.)
  - Hazard behaviour
  - Stressed challenges and capabilities (from lessons learnt capability challenges, CCC matrix)

3. Scenario Matching / Hazard Behaviour

- Forest fire behaviour:
  - Fire Types Concept* well-established in the European Fire and Rescue Community
    - Filters: Fire type, fire propagation type
    - Matching criteria: Mean flame length sustained in the head, mean propagation velocity, distance to secondary focus - massive
- Flood and flash flood behaviour
  - EC Floods Directive on flood risk assessment and management (2007/60/EC)
    - Matching criteria: Water height, water velocity

*A.L., Bover, M.M., Kraus, P.D., 2011. **Prevention of large wildfires using the fire types concept**, first edition: March 2011. ed. Generalitat de Catalunya [u.a.], Barcelona.

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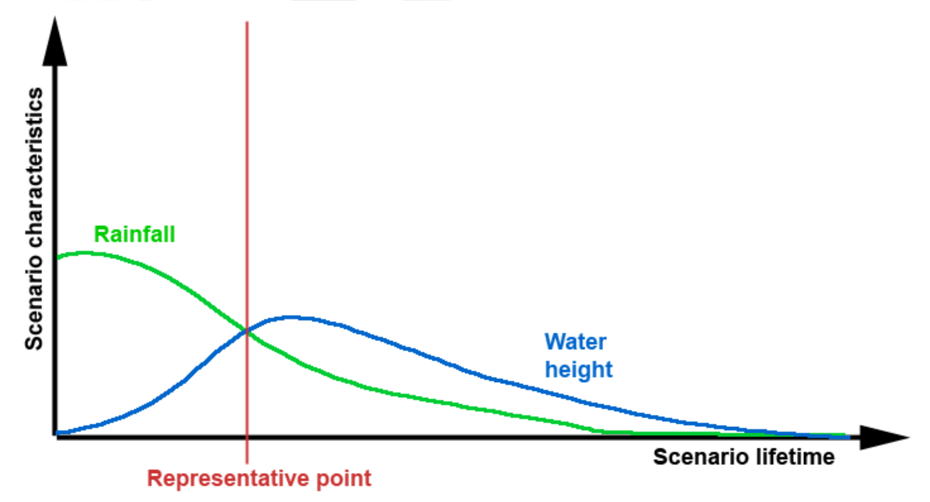
3. Scenario Matching / Example: 2012 La Jonquera Fire (one of HEIMDALL's case studies and exercise scenarios)

- On-field, it becomes clear that the fire is not a linear front with secondary focus but a fire with a big opened head that generates massive secondary focus... It is a 5th generation fire which means several points:
  - It has major fire behaviour
  - Requires simultaneous responses
  - It is a Civil Emergency – Wildland Urban Interface (WUI)
- At this point strategists can search for similar situations, based on the observed fire behaviour and strategical challenge, for a scenario of reference that will help them to a) assess which sort of situation they will front and b) learn from past to apply knowledge to the present situation
- Matches 1986 La Jonquera Fire that led to the l'Albera-les Salines channel/strait

3. Scenario Matching / „Representative“ point

- Matching of representative point in time during disaster
    - Good starting point, but requires end users to identify this point
    - Possible solution: Instead of comparing for example the maximum water height at a specific point in time it may be more reasonable to compare the water level increase and decrease over time



? Future research needed towards curve progression matching

3. Scenario Matching / Mismatch

- Mismatch for every criterion
- Mismatch represents the distance of a given value to a scenario parameter value in such a way, that the scenario parameter value corresponds exactly to the compared situation when the distance is zero.
- Matching metrics - examples:
  - The spatial mismatch is calculated by applying the geodesic distance computation to the centroids of the hazard (e.g. flood, fire) location geometries*
  - The mismatch of stressed capabilities in the compared situations is computed using the Jaccard similarity**.The metric measures the similarity between finite sample sets.

*Karney, C.F.F. (2013). **Algorithms for geodesics**. Journal of Geodesy 87, pp. 43-55, doi:10.1007/s00190-012-0578-z
Han, J., M. Kamber and J. Pei (2006). **Data Mining: Concepts and Techniques. Elsevier Science & Technology, Burlington, United States

3. Scenario Matching / Combined Mismatch

- The individual mismatches are combined using the Simple Additive Weighting (SAW) approach*, **, ***
- The relative importance of the matching criteria can be influenced by adding weights to each criterion

? Future research needed towards sensitivity analysis*** once scenario database is completed

*Behrens, J., A. Androsov, A.Y. Babeyko, S. Harig, F. Klaschka and L. Mentrup (2010). **A new multi-sensor approach to simulation assisted tsunami early warning**. Natural Hazards and Earth System Sciences 10, pp. 1085-1100, doi:10.5194/nhess-10-1085-2010

De Brito, M.M. and M. Evers (2016). **Multi-criteria decision-making for flood risk management: a survey of the current state of the art. Natural Hazards and Earth System Sciences, 16(4), pp. 1019-1033

***Goodridge, W.S. (2016). **Sensitivity analysis using simple additive weighting method**. International Journal of Intelligent Systems and Applications, 8(5), 27

3. Scenario Matching / Scenario Data Model

Further implications for scenario model

Scenario

Revision of Response Plans
Access to lessons learnt, decisions and measures taken

Situation Assessment
Synoptic situation assessment; tracking of hazard behaviour throughout scenario duration; „representative" point in scenario lifetime;

Cooperation and Communication
Harmonized sub-hazard types; harmonized hazard behaviour;

Risk and Impact Assessment

(What-if) Analysis of possible future scenarios
Scenario status and urgency (i.e. „actual", „fictional", etc.)

Scenario Matching
Matching criteria; mismatches, per criterion and total sum; criteria weights and filters; Metrics per criterion; Configuration and custom „templates"

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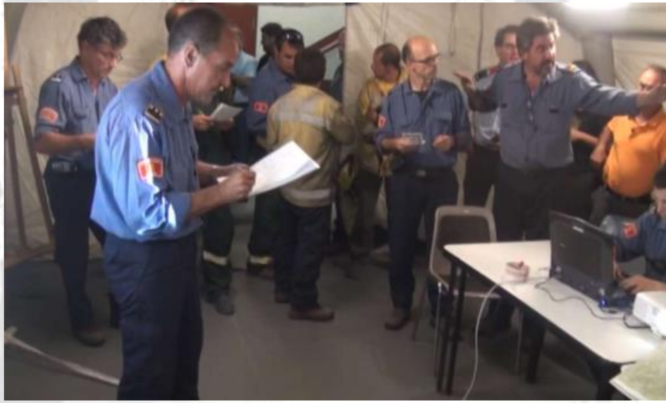
Conclusions (1)



- The combination of recording and matching scenarios including lessons learnt from prior incidents can improve the ability of stakeholders to learn and evolve from complex situations and thereby allow them to respond more effectively and operate more efficiently during disasters

Conclusions (2)

- Results of successive user exercises and evaluations of the implemented products and tools throughout the project underpin this assumption and at the same time indicate future research needs, e.g. matching criteria and metrics need to be (re-)evaluated while the scenario database gets more and more populated

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Thanks for your interest and feedback!

Monika.Friedemann@dlr.de

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