Conceptual scenario model for collaborative disaster response planning

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1. Introduction

In recent years, there have been increasingly severe and complex natural and man-made disasters affecting Europe [1]. Episodes of extreme forest fires (e.g. Portugal in 2003, 2005 and 2017, Greece in 2007, Spain in 2015 and France in 2016) and region-wide flood events (e.g. Serbia and Croatia in 2014, United Kingdom in 2014, Austria and the Czech Republic in 2013, Germany in 2002, 2006 and 2013), with thousands of people affected, resulted in significant destruction of property and major impacts on the economy and the environment across different regions and countries. Hazard interdependencies and cascading effects amplified intensity and impact. These complex situations have shown that there's a need to improve collaborative strategic planning on a regional scale among the many affected actors concerned with disaster risk management and response. In the European Commission (EC) H2020-funded project HEIMDALL on a Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building [2] we aim at improving immediate and long-term cooperative situation assessment and response planning activities. As response plans should be firmly based on scenarios of what is likely to happen [3] we want to support emergency services in the creation, analysis and exchange of realistic multi-disciplinary disaster scenarios. Therefore, the paper is motivated by the two research questions: (1) Which activities in the response planning process for complex multi-hazard crisis situations, specifically weather related events, involve strategic planning scenarios and (2) which information needs to be represented in a scenario to improve these activities?

The paper continues with an overview of related work. In section 3 we present the results of two different activities which we have conducted in order to approach the research questions. Section 4 concludes with a short overview of upcoming tasks.

2. Related Work

The scientific community has been addressing scenario-based strategic planning for years where the main goal was to develop different possible views of the future and to analyze their possible consequences [4]. However, the information shared on situational status, possible future alternatives or strategical decisions is typically short unstructured messages with occasional tabular data, and is often encoded as PDF or

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Microsoft Word documents [5]. The two major challenges in the management of disasters lie in improving procedural/organizational and semantic interoperability [6]. Ontologies and emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards [7] have been used to overcome the problems of interoperability and semantic heterogeneity and to ensure the optimal provision of disaster-related information for fast decision-making in a highly coordinated manner [5][8][9]. There are quite a few projects and initiatives that combine ontologies, taxonomies or information models with EDXL for interoperability in specific domains such as alert notifications [10][11][12], crowdsourcing [8], data model interoperability between mobile devices of field commanders and command and control centers [13], between civil and military organizations [14] or between sensors [15][16].

3. Results

While EDXL carries potential for the scenario-based response planning process it lacks research on process-specific knowledge to be used and adapted. In this work-in-progress paper we present a conceptual scenario model for a holistic semantic integration and representation of process-specific knowledge across all process phases based on EDXL. Approaching the research questions, a methodology has been chosen which combines methods to identify scenario information elements and methods to deepen the specification of these elements focusing on fire, flood and landslide events along with hazard interactions. On the one hand, the scenario model elements have been elaborated by a combination of a faceted model formalization based on EDXL and an evaluation of a semi-structured questionnaire provided to emergency response experts involved in the EC H2020-funded project PHAROS [12]. On the other hand a second semi-structured questionnaire and in-depth interviews with experts in response planning were taken into consideration. Our approach is outlined in Fig. 1.

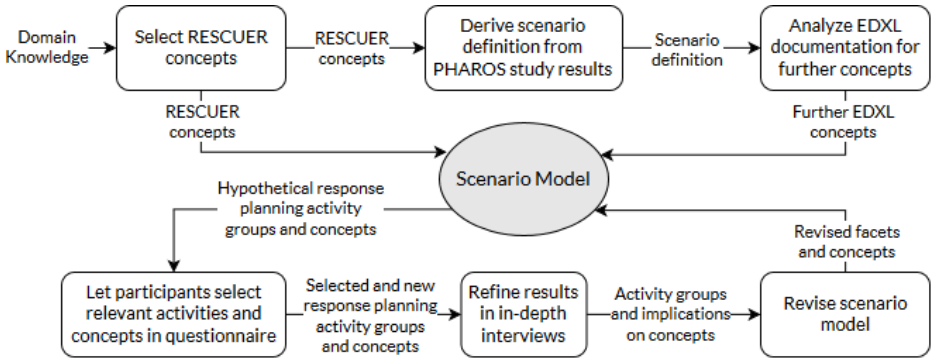

Fig. 1. Scenario model formalization approach

3.1 First conceptual scenario model based on EDXL

First, we have performed a bottom-up analysis of the EDXL documentation following the faceted taxonomy approach applied in the RESCUER project [8] for the identification of major information

domains (i.e. facets), terms within the same domain (i.e. related concepts) and relationship definitions. We have chosen a faceted approach to a scenario taxonomy, as the multidisciplinary and multi-hazard character of the research question requires a flexible and incremental specification. As a starting point, we have selected relevant concepts from the RESCUER ontology created for the coordination and exchange of crowdsourcing information during an emergency situation. Accordingly, the concepts Incident, Severity, WeatherEffects and Resource formed the cornerstone of the first scenario model.

Based on these concepts, we have analyzed the EDXL documentation for further facets and terms relevant to scenario-based response planning. As a red thread, we made use of the results of a user study involving an e-mail questionnaire performed with emergency response experts in the aftermath of the project PHAROS. Some of the experts which took part in PHAROS (e.g. as members of the Advisory Board) now participate in the HEIMDALL consortium which strives to reuse the concepts and the software framework developed in the former project. The study examined which information and information values are important to be gathered in the decision-making process. We mapped the study results onto a response planning context and derived the following definition of a response planning scenario as the red thread for our EDXL analysis: A scenario should consist of a real or hypothetical hazard, current conditions in the local area, information on where physical impacts are likely to occur, how they will have an effect on people and buildings, and what measures, resources and forms of organization are needed in order to reduce the consequences. Hence, the EDXL facets SituationSummary, CasualtyAndIllnessSummary and IncidentDecisionSupportInformation have been added to the scenario model. SituationSummary provided us, for instance, with the concepts SignificantEvents, TransportationSystems and FollowOnIndication whereas IncidentDecisionSupportInformation delivered LifeAndSafetyThreat, InfrastructureAffected and PropertyDamage.

3.2 Response planning activities as context for scenarios

The first conceptual model has been formalized in the form of a second questionnaire. The questionnaire has been structured along the hypothetical response planning activity groups (a) detection, (b) incident identification and classification, (c) assessment of risk, situation and decision options, (d) emergency management, (e) demobilization, and (f) communication. Each activity block consisted of a list of model concepts expressed as an activity, e.g. the Severity concept has been formulated as “assessment of incident severity”. In the frame of a study, the questionnaire has been provided to different groups of experts. These experts were selected from five groups of emergency management organizations from different European countries (firefighting units, medical emergency services, police departments, civil protection units and command and control centers) as well as experts in ethical, legal, and social issues (ELSI), all represented in the HEIMDALL consortium. The study participants had to select model concepts relevant to them and their goals in response planning. Through custom answers for both, activity groups and concepts, they were able to bring up new ideas. Afterwards, we have conducted in-depth interviews to refine the questionnaire results. Six major groups of response planning activities involving scenarios with implications on needed model concepts have been identified (summarized in Table 1):

- Situation assessment: During a disaster situation, scenarios can act as pools of relevant information (weather effects, actual events and actions, decisions, etc.) as the situation evolves. The scenario model shall allow for iterations and replays. These are triggered by changes in the environment, planned decisions, projections or re-evaluations based on lessons learnt. Thus, traceability of all elements is needed, implying the requirement of history management.
- Risk and impact assessment: Assessment of consequences of the disaster, cascading effects and interacting hazards, prevention or mitigation measures as a basis for decisions on the path to follow to achieve the desired outcome. In order to reflect the respect for autonomy of the user the underlying criteria for the selection of this kind of information shall be made visible.
- Scenario matching: Allows for finding disaster situations in a database similar in occurrence, behavior and impacts that require a similar strategic and tactical response. Information on prevention and response measures taken in similar scenarios and their outcomes supports the evaluation of suitable working strategies. The suitability of a scenario parameter for matching has an impact on its relevance for the model. For instance, the Severity concept has no relevance as it implies no information on the actual impact and response. In order to define the reason for similarities, the matching results shall make the used matching criteria transparent.
- Analysis of possible future scenarios: The consideration of multiple possible future alternatives helps emergency managers to assess the effectiveness of potential working strategies and identify options and contingencies. For instance, scenario-based analysis may consider simulating the effect of fire breaks on the forest fire evolution or running a scenario for several sets of circumstances, such as daytime and night-time, a working day and a holiday, and so on.
- Cross-stakeholder cooperation and communication: A major goal is to form a common vocabulary for cooperation, based on standards of Disaster Risk Reduction (DRR) and emergency management, e.g. definitions of the Incident Command System (ICS). At the same time, agency-specific tactical information has to be considered. Experience and knowledge from managing complex disasters needs to be exploited and shared among other emergency actors.
- Evaluation and revision of response plans based on lessons learnt from disasters: scenarios act as means for tracking lessons learnt in the aftermath of a disaster.

Activities	Implications for scenario model
Situation assessment	Model must contain concepts for changing weather-related conditions, events, actions, prevention or mitigation measures and decisions; History management is needed
Risk and impact assessment	Scenario must contain information on risk and levels of risk for people, strategic infrastructures, objects or places of interest, impact assessment for measures taken to reduce the consequences, on potential cascading effects and interacting hazards

Scenario matching	Different related (similar) scenarios must be represented together with matching criteria and metrics and the numerical mismatch which represents the distance of a given scenario to another scenario; Severity concept is not useful
Analysis of possible futures	Model must allow for different scenario options relating to each other, different simulated weather conditions, situation evolutions and effects; Contingencies must be formalized; A credibility concept is needed for scenarios; Distinction between "real" and "simulated" scenarios is needed
Cross-stakeholder cooperation and communication	Common vocabularies must be considered; Flexibility towards agency-specific strategic and tactical descriptions are required
Evaluation and revision of response plans	Concepts for lessons learnt and pre-defined response plans are required

Tab. 1. Identified groups of response planning activities that involve scenarios and implications for needed scenario model concepts

4. Results

In this work-in-progress paper we have presented our approach towards the identification of information elements needed in a conceptual scenario model to improve six groups of response planning activities in complex multi-hazard crisis situations. Based on derived implications, we are in the process of revising the model concepts. There's still research to do in finding ways to populate the scenario model with other vocabularies, e.g. used in DRR. In addition, together with weather experts, we must investigate if the concept WeatherEffects needs to be refined in order to give command and control centers a good overview on the current and future weather situation. In the next project phase, the model will be used as the backbone for intermediary proof-of-concept implementations and software releases. First, a specific scenario data model and a scenario management component will be implemented. Then, different HEIMDALL components will set up on this specific model in order to (a) map process-specific knowledge onto EDXL for standards-based sharing, (b) visualize scenarios, (c) perform simulations and impact assessment for different alternative scenarios and (d) compare scenarios with each other. These implementations will undergo exercises in real-environment conditions giving us, the end users and the ELSI experts the possibility to reflect on current solutions, to validate these and to identify problems. We expect the acquired and evaluated data to be the basis for further refinements of our conceptual model.

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