Conceptual scenario model for collaborative disaster response planning

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Abstract. 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 HEIMDALL project 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 by supporting emergency services in the creation, analysis and exchange of realistic multi-disciplinary disaster scenarios. Therefore, the paper is motivated by the research question: Which information needs to be represented in a strategic planning scenario to improve the response planning process for complex multi-hazard crisis situations, specifically, weather related events?

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 [3]. 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 Word documents [4]. The two major challenges in the management of disasters lie in improving procedural/organizational and seman-

tic interoperability [5]. Ontologies and emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards [6] 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 [4][7][8]. 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 [9][10][11], crowdsourcing [7], data model interoperability between mobile devices of field commanders and command and control centers [12], between civil and military organizations [13] or between sensors [14][15].

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 question, a methodology has been chosen which combines methods to identify scenario information properties and methods to deepen the specification of these properties focusing on fire, flood and landslide events along with hazard interactions. Hence, the scenario model properties and structure have been elaborated by a combination of a faceted model formalization based on EDXL and an evaluation of a semi-structured lessons-learnt questionnaire provided to stakeholders involved in the EC H2020-funded project PHAROS [11] on the one hand as well as a semi-structured questionnaire and in-depth interviews with experts in response planning on the other hand. 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.

As a first step, we have performed a bottom-up analysis of the EDXL documentation following the faceted taxonomy approach applied in [7] for the identification of structural properties 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. In order to narrow down the EDXL contexts which are relevant to HEIMDALL, we have analyzed the results of a user study involving a questionnaire performed with end users in the PHAROS project. Hence, a response planning 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. The first conceptual model has been formalized in the form of another questionnaire. In the frame of a study, the questionnaire has been provided to stakeholders from end user organizations and ELSI experts participating in the HEIMDALL project. The study participants had to select domain-specific contexts and properties relevant to them and their goals in response planning. Afterwards, we have conducted in-depth interviews to refine the questionnaire results. Six major groups of response planning activities involving scenarios and required information elements have been identified:

(a) Situation assessment: During a disaster situation, scenarios can act as pools of relevant information (conditions, 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.

(b) Risk and impact assessment: Assessment of consequences of the disaster situation, cascading effects and interacting hazards, prevention or mitigation measures and contingencies. In order to reflect the respect for autonomy of the user the underlying criteria and decisions for the selection of this kind of information shall be made visible.

(c) Scenario matching: Many natural disasters have similarities in occurrence, behavior and impacts that require a similar strategic and tactical response. Access to similar scenarios shall support the application of lessons learnt from past events. The suitability of a scenario parameter for matching has an impact on the relevance of the parameter in the model. For instance, the entity 'hazard intensity' has no relevance for the model as it implies no information on the actual impact and response. In order to define the ground for similarities, the matching results shall make the used matching parameters transparent.

(d) Analysis of possible futures: 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.

(e) Cross-stakeholder cooperation and communication: A major goal is to form a common vocabulary for cooperation, based on standards of DRR and emergency management. For instance, the definitions of the Incident Command System (ICS) have to be considered. At the same time, agency-specific tactical information has to be considered. Experience and knowledge from managing extreme and complex disasters needs to be exploited and shared among other emergency actors.

(f) 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.

Findings and implications on the scenario model will be summarized in a table in the final paper. Based on the identified implications, we have updated the conceptual model. There's still research to do in finding ways to populate the scenario model with other vocabularies, e.g. used in DRR. 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, (b) perform simulations and impact assessment for different alternative scenarios and (c) compare scenarios with each other. These implementations will undergo demonstrations and 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 feedback to be the basis for further refinements of our conceptual model.

Keywords: Disaster Management, Disaster Scenario, Response Planning, Strategic Planning, Scenario Matching, Interoperability, EDXL

References

1. ECHO (Directorate-General for European Civil Protection and Humanitarian Aid Operations; European Commission): Overview of natural and man-made disaster risks the European Union may face. Publications Office of the European Union, Luxembourg (2017)
2. HEIMDALL Project Homepage, http://heimdall-h2020.eu/, last accessed 2018/05/20 (2017)
3. Amer, M., Daim, T.U., Jetter, A.: A review of scenario planning. In: Futures 46, 23-40, https://doi.org/10.1016/j.futures.2012.10.003 (2013)
4. Hristidis, V., Chen, S., Li, T., Luis, S., Deng, Y.: Survey of data management and analysis in disaster situations. In: Journal of Systems and Software, Vol. 83(10), 2010, Pp. 1701-1714, https://doi.org/10.1016/j.jss.2010.04.065 (2010)
5. Pottebaum, J., Schäfer, C., Kuhnert, M., Behnke, D., Wietfeld, C., Büscher, M, Petersen, K.: Common information space for collaborative emergency management. In: Proceedings of the IEEE International Symposium on Technologies for Homeland Security 2016. Waltham, MA, USA (2016)
6. OASIS Emergency Management TC. https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency, last accessed 2018/05/28.
7. Barros, R., Kislansky, P., Salvador, L., Almeida, R., Breyer, M., Pedraza, L. G., & Vieira, V.: EDXL-RESCUER ontology: an update based on Faceted Taxonomy approach. In: Proceedings of the Brazilian Seminar on Ontologies (ONTOBRAS 2015), São Paulo, Brazil (2015).
8. Kantorovitch, J., Giakoumaki, A., Korakis, A., Papadopoulos, H., Milis, G., Kolios, P., Staykova, T.: Knowledge modelling framework. In: Proceedings of 2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM), Rennes, 2015, pp. 145-151, doi: 10.1109/ICT-DM.2015.7402037 (2015).
9. Malizia, A., Onorati, T., Diaz, P., Aedo, I., Astorga-Paliza, F.: SEMA4A: An ontology for emergency notification systems accessibility. In: Expert Systems with Applications, vol. 37, issue 4, pp. 3380-3391 (2010).
10. Lendholt, M., Esbri, M., Hammitzsch, M.: Interlinking national tsunami early warning systems towards ocean-wide system-of-systems networks. In Proceedings of the 9th international ISCRAM conference, Vancouver, Canada (2012).
11. Mulero Chaves, J., Raape, U., Mendes, M., Ladoire, T., Pantazis, S., Podolski, H, Vilalta, O., Van Setten, W., Campo, R.: Integrated Open Service Platform for Enhanced Risk and Emergency Management: the PHAROS Solution. In: Proceedings of the International-Emergency-Management-Society (TIEMS) 2015 Annual Conference (2015).
12. Dorfinger, P., Tüllenburg, F., Panholzer, G., Pfeiffenberger, T.: A Flexible Self-Aligning Communication Solution for Multinational Large Scale Disaster Operations. In: Proceedings of the ICN 2015: The Fourteenth International Conference on Networks, April 19 - 24, 2015 - Barcelona, Spain (2015).

13. Dogac A., Kabak Y., Bulca A., Namli T., Erbas C., Yilmaz B., Tuncer F.: RECONSURVE: JC3IEDM and EDXL based Emergency Management Service Oriented Architecture for Maritime Surveillance. In 22nd annual eChallenges e-2012 Conference & Exhibition, October, 2012, Lisbon, Portugal (2012).
14. Rieser, H., Dorfinger, P., Nomikos, V., Papataxiarhis, V.: Sensor Interoperability for Disaster Management In: Proceedings of the Sensor Applications Symposium (SAS2015) Zadar, Croatia (2015).
15. Božić, B., Gençtürk, M., Duro, R., Kabak, Y., Schimak, G.: Requirements Engineering for Semantic Sensors in Crisis and Disaster Management. In: Proceedings of ISESS 2015, IFIP Advances in Information and Communication Technology, AICT-448, pp. 397-406 (2015)