

Chapter 14

A Distributed Scenario–Based Decision Support System for Robust Decision–Making in Complex Situations

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ABSTRACT

Decision-making in emergency management is a challenging task as the consequences of decisions are considerable, the threatened systems are complex and information is often uncertain. This paper presents a distributed system facilitating better-informed decision-making in strategic emergency management. The construction of scenarios provides a rationale for collecting, organising, and processing information. The set of scenarios captures the uncertainty of the situation and its developments. The relevance of scenarios is ensured by gearing the scenario construction to assessing alternatives, thus avoiding time-consuming processing of irrelevant information. The scenarios are constructed in a distributed setting allowing for a flexible adaptation of reasoning (principles and processes) to both the problem at hand and the information available. This approach ensures that each decision can be founded on a coherent set of scenarios. The theoretical framework is demonstrated in a distributed decision support system by orchestrating experts into workflows tailored to each specific decision.

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INTRODUCTION

The growing complexity of contemporary industrial production systems in conjunction with an increased vulnerability clearly indicates the need for a well-structured risk and emergency management (Cruz, Steinberg, & Vetere-Arellano, 2006). In industrial production, emergencies are frequently caused by singular large-scale high impact events and confront society, economy and environment with substantial consequences (Cutter, 2003). Decision-making in emergency management presents all experts involved with demanding challenges, which stems to a great extent from the situation's complexity (Papamichail & French, 2005). This complexity arises from several sources. First, information from different domains and disciplines, such as natural and engineering sciences, medicine, law and economy, about the concerned systems or processes needs to be combined. Additionally, the information available is prone to be uncertain: it is frequently not (yet) confirmed, noisy, uncertain, or lacking (Cutter, 2003; Wright & Goodwin, 2009). Second, a consensus taking into account the objectives and value judgments of numerous actors must be found. Often, the objectives are conflicting and tradeoffs need to be made.

Two types of decision support systems have been developed to handle both types of complexity: the first due to the complexity of and the uncertainty about the system under scrutiny, the second due to the complex structure of the decision makers' preferences and objectives. *Scenario-based approaches* help the decision makers in structuring the information on the emergency and its possible developments. *Decision support systems* modelling all actors' perception of the decision problem have proven useful for reducing the complexity in the evaluation of decision alternatives (Papamichail & French, 2005).

This paper presents a method exploiting the integration of scenarios and Multi-Criteria Deci-

sion Analysis (MCDA) in a distributed decision support system addressing medium to long term emergency management. This approach has several phases. First, scenarios tailored for the decision at hand need to be constructed. Second, these scenarios must be evaluated and the results must be presented to the decision makers in an easily understandable manner. Both steps of the process are complementary in the sense that the development of scenarios is geared to assessing decision alternatives, while MCDA serves as a mechanism to evaluate and prioritise scenarios. Thus the integrated SBR & MCDA approach helps avoiding information overload, time-consuming analysis and processing of irrelevant information while ensuring that each single scenario as well as the set of scenarios is sufficiently rich to be a valid basis for the decision-making. Furthermore, unlike in standard scenario approaches, constraints with respect to the time, information and expertise available are respected.

The paper is structured as follows. The next section discusses the notion of robustness and discusses briefly some approaches used to support robust-making in emergency management. We give a general explanation on how a decision problem can be structured via directed acyclic graphs (DAGs). Particularly, it is highlighted that the use of DAGs facilitates the implementation of the scenario construction on basis of a service-oriented approach. Next, we describe the construction of scenarios. This procedure includes two steps. First, workflows that link locally available expertise and thereby structure the flow of information are created. Second, the resulting DAG is used as the basis for the construction of scenarios that fulfill a set of quality requirements as well as possible, given limited time and availability of experts. We show how this approach facilitates decision-making under severe (i.e., non-quantifiable) uncertainty. An example developed together with experts and users from the Danish Emergency Management Agency (DEMA) high-

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