# A model driven system to support optimal collaborative processes design in crisis management

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## ABSTRACT

This paper presents a system dedicated to support crises managers that is focused on the collaboration issues of the actors involved in the response. Based on context knowledge, decision makers' objectives and responders' capabilities, the system designs in a semi-automatic way a set of collaborative process alternatives that can optimize coordination activities during an ongoing crisis resolution. The technical design of the system mixes optimization algorithms with inference of logical rules on an ontology. Candidate processes are evaluated through multi-criteria decision analysis and proposed to the decision-makers with associated key performance indicators to help them with their choice. The overall approach is model driven through a crisis meta-model and an axiomatic theory of crisis management.

### Keywords

Crisis management, collaborative process design, model driven process design, inter-agencies coordination.

## INTRODUCTION

Management of critical situations such as natural disasters or industrial incidents still represents a major challenge for our society. Indeed, during the last decade, crises killed on average more than 100,000 people per year according to the last statistical review of the international Emergency Event Database (Guha-Sapir, Hoyois, Below, 2012).

Many researchers have studied past emergency events to improve their management and so reduce their catastrophic consequences. Most of the practitioners (Altay, Green, 2005) refer to crisis management through four phases: prevention, preparation, response and recovery. The system targeted by this study mainly addresses response and recovery phases. It aims to support decision-makers by proposing them collaborative processes that coordinate involved stakeholders in an optimal way during the ongoing crisis resolution.

The organization of this article is the following: first, a brief overview of collaborative crisis management issues brings to light problems that usually limit the efficiency of stakeholders during critical situation resolution. The following section presents how collaborative process building can solve these issues. The third section describes a decision support system dedicated to design optimal collaborative crisis management processes. The technique used to design the collaborative processes and to guarantee that these processes are adapted to the ongoing crisis is also described. Finally, a concluding section sums up the added value of the project and introduces some perspectives. This paper purposefully remains at a conceptual level, due to the incompatibility between an in-depth analysis and the imposed paper limit.

## COLLABORATION ISSUES IN CRISIS MANAGEMENT

In this study, a crisis is defined (CCA, 2009) as a situation that has long-term consequences due to an event that has caused extensive damage and losses resulting in an interruption of one or more critical activities within some part of the world.

When such a crisis occurs, many actors (emergency services such as fire department or police, organizations, companies…) are involved in responding to it. Management of such a response is generally charged to a so called *emergency committee* composed of crisis stakeholders: one or more decision-makers assisted by relevant actors and experts according to the situation. Often, these stakeholders are both heterogeneous (at cultural, functional and technological levels) and poorly, if at all, trained to work together in the evolving context. This leads to critical collaboration issues that may strongly limit the efficiency of their collective actions. This point is highlighted by a large body of feedback from past crises (Guedj, 2009), which shows that coordination maturity between stakeholders is the limiting factor in crisis management.

An attempt to address these issues consists in drawing preventive contingency plans. Unfortunately, such plans, if tailored to foreseeable situations, are not relevant to solve crises (almost by definition) as actual situations often diverge from planned ones. The inadequacy of such plans in the face of real situations has been observed by many practitioners and justifies Dwight D. Eisenhower famous quote “Plans are nothing; planning is everything”.

Consequently, appropriate collaboration between heterogeneous actors in an unpredictable crisis context is a major challenge that decision-makers must overcome.

## COLLABORATIVE PROCESS IN CRISIS MANAGEMENT

Collaborative process driven management is potentially a powerful tool in a crisis context because it solves the issues identified above. It improves collaboration maturity between emergency committee members as it forces a shared common viewpoint of the situation. Indeed, stakeholders must agree on the crisis context, the objectives they want to achieve as well as their available capabilities.

A collaborative crisis management process is a process which orchestrates – or choreographies – activities to be performed by different organizations. It contains all activities that should be deployed to solve the ongoing crisis and meets all the high level objectives, constraints and preferences of the decision-makers. Such a process overcomes the limitations of preventive contingency plans as it is designed specifically for a real emergency situation.

Based on the stakeholders shared knowledge, an optimal collaborative crisis management process could be generated. Nevertheless, gathering crisis knowledge and transforming it into such a process in a specific crisis context is still a difficult task. As a time-honored principle to solve knowledge-intensive problems, model driven engineering is a good candidate to achieve it. It helps stakeholders to formalize the problem through various models and turns them into new ones which contribute to find the crisis solution. Stakeholders’ willingness to cooperate and share information is assumed as it is required to design efficient models.

## MODEL DRIVEN DESIGN OF OPTIMAL COLLABORATIVE CRISIS MANAGEMENT PROCESSES

The ISyCri project sponsored by the French National Research Agency (Truptil, Bénaben, Chapurlat, Hanachi, Pignon, Salatgé, 2009) and (Truptil, 2011) have demonstrated conceptual feasibility of semi-automatically designing collaborative processes based on modeled crisis knowledge to support decision-makers in crisis management.

The present work (see figure 1 below) extends the scope and functionality of these results. It contributes to the state of the art by adding evaluation mechanisms to them. The proposed system helps the stakeholders to model the crisis context, the objectives they expect to achieve and the responders’ capabilities. Using these data as inputs, the system then elaborates collaborative process alternatives based on emergency committee preferences and some predefined design constraints. These processes are evaluated according to a multi-criteria decision analysis model and optimized. Processes are presented to decision-makers with associated key performance indicators to help them choosing the one they want to execute. See (Belton, Stewart, 2002) for a multi-criteria decision analysis overview.

Agility is ensured by re-performing the design mechanisms as soon as the context (situation, actors’ capabilities, objectives…) is modified.

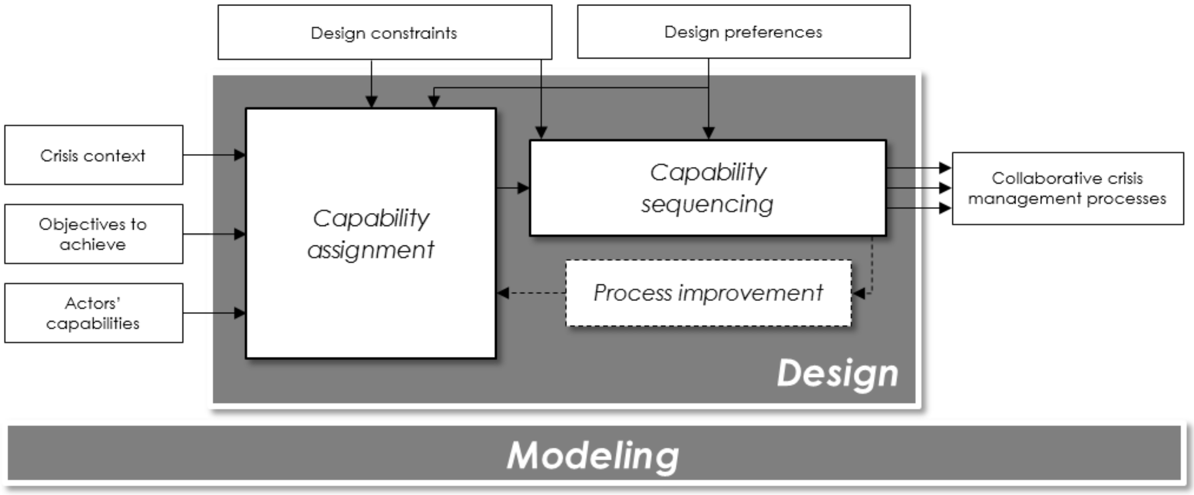


**Figure 1. A decision support system to design optimal collaborative crisis management processes**

## Problem modeling

### *A model driven approach*

Modeling the problem with the relevant granularity and completeness is the keystone of the proposed approach. This requires formalizing the entire problem in such a way that it can be both shared amongst emergency committee members and be processed by a computer at the same time. Furthermore, it must be proven that this formalization is sufficiently descriptive to deduce collaborative processes capable of solving the ongoing crisis.

In order to meet these requirements, as usually done in model driven systems, the complete problem is formalized through a meta-model. This meta-model contains all the required concepts to produce the *crisis context*, *objectives to achieve*, *actors' capabilities*, *design constraints*, *design preferences* and *collaborative crisis management processes models* represented in figure 1. This crisis meta-model extends the existing ones (Macé Ramète, Lamothe, Lauras, Bénaben, 2012; Rajsiri, 2009) by adding such concepts (required by the system) as sharable resources, emergent collaborative capabilities and possible worlds. Possible worlds are one of the core concepts used in this study; see (Menzel, 2013) for a full description.

On top of that, an axiomatic theory of collaborative crisis management is designed. It provides the ability to prove that the defined meta-model has enough expressive power to support collaborative crisis management processes elaboration and highlights logical rules that need to be triggered during the design phase. Moreover, the meta-model can also be tested – for validation – with practitioners through use-cases by modeling crises and evaluating the produced models.

### *Modeling crisis context, decision-makers' objectives and actors' capabilities*

The *crisis model* represents the part of the world in crisis. It contains elements produced by a risk analysis as well as components of the portion of real world impacted by them. Assuming the ability of decision makers to define their objectives and the related key performance indicators into the *objectives to achieve model,* the *actors' capabilities model* captures concepts such as stakeholders' capabilities and related resources. In real context of crisis management, practitioners often write such information on a flip chart. It is expected that formalizing the problem through models will take the same amount of time thanks to efficient tools.

Once the problem is formalized, models are injected into a crisis ontology (see (Grubber, 1995) for a complete definition) containing crisis management patterns as well as models and feedback data from past crises managed by the system.

The collaborative crisis management processes that result are highly dependent on the quality of these user-made models. Consequently, the proposed system first runs logical rules on the ontology via an inference engine to check the quality of the stakeholders' models in order to propose adjustments if necessary.

#### *Modeling design constraints and preferences*

A predefined *design constraints model* imposes some properties on the designed solutions. These properties can be operationally driven such as the *realisability property* enforcing solutions to be effectively executable by crisis actors in regards to their available capabilities and related resources. Furthermore, some properties are justified by technical reasons thus assuring that the system is able to find solutions in a reasonable time (a few minutes on a standard computer).

The *design preferences model* is used to define what an optimal solution is from the decision-makers viewpoint. These preferences drive the design through a multi-criteria decision analysis. Decision-makers can choose predefined evaluation models or create custom ones. For instance, the system may be configured to design the fastest solutions or the cheapest ones. Moreover, it can also design custom solutions such as the “best” processes according to feedback from past crises while minimizing requests of a particular resource.

### Optimal collaborative crisis management processes design

Building processes that are not only admissible (by respecting the design constraints) but also optimal (in line with the evaluation model) is quite complex. The design box in figure 1 illustrates how the system solves this problem. First, actors’ capabilities are assigned to decision-makers’ objectives. Next, these capabilities are sequenced to form collaborative crisis management processes. Optionally, some process improvement mechanisms may be executed if necessary (see below “Handling non optimal cases”).

#### *From models to capability assignment*

The capability assignment algorithm aims to identify the best capabilities that should be executed to reach the state of the world targeted by the decision-makers from the current state of the world. Unfortunately, testing all the capability assignments that can be generated from the crisis ontology is not computably practicable because of the combinatorial complexity it involves.

The system uses the *design constraints model* to reduce the set of capability assignments by eliminating non admissible ones. Once all the constraints have been applied, building the remaining capability assignments is achievable. This is possible thanks to technically driven properties imposed by some constraints such as the *island driven search property* that greatly reduces combinatorial complexity (see (Pool, Mackworth, 2010) for an in-depth description).

The *island driven search property* enforces the condition that possible worlds defined by decision-makers’ objectives must be successively reached during the execution of a capability assignment by responders. This property allows the system to look for all the partial capability assignments between two successive objectives rather than all the capability assignments between the initial state of the world and the targeted one. This is operationally acceptable as objectives are defined by the emergency committee. As solutions might suffer from a poor objective choice, the system implements an island driven search variant allowing some objectives to be skipped if it improves the results.

Finally, an expert system infers some logical rules on the crisis ontology to build the best partial capability assignments according to a multi-criteria evaluation model (as well as the best capability assignments added by the previously mentioned variant).

#### *From capability assignment to collaborative crisis management processes*

Next, the system designs global capability assignments (from the initial state of the world to the targeted one) aggregating all the partial capability assignments generated from the crisis ontology.

Global capability assignments are then sequenced to form collaborative crisis management processes. While building these processes, the system maximizes capability parallelization, as time is often a critical factor in crisis context. In fact, the algorithm sequences capabilities according to objectives priority while maintaining the *realisability property* by respecting some rules such as “do not exceed any responder maximum workload”.

Lastly, all the collaborative processes are evaluated through multi-criteria decision analysis thus allowing the system to present the optimal one (or the preferred ones) to stakeholders. Nevertheless, it should be mentioned that optimality is not always achievable depending on the *design preferences model* used. In these cases, the system implements a best effort behavior providing processes supposed good by design as described in the next section.

### *Handling non-optimal cases*

Evaluation criteria that can only be valuated when the whole process is designed are difficult to handle, as they lead to intractable problems for which it is impossible to find optimal solution in reasonable time. To manage these cases, the system performs a trade-off between optimality and computability by adapting the criteria prior to running the previously described steps. Designed processes are then recursively improved thus mitigating the performed trade-off. Once processes are considered as satisfactory, they are presented to decision-makers.

## CONCLUSION AND FUTURE WORK

The system described throughout this article is dedicated to support decision-makers in crisis management. It provides modeling tools to formalize the overall crisis context, the objectives to be achieved as well as the capabilities of the actors involved in the response. Based on this knowledge, it designs and proposes (taking into account design constraints and end-user preferences) collaborative processes to be implemented by the actors to resolve the ongoing crisis. Due to the model-based approach, the mechanisms developed guarantee both adaptability to the real life context and optimality regarding the decision-makers operational objectives.

Feasibility studies have proved that methodology and mechanisms proposed in this paper are fully implementable. Future work will include the development of the system based on a client/server architecture. As a result, practitioners will only need a web browser to use the system. Such an architecture will allow it to be fastly deployed anywhere – as critical situations often requires. Furthermore, the prototype will be tested through various sets of use-cases, verified during full-scale crisis management exercises, and validated based on extensive practitioners' feedbacks. Later, it might be connected with related works such as the ones focused on agility management in emergency contexts (Bénaben, Lauras, Truptil, Lamothe, 2012).

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