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A Formal Framework for Crisis Management describing information flows and functional structure

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Abstract

Crisis management is a very empirical activity, most of the time based on human ability to deal with the unexpected and to fusion all kinds of information to provide the best decision and the best associated action. However, the information flows and the high level activities are not so well described. This article aims at providing a formal framework describing these elements. The presented framework is the basement for the establishment of a software suit dedicated to formally manage information flows in crisis context and exploit them to provide crisis managers with a computerized decision support system. Even if this software system is not the topic of the paper, it is the justification for the presented structuring framework. The framework is based on two main structuring elements: the nature of available or required information and the functions that should be able to use them to provide crisis management domain with a relevant decision support system.

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1. Introduction

There are several definitions of Crisis ([1] and [2]). In this article, we consider the following one (from [3]): Crisis can be considered as *a disruption within the state of a system, which reveals instability and discontinuity and which requires a specific treatment to deal with the unwanted consequences and to obtain a new acceptable state of the considered system*. Besides, this article considers the notion of *Crisis Management* from a functional perspective, considering consequently that there is a knowledge background necessary as input to perform this global function. Therefore, the overall purpose of this article is to define a formal framework dedicated to define (i) main functions and (ii) information flows of crisis management.

The article is structured according to the following parts: Section 2 describes a formalized vision of crisis in terms of required information to characterize significantly such a situation. Section 3 presents a functional decomposition of crisis management. Section 4 introduces the information flows associated with the functions presented in section 3. Section 4 draws some conclusions and consequences of the framework described in the previous sections.

2. Characterization of crisis concept

For the last ten years, there have been a lot of research works attempting to formalize knowledge in the field of crisis management (see for instance [4], [5], [6] and [7]). In this article, the background metamodel is the one presented in [3] (that inherits mainly from [7]) but can be considered as ensuring consistency with most of the others. Based on this result, the characterization of a crisis situation, in the perspective of crisis management, requires to describe: (i) the *context* of the crisis situation (where? What perimeter? What stakes are concerned? Etc.), (ii) the potential *partners* that can be mobilized and

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invoked (who? What capacities? Which availability? Etc.) and (iii) the *objectives* associated with the faced situation (what? Which facts on the crisis site? Which risks on the crisis site? Etc.). As a minimal vision we need to describe the following elements:

- *Context*: including the description of *intrinsic risks* (risks specifically associated to the impacted part of the world) and *stakes* (population, goods and others valuable elements of the impacted part of the world).
- *Partners*: including the description of the *functions* the partners are able to provide the crisis management with.
- *State*: including the actual *effects* on the crisis site (such as injured people or destroyed facilities) and the *emerging risks* (risk specifically appeared with the crisis situation and which were not conceivable before).

Furthermore, in a very classical meaning, *Crisis* may be considered from the three following points of view:

- *Location and Perimeter*: This is usually the easiest criterion to obtain. Actually, it describes the geographical area impacted by the crisis situation.
- *Gravity*: This criterion describes the importance of the crisis. However, it is difficult to have rigorous and relevant evaluation, especially in terms of used units. Some authors suggest to use money or victims or even minutes on TV news shows.
- *Type*: This criterion describes the nature of the crisis. It is also very difficult to define due to the different taxonomies and hierarchized structures of disaster types. Besides, it is also difficult to have a continuum of crisis types (it is easy to define a list of independent types). Some authors suggest using the level of human responsibility to build this continuous scale of crisis types.

Finally, the crisis concepts can be characterized easily with (location, gravity, type) but for crisis management, it should be characterized with (context, partners, objectives).

3. Functional description of crisis management

To perform a relevant and efficient crisis management, the three main objectives are: to *define the response*, to *realize the response* (considering that it is not because the response schema is correctly described that it will be performed) and to *maintain the response* (considering also that the crisis situation may evolve or the crisis response may not have the expected consequences). In the following, these three objectives will be described as functions, based on the description of a crisis situation from section 2.

First, let's consider *O as a set of crisis management objectives* O_i (mainly "prevent a risk" or "treat an effect"), *F as a set of partners functions* F_i and *P as a set of crisis management business processes* p. So, we can describe:

$$Define: O^n \times F^n \rightarrow P$$
$$([O_1, \dots O_n], [F_1, \dots F_n]) \mapsto p = the\ process\ reaching\ the\ objectives\ with\ the\ available\ functions$$

The *Define* function is in charge of taking into account the actual objectives of the management of the crisis situation (the objective vector) and the available functions of partners (the function vector) to build the business process dedicated to reach these objectives with these functions. Obviously, there might be several processes built through several invocation of the *Define* function.

$$Realize: P \times F^n \times O^n \rightarrow O^n$$
$$(p, [F_1, \dots F_n], [O_1, \dots O_n]) \mapsto [O'_1, \dots O'_n]$$
$$= the\ status\ of\ the\ objectives\ updated\ on\ the\ fly, according\ to\ the\ progress\ of\ the\ process$$

The *Realize* function is in charge of performing the process built by the *Define* function. Consequently, it is dedicated to invoke the relevant functions of partners according to the schema proposed by the process. Furthermore, the *Realize* function continuously provides as well a set of updated objectives. These objectives are the expected status of the crisis situation according to the progress of the process (*i.e.* the expected situation at this stage). There might be several executions of several processes through several invocation of the *Realize* function.

$$Maintain: O^n \times O^n \times F^p \rightarrow P$$
$$([O_1, \dots O_n], [O'_1, \dots O'_n], [F_1, \dots F_n]) \mapsto p' = the\ process\ that\ fits\ the\ best\ with\ updated\ objectives$$

The *Maintain* function is in charge of performing agility in the response. Actually, this function aims at comparing the expected situation (objectives provided by the *Realize* function) and the real situation (objectives from the picture of the situation). So, this function compare both these sets of objectives and then, according to the potential differences between these sets of objectives, it uses the *Define* function, the set of current objectives and the set of functions to infer a new process, more adapted to the current situation.

These three functions are absolutely not obvious. However, they are delimitating and defining the exact functional actions to be performed in crisis management context. They are also describing the inputs and outputs of such functions to contribute to define information flows.

4. Information flows related to the functions of crisis management

The objective of this section is mainly to make the link between section 2 (characterization of crisis situation) and section 3 (exploitation of the characterization of crisis situation to perform crisis management). From the three crisis management functions described in section 3, we know that the expected inputs to perform crisis management are: the set of available *functions* and the set of *objectives* (constantly updated). Actually, with these elements, and supposing that the *Define*, *Realize* and *Maintain* functions exist and provide the described services, it is possible to achieve crisis management. Consequently, the main question is: How to get these two sets of elements? To answer this question, we need first to remember that it is usually easy to know the *location*, the *gravity* and the *type* of the crisis. Second, we need to understand that from this information, we can infer the *context*, the *partners* and the *state* of the crisis situation. Actually, the four following functions represent this matter of fact. First, let's consider *G as the set of geographical/social areas l* (used to describe the location and the perimeter of a crisis situation), *T as the set of types of crisis situations t* (such as natural disaster, industrial accident, terrorist attack, etc.) and *the g gravity defined as a value between 0 and 1* (no matter how it is calculated). Let's also consider *S as the set of stakes* S_i (as defined in section 2), *IR / ER as the set of intrinsic / emerging risks* IR_i / ER_i (as defined in section 2), and *E as the set of effects* E_i (as described in section 2). Accordingly, we can describe:

$$Function: G \times T \times]0,1[\rightarrow F^n$$
$$(l,t,g) \mapsto [F_1, \dots F_n] = the\ set\ of\ available\ and\ invocable\ functions$$

The *Function* function is in charge of delimitating the impacted subpart of the world to infer, from the type and the gravity as well, the available responders and their competencies.

$$Stake: G \times T \times]0,1[\rightarrow S^n$$
$$(l,t,g) \mapsto [S_1, \dots S_n] = the\ set\ of\ potentially\ impacted\ stakes$$

The *Stake* function is in charge of delimitating the impacted subpart of the world to infer, from the type and the gravity as well, the possibly threatened stakes in the area.

$$IntrinsicRisk: G \times T \times]0,1[\rightarrow IR^n$$
$$(l,t,g) \mapsto [IR_1, \dots IR_n] = the\ set\ of\ intrinsic\ risks\ to\ take\ into\ account$$

The *IntrinsicRisk* function is in charge of delimitating the impacted subpart of the world to infer, from the type and the gravity as well, the intrinsic risks to consider in the area.

$$Objective: S^n \times IR^n \times ER^n \times E^n \rightarrow O^n$$
$$([S_1, \dots S_n], [IR_1, \dots IR_n], [ER_1, \dots ER_n], [E_1, \dots E_n]) \mapsto [O_1, \dots O_n]$$
$$= the\ set\ of\ objectives\ of\ crisis\ management, based\ on\ all\ concerned\ risks, effects\ and\ stakes$$

The *Objective* function is in charge of identifying the entire list of objectives of the crisis management by considering all risks (intrinsic and emerging ones), all effects and impacted stakes as well.

Among these four functions, the three first ones are very similar: delimitating a geographical/social area impacted by an identified crisis (in terms of type and gravity) in order to infer the available *functions*, the concerned *intrinsic risks* and the threatened *stakes*. The fourth one concerns the aggregation of risks and effects (with regards to impacted stakes) to build a set of objectives (in the meaning of section 3, *i.e.* mainly "prevent a risk" or "treat an effect") to drive the management of the crisis.

Similarly to the previous section, these functions are definitely not obvious, however, considering that they might be performed in the frame of information gathering and fusion, these functions show that by gathering information regarding the *location*, the *type* and the *gravity* of the crisis situation, associated with the set of *emerging risks* and *effects* of the crisis, it is possible to obtain the *functions* and *objectives* required for the whole crisis management (as stated in the beginning of this section). Obviously, this implies to have the four functions *Function*, *Stake*, *IntrinsicRisk* and *Objective* to perform efficiently their duty.

5. Conclusion

This article mainly defines a functional structure of crisis management, identifying the information flows as well. This functional structure is an abstract and generic vision of the crisis management activity: it introduces what could be a formal and relevant computerized system, dedicated to support efficiently crisis management and provide decision makers with a decision support system.

The following pictures presents this framework as a functional diagram (flow-oriented) where: (i) the input information identified in section 2 are used as inputs for the whole structure, (ii) the functions introduced in section 3 are grouped in the "crisis management" box, and (iii) the functions described in section 4 are distributed in the "Crisis definition" and "crisis analysis" boxes.

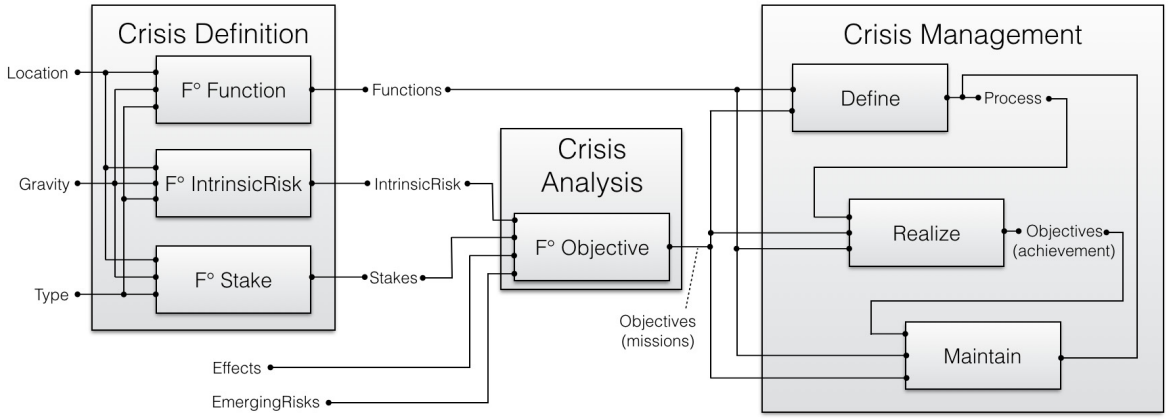

Fig. 1. Big-Picture of the presented framework for crisis management.

There are two main steps following this first result: The first one is about analysing this framework and deducing the consequences of this structure. For instance, considering that critical information (to initiate the crisis management process) has been identified, what would be the technological solution able to feed the crisis management with this information? (Social networks? Sensors? Opendata? Etc.). Similarly, considering that required functions have been identified, what could be the theoretical and practical solutions to implement such functions? Which ones should remain human-based? This first step would allow defining precisely the requirements and specificities of the technological platform able to support crisis management efficiently. In [3], an analysis based on statements and conclusions of [8] claims that in crisis management domain, the lower level (data gathering) and the upper level (information exploitation) are very open area. This is clearly different from industrial domain where data sources and objectives are usually well known. Consequently, the whole data management chain could not be (entirely) based on the same approach and tools. Actually, an interpretation layer is mandatory to transform raw data (extracted from social networks, sensors, open data, human reports, etc.) into formalized situation models. This step is definitely specific to domains with open lower and upper layers. The second step concerns obviously the implementation itself to obtain such a technological platform. The unavoidable dynamicity of crisis management implies to use an agile platform (as exposed by the function "maintain" and the associated control loop(s)). Service Oriented Architecture (SOA) and Event-Driven Architecture (EDA) are relevant options to implement such a platform. A proposal for an agile crisis management platform based on the framework presented in this article and based on those technologies paradigms is described in [9]. Of course, there are also plenty of discussions to have about the limits of the presented framework and the specific natures of crisis or management approaches it is appropriate for.

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