Towards an Organizational and Socio-Technical Context-Aware Adaptation of Emergency Plans

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ABSTRACT

In France, facilities listed under environment protection regulations are required to draw up emergency plans. During a crisis situation, facing an unexpected event, these plans may be irrelevant. They have to be adapted to the current crisis situation and its observed or anticipated evolutions, using data emitted by the crisis ecosystem. But this adaptation requires lots of effort and is time-consuming. This article aims at presenting an approach to ensure the dynamic adaptation of emergency plans. We propose to identify generic configuration variables (representing interactions of physical phenomena and human factors on the facility) and to feed these configuration variables by collecting and processing data emitted by sensors, social networks, official reports, etc. Therefore, emergency plans could natively integrate agility by their ability to detect and take into account a change in the crisis situation and decision makers will be supported since the early stage of the crisis response.

Keywords

Agility, context awareness, emergency plan, preparation, response.

INTRODUCTION

In France, any facility –from industrial sites, farm businesses to universities – that is likely to result in hazards or pollution, especially regarding the health and safety of the border residents, is a classified facility(*Code de l'environnement - Article L511-1* 2011). The French national government defines and frames the procedures related to ICPEs ("Installations Classées pour la Protection de l'Environnement")[1]. The government requires from (i) operators to draw up an internal emergency plan and (ii) competent authorities (Prefect) to draw up an external emergency plan. This is to minimize and reduce the risks and their associated consequences in the case of the most hazardous ones: ports, refineries, nuclear plants, underground gas storages, large dams, microbiology laboratories, upper tier sites of the SEVESO III Directive, and any facility that has been classified by decision of the Prefect[2].

All these emergency plans are based on risk assessment and alert pattern analysis. They describe human and material resources to be deployed to coordinate action for rescue and relief facing a crisis situation. The Internal

[1] This can be understood as "Classified Facilities for the Protection of the Environment", meaning facilities requiring environmental impact assessment.

[2] State's representative of the lowest level of administrative divisions of France.

Operation Plan (implemented by the operator) has to define the organization and internal resources to control an accident within the boundaries of the site. It prescribes the organization, resources and intervention strategies by analyzing potential accidents. These potential accidents can be specific to one facility or generic. The Specific Response Plan, established by the Prefect, involves public emergency services (firefighters, police, emergency medical services), all State services, municipalities and private players (associations, network operators, etc.). To define the operational measures and scope of the Specific Response Plan, all hazardous phenomena and their effects should be taken into account through scenarios, regardless of their intensity and probability. These scenarios determine the population protection and intervention strategies to be adopted, according to the nature and scale, seriousness and kinetics of the effects. In the case of an accident exceeding the boundaries of the facility, the Prefect assumes leadership of emergency operations by implementing the measures prescribed in this plan. Cities and villages close to classified facilities are also required to draw up emergency plans called Community Protection Plan and Specific Safety Plan. The following Table 1 presents the vertical granularity of the French emergency plans. Levels are activated upon the perimeter of the crisis situation.

Table 1. French emergency plans (by decreasing granularity)

Level	Leadership	Emergency plan(s)
National	Ministry of the Interior	ORSEC plan (national level)
Zonal	Prefect	ORSEC plan (zonal level)
Departmental	Prefect	ORSEC plan (departmental level) Specific Response Plan Specific Safety Plan
Municipal	Mayor	Community Protection Plan Specific Safety Plan
Local (ICPE facility)	Plant operator	Internal Operation Plan

Based on this, several observations are made. First, facing an unexpected event, new scenarios appear, and the established strategies (i.e. crisis response) corresponding to the defined scenarios may be not relevant (either immediately or after a while). As it is not realistic to describe and cover all potential situations to define all potential crisis responses, it is necessary to provide agility to the prepared emergency plans. In our research work, we understand the concept of agility as defined by Barthe-Delanoë et al. (2014), i.e. the ability to detect a mismatch to a given situation and to set up the required adaptation, as quickly as possible. Moreover, in a Command and Control context, agility is also seen as the ability for an organization to meet the challenges of uncertainty and complexity, as defined by Alberts (2007). Applied to emergency plans, agility is the ability to detect evolutions of the crisis situation to accurately assess risks and anticipate their effects on the selected strategies to adapt the above-mentioned strategies.

Then, as underlined by the French official report regarding feedback on crisis management, emergency plan information are underused (even during training), especially in the case of the Specific Response Plan (Direction Générale de la Sécurité Civile et de la Gestion des Crises (DGSCGC), Ministère de l'Intérieur 2013). The stakeholders ignore the prepared plans, and so the related issues (e.g. environmental concerns) and data. The same applies to the dedicated tools (mainly Geographical Information Systems) to support crisis response management, even if they are a mean to share information and visualize issues. This is due to several factors: complex documents (not necessary up to date), lack of clarity regarding the major scenario and its concerns, human factor.

The methodological and technical framework proposed in this paper is to two-fold: it aims (i) to provide agility to emergency plans to support the reconfiguration of these plans dynamically, and (ii) to make emergency plans scenarios clearer and easier to follow by the stakeholders. This framework is intended for facility operators and public authorities, both for crisis preparation and response phases. The paper presents these early stage research works as follows: first, we present in two sections respectively the need for the agility of emergency plan from the risk assessment point of view, and for context awareness. Then, the decision support platform to support the emergency plan agility is presented. Finally, the concept of configuration variables for risk assessment is detailed, before concluding in the last section.

AGILITY OF EMERGENCY PLANS

Providing agility to emergency plans comes first with the ability to detect the changes and evolutions in the description of the crisis situation, to accurately assess risks on which emergency plans are designed. In industrial processes, risk assessment is conducted through systematic risk analysis (as explained by (Kaplan and Garrick (1981)), which aims to identify possible adverse events then estimating their likelihood and their consequences.

Several methods are used to conduct such an analysis: HAZOP (HAZard and OPerability studies) (Kletz 1999), FMECA (Failure Mode, Effects and Criticality Analysis), What-if, etc. One of the main weaknesses of such methods is that they are qualitative, expert dependant, and represent risks as discrete events.

Besides, weak signals may be ignored, as methods like HAZOP cannot cope with events resulting from a combination of failures. The idea developed in this paper is thus to deduce risks or cascading effects based on the existing knowledge (from the previous situation) or capitalized knowledge from experts. This deduction could allow us to create risks' model. Moreover, modelling risks using fuzzy logic can help to define more general risks, quantitative evaluation of risks, and will facilitate reusing existing knowledge. Finally, it will also help to deal with incomplete or uncertain data regarding risk assessment, as shown in recent research works (Jamshidi et al. 2013; Petrović et al. 2014).

The social dimension and the time dimension of risks are not necessarily taken into account during the risk assessment step (Zánická Hollá et al. 2012). But social habits, the evolution of the population, the time of the day or the year may have a significant influence on the gravity of risk or the adopted crisis response. For example, an explosion occurring in a plant (with a beltway located nearby) on a Monday at 8:00 am will not have the same consequences as the same one occurring on a Monday at 11:00 am. The water level of rivers evolves depending on the time of the year and can endanger cooling systems fed by rivers. Or in some countries, during the period before Christmas, there are much more traffic jams on the roads, which will possibly delay timely rescue. It will be valuable to take into account studies, and research works about human factor and social behaviors such as the use of temporal profiles of population distribution as described in (Osaragi 2016).

The first pillar of the idea we aim to develop in our future research works is to provide agility in the design of the emergency plans through risk assessment that will (i) describe risks as continuous functions of time rather than discrete events, and (ii) take into account physical phenomena, human factor, and their possible interactions. This will help to anticipate a wider range of evolutions of the main crisis characteristics given the current situation with fewer efforts and to predict the consequences of the selected strategies.

RECONFIGURATION BASED ON CONTEXT AWARENESS

By nature and by effects of the selected crisis response to solve (or at least) reduce the crisis, crisis situations are unstable and evolutionary phenomena. Moreover, an emergency plan involves numerous stakeholders who have to work together: this is a collaborative situation. According to Camarinha-Matos et al. (2009) and Pingaud (2009), evolutions of such situations can be classified as follows: (i) evolution of context (i.e. the crisis' environment differs from the one taken into account to define the strategy) ; (ii) evolution of network (this kind of evolutions concerns the stakeholders, their abilities and or their resources) ; (iii) failure (one or several activities do not lead to the expected results, due to an incomplete initial definition of the emergency plan or an improper execution of them). It is, therefore, necessary to take into account the possible changes that can influence the emergency plan, to change it if required and to support the decision-making process of the stakeholders.

It is now acknowledged that context-awareness (Castillo 2016) is crucial to get an accurate view of an ongoing crisis situation. It can help to detect and define the evolutions of the occurring crisis situation. Various data sources emit data from the field: Open Data, social networks, sensors located in and around the facility, reports from stakeholders, local and national authorities, volunteers, etc. Moreover, new and evolving technologies are coming on the stream to allow processing of real-time measurements and information like Complex Event Processing (Etzion et al. 2015), mobile phones embedding sensors (not to mention the whole Internet of Things phenomenon). Some research works have explored this way in the domain of crisis management, as in the PRONTO project (Kaarela et al. 2011) or the PLAY project (Truptil et al. 2012).

But context-awareness should not be limited to the monitoring of technical characteristics of the crisis situation, as underlined in the NATO's technical report on C2 Agility (SAS-085 2014). It should also capture social and cognitive aspects that can challenge the defined response process, as rumors and misinterpretations of forecasts and official messages. For example, the 'cone of uncertainty' of hurricane track is often misinterpreted by the general public (Broad et al. 2007). During the hurricane Irma episode, people commented on social networks that areas out of the cone would be safe. But the cone does not represent the size of the hurricane; it is only a projection of a storm's path. In this case, these people will be reluctant to follow mandatory evacuation orders in these areas (Padilla et al. 2017) while they are not safe.

A DECISION SUPPORT TOOL TO RECONFIGURE EMERGENCY PLANS

Based on the previous observations and ideas, a decision support tool is proposed. This Dynamic Reconfiguration Platform lies in two dimensions: first, time (preparedness and response); second, agility (adaptation, detection, context awareness) (see Figure 1).

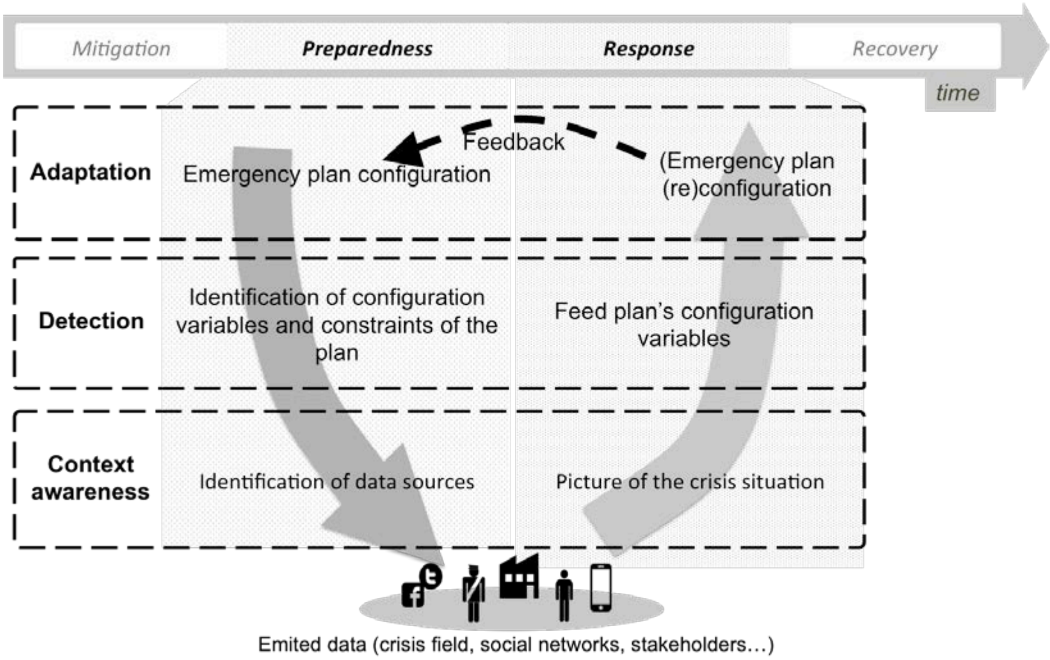

Figure 1. Principles of the proposed Dynamic Reconfiguration Platform process

At first, during the mitigation and preparation step, a generic emergency plan is designed. The emergency plan is seen here as a Constraint Satisfaction Problem (CSP). CSPs consist of a set of variables X with a set D of respective domains of value and a set C of constraints that describe allowed value assignments for variables. A solution to a CSP consists of an assignment of values to all the variables in a way that none of the constraints is violated. The variables represent physical, technical and social characteristics of the crisis situation, and the constraints the dependencies among variables. The solution is an adapted emergency plan. More evolved CSPs allow altering the original formulation of the problem to take into account evolutions of the set of constraints: constraints can be added or removed (Dynamic CSPs); constraints can be partially relaxed and the solution can comply with only a part of them (Flexible CSPs). As in crisis situation we face uncertainty and complexity, it can be difficult to satisfy all the constraints to solve the problem. This is why Flexible CSPs like Fuzzy CSPs where the satisfaction of a constraint can be a continuous function of its variables' values might be relevant to our context.

Then, potential data types and data sources are identified to feed and value these variables. When the crisis occurs, the data emitted regarding the crisis situation is gathered from these various sources (as evoked in the previous sections). All this data will provide context awareness to the emergency plans.

Indeed, it is crucial to collect relevant data. Regarding data aspects such as the volume, the variety and the velocity of the data sources, and also human factors such as the veracity and the validity but also the crowdsourcing and volunteering efforts, this part of the proposal is clearly related to the Big Data phenomenon applied to a crisis situation (Castillo 2016; Meier 2015). This will imply the use of Big Data techniques to identify, collect and process data to get a picture of the situation, which is relevant to feed the configuration variables. This picture of the situation can be a model of the current crisis situation. It has to represent at least the crisis cell (stakeholders and their activities), the crisis system itself (environment, goods, people, civilian society, risks, consequences, etc.). This model is an instance of a meta-model that has to meet the requirements of the French emergency plans regarding the crisis situation and the stakeholders' description, like the one presented in Benaben et al. (2017).

This model of the current crisis situation feeds the configuration variables. Using a constraint-programming solver engine (like Choco, http://www.choco-solver.org/), the emergency plan is configured to fit with the current crisis situation characteristics. It is then submitted to the decision makers.

From a user interface point of view, the emergency plan modelled as a CSP can be presented as a dynamic tree, with questions/answers, using the visualization interface of the constraint-programming interface. The nature and number of questions will evolve, depending upon the answers, as some decisions to be taken are only relevant depending on a previous choice.

IDENTIFYING CONFIGURATION VARIABLES

As presented before, we aim at using configuration variables and constraints to adapt the emergency plans to the current situation. The major issue here is to identify relevant configuration variables and constraint. What are the relevant risks based on physical phenomena, human factors, combination of both, etc. that can be identified in crisis situation implying ICPEs? Solving this problem requires exploring a large amount of data, from experts' interviews, existing emergency plans, to feedbacks from past crisis situations. Then, once identified, they have to be defined quantitatively, as function of time, etc. (as explained previously).

Finally, we also have to identify the "winning strategies", i.e. the relevant answers facing an identified risk and also their possible interactions, in order to build the constraints of the CSP. As stated before, the constraints represent the dependencies among variables (i.e. the physical, technical and social characteristics of the crisis). This way, with the help of consistency algorithms, the size of the search space is reduced. To this end, we envision to combine various techniques to automate knowledge retrieval from text documents (such as the existing plans and official reports from past exercises and accidents), using Natural Language Processing, as in (Zhang et al. 2017) combined with the ontology based on the above-mentioned meta-model (Benaben et al. 2017), and knowledge alignment (Wang 2015). Interviews of stakeholders (in the broad sense: authorities, plant owners, rescue services, citizens) are also envisioned, especially to capture knowledge about human factor.

CONCLUSION

In France, internal and external emergency plans are required for all classified facilities requiring environmental impact assessment. The strategies for crisis response are based on predefined scenarios that do not necessary take into account organizational and socio-technical factors. So, facing an unpredictable situation these plans have to be adapted, which is a time consuming and complex task. The idea developed in this paper is to identify configuration variables (both generic and domain specific) that influence the decision makers when it comes to define an adapted crisis response. This not only help them to have a clear picture of the planned scenario and of its issues, it is also a way to ensure the context awareness dimension of the emergency plans and to support their dynamic reconfiguration in real time.

The presented methodology and tool are at their early stages. In addition to the work to achieve on the risk assessment and configuration variables, further works also include the development of the Dynamic Reconfiguration Platform tool and its assessment through realistic use cases provided by practitioners. These use cases will be based on existing emergency plans from the industrials plants located in one of the major French ports with the help of stakeholders in charge of the port security. Moreover, the assessment will also be supported by the measure of Key Performance Indicators (embedded in the meta-model by Benaben et al. (2017) we plan to use).

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