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Crisis management: use of systemic approach for strategic decision-making training

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Our societies are regularly exposed to crisis situations due to natural or industrial disasters. Crisis management teams are involved to overcome these events by taking operational, tactic or strategic decisions. Any strategic decision must take account of various complexity factors e.g. spatial aspects, media or time pressure. The strategic decision is also constraint by human factors particularly those due to unprepared actor's reaction when facing intensity and rarity of the crisis. The territory concerned by the crisis highlights different resources, means and issues more or less strictly dependent. Decision makers have also to deal with uncertain, complex, missing or ambiguous information. So it seems important to prepare them as much as possible by training exercises. The systemic approach gives the possibility to model the crisis and so to give a tool for trainers. In this article the case of an industrial crisis will be modeled, first by defining the crisis environment system and then its evolution. All of the sub-systems of this environment will be analyzed by identifying their interactions, their internal and external logics, their goals and their missions. This case will be used to highlight a method to determine the consequences of a decision during a training session.

Keywords: Crisis Management, Strategic decision, training, evaluation of consequences, systemic approach, system engineering.

1. Introduction

Training exercises from various natures, represent a way to prepare decision makers regarding the different complexity factors of a crisis. Allowing them to improve their ability to anticipate and assess consequences of a decision is particularly important.

Various crisis management learning approaches already exist such as seminars, full-scale or functional exercises. These last ones are often based on crisis situation simulations which allow the trainees to test and feel the impacts of their strategic decisions (Tena-Chollet et al. 2017). In order to have a reinforced pedagogical approach, the trainers must be able to model, evaluate and explain the consequences of such decisions. For this, the trainers must have a global, confident and realistic vision of the situation throughout its simulation (behavior and evolution of the actors, of the hazardous event and of the structures).

The systemic approach, often unused for this kind of training activities, allows to model then to promote more realistic simulations of a crisis evolution, the behavior of its resources and other components of the territory. This expected realism requires first to be able to determine and formalize the interactions and behaviors of all the involved, concerned or impacted stakeholders or elements of the territory concerned by the crisis. Second, it requires to be able to exploit this model to allow the trainees to evaluate, justify and verify the scope of their decisions. The main goal of the study presented in this article is to improve the decision-making training process. Strategic decision-making principles and process are described first. Then the concept of system modelling is proposed in order to describe elements behaviors and interactions, the crisis territory and the occurring events. The whole is illustrated on an example of an industrial crisis. The third part of the article describes the method used to assess the consequences of a decision. The simulation tool is not described in this article. In conclusion, the limits of the method and the prospects for crisis management training are discussed.

1.1. What is a strategic decision?

(Ansoff and McDonnell 1989) introduce the concept of level of decision as a way to distinguish different decisions by their objectives. These authors introduce three levels of decision. Strategic decisions are bound to the distribution and use of resources. Administrative decisions are bound to the organization, the acquirement and the development of resources. Operational decisions are bound to the conversion of resources and control of the operations. In the literature, decisions that deal with operations direction are often called tactical decision. (Johnson et al. 2008) define the strategy as “the direction and scope of an organization over the long term, which achieves advantage in a changing environment through its configuration of resources and competences with the aim of fulfilling stakeholder expectations”. These authors argue the complexity of strategy depends on the uncertainty of information, the multiple actors and the constant evolution of the environment. They bind the strategic level to the tactic and operational levels needed to accomplish the goals of an organization.

(Richardson and Richardson 1992 in Ritchie, 2004) describe the 4 phases of strategic planning for crisis decision makers: the strategic analysis phase to gather the information, the strategic direction to choose the general direction and the process of problem resolution, the strategy implementation and control phases to apply the strategy on the environment and the strategic evaluation and feedback phase to adapt the strategy to the evolution of the crisis environment. (Ritchie 2004) matches these strategic planning phases with crisis common phases: the strategic analysis phase with the onset of the crisis, the strategy implementation and control phases with the acute phase of the crisis, while the strategic evaluation and feedback phase occurs from the beginning of the crisis to the healing phase. The feedback will continue until the next crisis.

As a consequence, a strategic decision seems to be a decision bound to the creation, control and reevaluation of goal. These decisions are taken throughout the crisis by the leaders of relief organizations.

1.2. How to evaluate the consequences of a decision?

We argue hereafter systemic approach is used here to model the behavior and the evolution of a crisis environment, and then to provide models being simulated. A territory and a crisis situation are then to be considered as systems. Each of them have been studied and modelled first separately then integrated as shown in the next example. This has been done by using SAGACE method (Penalva 1997), applying system principles (Le Moigne 1993) and using some modelling languages like SysML (System Modeling Language) or UML (Unified Modeling Language) as advised by (Bagheri and Ghorbani 2010).

By seeing the crisis as a series of undesirable events with different causes, the systemic approach allows us to model in same time the interactions between components from human, technical and organizational nature that evolve in the territory. The goal is then to model how the crisis system may evolve based these interactions and the various characteristics of these components. The goal is then to predict potential effects and impacts on each of these ones. This approach allows to model the hazardous phenomenon which causes the crisis but also actors, and various infrastructures that are implied, impacted or concerned by the crisis. These modelling crisis and territory systems are integrated to form the *crisis environment* model. During a crisis management training exercise, this model allows the trainers to simulate the behavior of the whole crisis, then to analyze its evolution thank to the various strategic decisions taken by the trainees. This prediction can also furnish information for debriefings and so allow the trainees to understand the consequences of their decisions.

2. Construction of the crisis example

The SAGACE method used to build the system is based on a set of three *views*. This allows an exhaustive definition of what the system does (functional view), what it is (structural view) and what it decides (behavioral view).

The studied system is called the *crisis environment*.

The *functional view* aims to represent the functional vision of the system. To do this, it is necessary to define why it exists (purpose), what it must do (mission) and what are its objectives (business, human, social, etc.) when fulfilling its mission. In our case, the purpose of the crisis environment is to enable the company to be sustainable and to continue to carry out its missions. Company’s mission consists in manufacturing and selling goods and/or services that meet the needs of customers and to limit the negative impacts of production. The missions of the crisis environment are therefore to get out the company from the crisis and limit its consequences. The crisis environment objectives are then:

- staff members must be protected so that nobody is injured and there is no death;
- the unproductive period of the company is minimized;
- environmental impacts of the crisis are minimized;
- the company's infrastructures suffer no damages;
- expenditure on crisis management is minimized;
- improvement of the branding and public opinion of the crisis management structure.

The *structural view* of the crisis environment aims to detail all the sub-systems i.e. infrastructures, actors, and phenomena (here after considered as particular sub-systems) that are involved, impacted or affected by the crisis. It is not limited by geographical or administrative boundaries; it is defined by its components that could be themselves considered as more or less complex sub-systems. Last this structure allows to make emerge the components that will interact in the crisis environment and the nature of their interactions i.e. the nature, role and impact of exchanged services between all these components. In this example the crisis is caused by a fire in a wine packing plant (Figure 1).

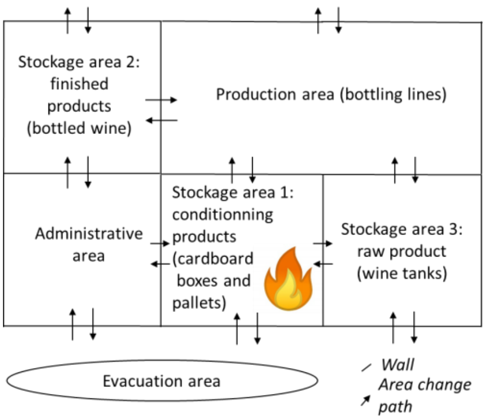

Figure 1: Internal structure of the company

The environment is therefore made of this company and its internal actors. This company is divided into (Figure 2):

- the crisis cell that will be played by the trainees;
- the intermediate managers who must translate the orders of the crisis cell into tactical decisions;
- the mobilized staff who will be in charge of limiting the effects of the dangerous phenomenon;
- the non-mobilized staff who must evacuate and put themselves in safety;
- the infrastructure of the company which will be affected by the dangerous phenomenon;
- the dangerous phenomenon which directly affects the enterprise: a fire in the storage 1 of packaging materials.

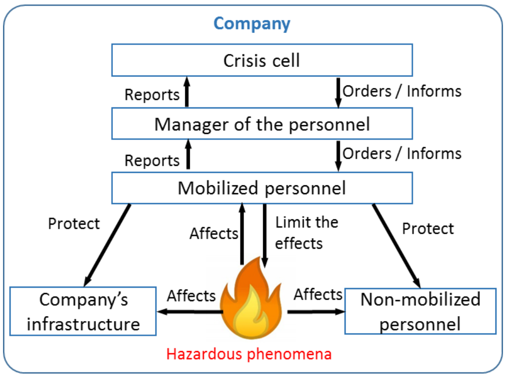

Figure 2: Internal interactions between company's components

To simplify the use of the consequence assessment method, the external environment of the enterprise is limited compared to usual actors of crisis management. In this crisis, neither media nor population are involved.
At the company's interface, the company's customers, suppliers, shareholders and subcontractors are affected by any changes in the company's production: they will exchange information to understand the situation and assess its consequences on their activities.
The infrastructures at the company's interface are also in the crisis environment because their operations (water network, road network, etc.) are affected by the change in the company's functioning.
Some experts are elements of the crisis environment in so far as they are involved in solving the crisis through their exchanges with the crisis unit or the relief services.
The emergency services are involved and impacted by the dangerous phenomenon, they intervene in limiting the impacts of the hazardous phenomenon at the human, economic or ecological level.
All the actors impacted (systems suffering the effects of the crisis), involved (systems seeking

to limit the effects of the crisis) or concerned (systems whose behavior is altered because of the systems involved or impacted) by the crisis and its consequences are represented in the crisis environment (Figure 3). But the subsystems of this environment are chosen in such a way that the system remains simple (neither population with behavior that is difficult to model nor media that adds the communication dimension).

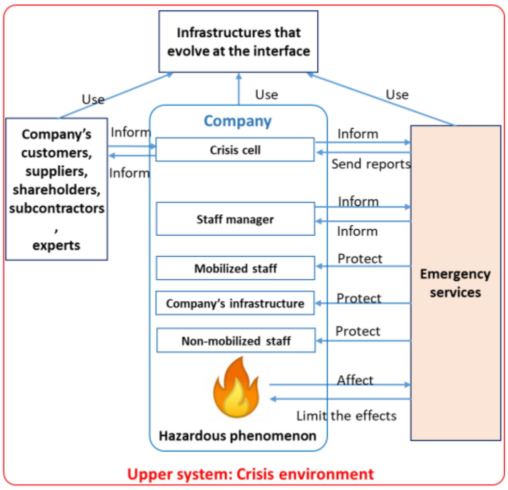

Figure 3: Crisis management system structure and interactions

Last, the *behavioral view* aims to detail the behavior of each of the system's components when they interact with each other in order to fulfil the crisis management system mission.
Each subsystem is characterized by its attributes (time, shape and space), its role, the procedures that concern it and the procedures in which it is involved. Again, the creation of these attributes responds to the need of realism and assessing the consequences of the decisions affecting each component. Thus, the mobilized staff that follows the procedures for mitigation of dangerous effects, for protecting property and people will need attributes to define their mastery of each procedure and the equipment they will need. This staff can move around the company, which is composed of the 5 areas as described in Figure 1.
It is therefore necessary to define where the mobilized staff is. Furthermore, each member may be injured, stressed or unable to act or move, so attributes relative to his physiological and psychological conditions must be created. It is also necessary to define his knowledge of the situation in order to define what information he will be able to relay to his manager.
Once attributes are defined for a subsystem, the next step is to create the diagrams that will define their behaviors. These diagrams mark the transitions between the status of the subsystems and the behaviors they have in those status. The modeling language used is based hereafter on State Diagrams. Figure 4 gives an example for the mobilized staff subsystem.

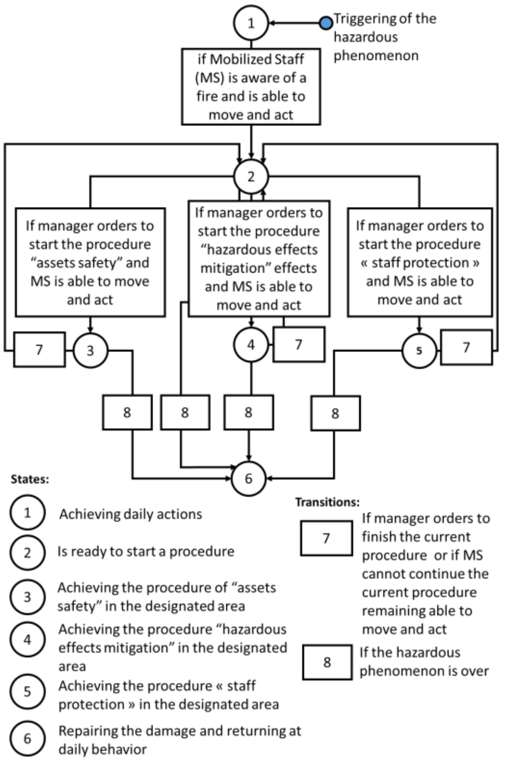

Figure 4: Behavior diagram of mobilized staff

Each procedure can itself be broken down into a behavior diagram, such as the procedure for securing people (Figure 5).

All of these behavior diagrams make it possible to follow the changes in the status and therefore in the behavior of each of the actors and structures. To simplify the model, all persons (operations managers, emergency services, mobilized and non-mobilized staff) follow the given instructions, the procedures in which they are involved and succeed in all their actions (for example when caring for an injured person).

Once all the diagrams are done, it is necessary to create a crisis scenario. In the case of this simplified example, only an initial event (a fire) is necessary. Then the consequences of the decisions (or the absence of decision) of the crisis unit automatically modify the situation.

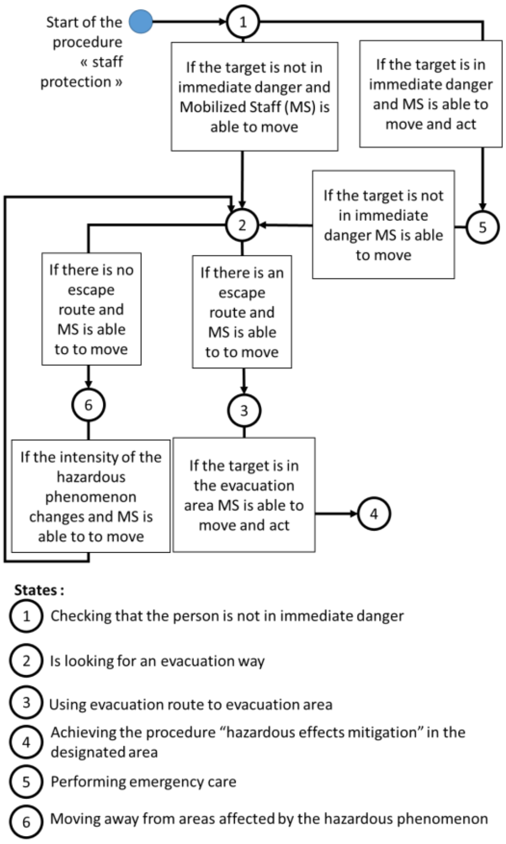

Figure 5: Behavior of a mobilized staff member who performs a "staff protection" procedure

The initial situation: 5 mobilized staff present in the production area, 6 staff not mobilized present in the administrative area, the 2 operational managers present in the production area, fire detectors in all areas and fire in storage area 1 with uncontrollable intensity.
The aim of this study is to develop a method to support crisis management training by providing information to trainers such as the consequences of trainees' decisions.
This system is used in crisis management training, so it is modelled and simulated to support this training. Since training focuses on decision-makers present in the crisis cell, its interactions with the rest of the system are therefore essential to define. The mission of the crisis unit is to propose decisions suited to the crisis resolution; based on available information (plans, procedures, field information, expertise). These decisions can be orders to operations managers (change of zone, change of activity, etc.) or transfers of information to internal or external actors.

2.1. *What is a consequence of a decision?*

The concept of consequence can be defined as all the results linkable to a decision. (Lauras, Truptil, and Bénaben 2015) define consequences during a crisis as "*Noticeable impact of the studied crisis*". (Bagheri and Ghorbani 2010) divide consequences between direct and indirect consequences: "*They can either be direct or indirect. A direct consequence of a hazard is its visible effects on the outside environment, whereas the indirect consequences are those veiled impacts that this hazard poses*.". Indirect consequences are consequences of consequences, linked to a chain of events. The direct and indirect consequences can be felt on all subsystems of the crisis environment.
People can be physically (injury, incapacity, etc.) or psychologically (stress, loss of consciousness, etc.) impacted during the crisis or over a longer term.
Assets, equipment and infrastructure may be affected by the crisis unit's decisions on its condition (completely protected, partially damaged, destroyed, etc.) or its ability to function (in operation, switched off, put out of use for several days, etc.).
The ecosystem and the economic environment can be impacted by crisis cell decisions, mainly with indirect consequences (the discontinuation of the production chain, which results in a decrease in revenue for the company and costs for customers, the extinguishing waters will affect biodiversity, etc.)
All the subsystems of the crisis environment can be affected and the consequences can be divided into three components: a human component, an environmental component and a financial component. In the example system, in order to avoid an unrealistic estimate, they can take four values: low (the consequences does not last for more than few days), medium (the consequences will affect the operation for some weeks), strong (the consequences will affect the operation for some weeks and will need

remedial actions) or very strong (the consequences will affect durably the operation). For example, the destruction of the storage of packaging products will have a low indirect impact on the human component, like partial unemployment. This destruction will have a medium direct impact on the economic component: the stock must be bought back. Finally, it will have a low direct environmental impact: CO_2 emissions due to the combustion of materials.

2.2. Principles of the consequences assessment method

In order to facilitate the debriefing step, the aim is to be able to assess all the consequences of a decision as time goes and to report these consequences to the trainers. It is possible to relate a decision to its consequences by modelling the system and simulate the behavior of each crisis environment components, of their interactions, of the territory, the events and the phenomena affected by the crisis.

A first approach involves measuring all the changes in system status (number of people injured, number of people evacuated, collapse of the walls, etc.) as time goes on and making them appear in the form of graphs or timelines. It is therefore necessary to measure the time of the decision, its addressee and its nature (information sharing or order). It is also necessary to record all the impacts on the subsystems. This method alone is insufficient to show the links between decisions and their consequences (to the extent that some decisions may have indirect or time-lagged consequences). To obtain the link between decisions and their consequences, it is necessary to use the dynamic diagrams and to analyze the behavior of the different subsystems. The changes in the status of each subsystem have to be recorded. The consequences can be linked to the decisions by following a risk analysis approach like the fault tree method. This approach requires to begin with the final status of a sub-system and to ask “how does it got through in this status?”. This question has to be asked until the path of subsystem from its initial status to its final status is drawn. The crisis cell decisions must appear in the process as causes of status evolution.

This method must be followed when creating the system in order to link the potential consequences to the decisions that may result. The idea is to use the dynamics of the dangerous phenomenon to identify the subsystems it may affect and the conditions of effects. It is then necessary to successfully escalate effects conditions to the instruction that put the subsystems in these conditions.

2.3. Application of the method on the example system

The aim of this method is to report the consequences of decisions to the trainees. With this system and these rules of operation and behavior, a time step of five minutes allows to have a vision of the evolution of each subsystem without omission.

Let us start from the initial situation: the fire alarm rings and all the people in the company have a weak knowledge of the situation: they only know that there is a fire.

At 5 minutes, the mobilized staff goes to check and communicate the situation to their managers who report to the crisis cell: they see a fire in storage area 1 that spreads to adjacent walls. The evacuation of non-mobilized staff begins, the evacuation route is free, they use it. The production line is stopped.

At this point the crisis cell must make decisions: call the emergency services (or not), define the firefighting strategy and the priority targets to protect, activate or not the firefighting system.

Let’s describe a situation in which the chosen strategy corresponds to the backup of storage 1:

At 10 minutes, the operations manager translates the storage backup strategy from the cell crisis in orders for mobilized staff: to start the procedure of safety of the assets of Storage Area 1. The mobilized staff put on the fire protection equipment. The rescue services are on their way. Fire intensity on adjacent walls is low. All non-mobilized staff evacuate. 20% of storage 1 is destroyed. The extinguishing system is used in storage area 1. Walls are 10% damaged due to fire intensity on storage area.

At 15 minutes, the 5 mobilized staff members start the procedure of securing the assets on the storage area 1. 40% of storage 1 is destroyed. Walls are 30% damaged due to fire intensity on storage area and fire intensity on them.

At 20 minutes, 60% of storage 1 is destroyed, 40% of storage is put into safety. The intensity of the fire on the walls is intense. Walls are 50% damaged due to fire intensity on storage area and fire intensity on them. The fire in the storage area is stabilized. The walls of this area are still on fire. The fire spreads to adjacent areas (storage area 3, administrative area, production area), the intensity in these areas is low. The mobilized staff is reassigned to the procedure of fighting against the effects of the dangerous phenomenon; the firefighting systems are activated in the administrative zone, the storage zone 3 and the production zone.

At 25 minutes, the mobilized staff begin the procedure of limiting dangerous effects on the walls of the storage area. Walls are 60% damaged due to fire intensity on them. The production line, storage area 3 and administrative area are 10% destroyed.

At 30 minutes, emergency services arrive at the company site and begin to deploy. The condition of the walls of storage area 1 is stabilized and damaged at 70%. The water level is at 90%. The production line, storage area 3 and administrative area are 20% destroyed. Fire intensity on the walls of storage area 1 is low. The fires are extinguished in storage area 3, production area and administrative area.

At 35 minutes, following the intervention of the emergency services, the fire intensity at the walls is zero, the fire is extinguished. The water level is at 60%, the extinguishing systems are stopped.

Final balance: partial destruction of storage 1 (60%) and 3 (20%). 4 walls, production and administrative area need repairs. The production line will be shut down until its complete reparation. The reparation and the loss of stocks have strong direct impact on the company, but the indirect economic consequences will be low: the remaining stock can respond to the client demand. The short shutdown has no real human impact and the gas emission of the fire has low ecological impact.

Let’s describe another situation in which the chosen strategy corresponds to the abandonment of storage 1 and the securing of other areas of the company:

At 10 minutes, the operations manager translates the strategy of securing other areas (crisis cell decision) in order of limitation of the hazardous effects process on the walls of storage area 1. The mobilized staff puts on the equipment of protection against the fire. Emergency services are on their way. Fire intensity on adjacent walls is low. All non-mobilized staff is evacuated. 20% of storage 1 is destroyed. The extinguishing system is used in storage area 1. Walls are 10% damaged due to fire intensity on storage area.

At 15 minutes, mobilized staff starts the procedure to mitigate the dangerous effects on the walls of storage area 1. 40% of storage area 1 is destroyed. The intensity of the fire on the walls of the area are stabilized by the procedures to limit the dangerous effects. Walls are 20% damaged due to fire intensity on storage area.

At 20 minutes, 60% of storage 1 is destroyed. Walls are 30% damaged due to fire intensity on storage area.

At 25 minutes, 80% of storage 1 is destroyed. Walls are 40% damaged due to fire intensity on storage area.

At 30 minutes, emergency services arrive at the company site and begin to deploy. Storage 1 is completely destroyed. Water level is at 90%, Walls are 50% damaged due to fire intensity on storage area.

At 35 minutes, following the destruction of the storage and failure to propagate, the fire is extinguished, the extinguishing system is stopped.

Final balance: total destruction of storage 1. 4 walls need repairs. The reparation and the loss of stocks have medium direct impact on the company, but the indirect economic consequences will be null: the stock of packaging product can be easily and quickly rebuilt. There is no real human impact and the gas emission of the fire has low ecological impact.

The difference in consequence is explained by the difference in strategy. Here, all the consequences are linked to the strategy choice. The evolution of each subsystem are determined by following their different behavior diagrams. Other scenario with other decision can be followed in particular with the unlikely decision of no use of the extinguish system. This simple system doesn’t allow a more complex use of this method.

2.4. Discussion on the limits and opportunities of the method

The example system is today too simple to deploy the whole method. To check the efficiency of the method, a succession of decisions that leads to crossed consequences is needed. The next step of this study is to build a more complicated scenario which needs more

decisions from the trainees as advised by (Limousin 2017).
However, this method makes the assessment of the consequences of the trainees' decisions simpler for the trainers. In fact, it is possible for them to follow the evolution of the status of each sub-system and record these evolutions. The final balance becomes easy to write with all the consequences on each sub-system already detailed.
This system can be improved by making it more realistic. The phenomenon can be modeled by tools that can predict its evolution based on its precise characteristics. The behavior of people and its interaction on the system can be more realistic and based on social science works. The media and the population can be added for an additional level of complexity.
The final step of this study is to insert this crisis environment system and this consequences assessment method in the crisis management training. This step needs the modeling of the training system, the goal of its actor, their interaction and the place of the simulated crisis environment.

3. Conclusion

The support of the system approach gives the opportunity to follow the evolution of each actor during a crisis situation. The building of the system needs a framework that assures its realism and its completeness. Once the crisis is modelled, the goal is now to develop simulation mechanisms allowing to execute this model for instance as proposed in (Chapurlat et al. 2016). The method described in this article might help trainers in training sessions based on crisis simulation. The track of the digital tool to automatize the evaluation method by exploiting the simulated system will be explored in a further work.

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