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Crisis and emergency situation Simulation considering cascading effects methodology

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Deliverable Number:	D6.6 – Topic 5
Date	31/07/2017
Due Date (according to DoW)	31/07/2017
Dissemination level	PU
Reviewed by	Florence Carre (INERIS) Camilla Mörn (MSB)

Grant Agreement No:	607665
Coordinator:	Anders Lönnermark at SP Sveriges Tekniska Forskningsinstitut (SP Technical Research Institute of Sweden)
Project acronym:	CascEff
Project title:	Modelling of dependencies and cascading effects for emergency management in crisis situations

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Introduction

Practice and more particularly, simulations enable to promote preparedness by allowing participants to experience an environment which looks the most realistic possible to the chosen situation whether an emergency situation or a crisis.

Crises situations are unique (Lalonde and Roux-Dufort, 2013). In order to cope with the crises situation, managers must develop adaptive response procedures under stressful conditions, including uncertainty and time pressure (Wiener and Kahn, 1962) based on previous experience not framed to this unique situation (Tena-Chollet et al., 2016). It is then crucial that managers are alert to opportunities that arise during a crisis situation. Learning from failures promotes preparedness and experiences may increase their effectiveness in the future (Carmeli and Schaubroeck, 2008; Cesta et al., 2014; Kim and Lee, 2011). These experiences can also help prevent unprepared organizations from allowing a situation to worsen (Starbuck et al., 1978).

Simulation is intended to provide experience to crises managers and more generally to participants by allowing them to cope with a virtual but realistic situation that raises opportunities for their organization. To create simulations capable of creating such opportunities, it is important to verify that the simulations reproduce the specific conditions of a situation, as well as ensuring that participants experience the most realistic environment possible (Borodzicz and Van Haperen, 2002). Crisis simulations aim to increase awareness by reproducing the psychological atmosphere of a crisis as accurately as possible. Emergency simulations objective is to test the applicability of a plan. Therefore, they must reproduce a physical reality as accurately as possible. Concepts and design of simulation are presented in the following sections.

1 Key concepts – setting the stage

In order to avoid misunderstandings, it is essential in any work to set common definitions. In the domain of crisis and emergency management, this need to clarify the key concepts is crucial due to the large number of different involved stakeholders who do not share the same vocabulary. Furthermore, management mistakes can result in very high consequences in these situations.

1.1 Cascading effects

Broadly speaking, cascading effects arise when an incident affecting one system or function in society propagates to another function or service, due to a dependency between these systems[1]. More specifically, cascading effects are here defined in the following way.

Cascading effects refer to the impacts of an initiating event where:

- system dependencies lead to impacts propagating to other systems, and;
- the combined impacts of the propagated event are of greater consequences than the root impacts, and;
- multiple stakeholders and/or responders are involved.

A simple example can be used to explain the main features of this definition. First of all, an initiating event of some sort must occur that affects one or several systems. This initiating event may for example be a fire in a power station. While this event in itself may result in direct economic consequences and impacts on the power system, it does not per se give rise to cascading effects unless other systems or functions are affected by the degraded function of the power system. Cascading effects occur when the fire in the power station results in failures in railway transport. This is a result of the existence of a dependency between the power system and the railway system (first part of the definition). In this case, the railway systems is dependent on the power system for its traction power.
The combined impacts of the consequences arising in the two systems are clearly greater than the impacts of the initial fire itself, for example resulting in trains not arriving on time, etc. (second part of the definition).
Finally, in order to manage this type of event, it is not sufficient for first responders to extinguish the fire, but infrastructure providers need to mobilize their ability to manage the consequences arising in the power system and the transport system. In this way, multiple stakeholders and responders are involved (third part of the definition). This example is generically illustrated in Figure 1 below.

[1] For further details, see the training material on Cascading Effects

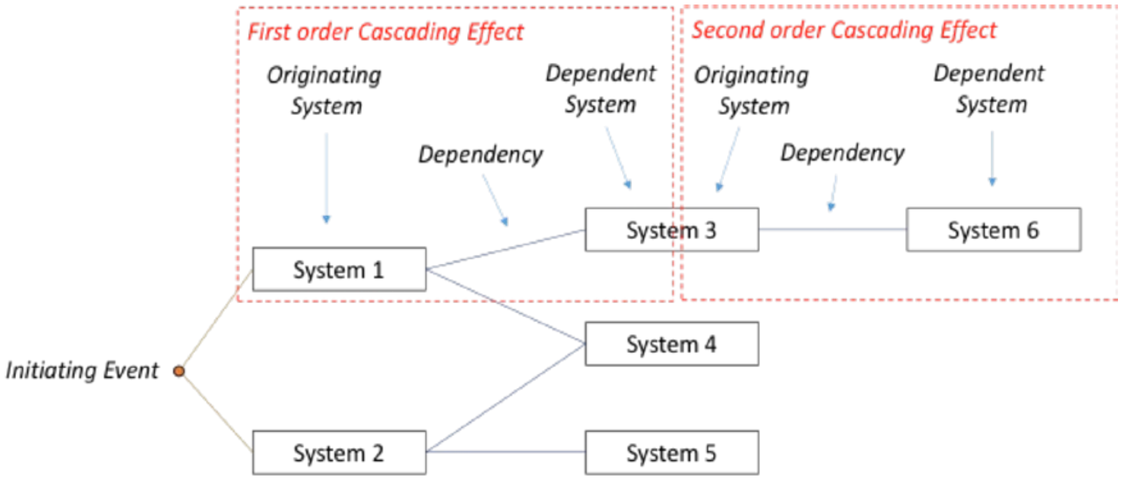

Figure 1. Conceptual model of the propagation of effects between systems in an incident involving cascading effects.

In Figure 1, it can be seen that an initiating event may affect one or several systems (System 1 and System 2). These are referred to as the **originating systems**. This event could be, for example, a natural event such as an earthquake, an accidental event such as an explosion, or an internal system failure such as malfunctioning of a technical component Due to dependencies to other systems, cascading effects may arise when impacts arise in other systems (Systems 3, 4, and 5).

Returning to the example above, the initiating event is a fire in a power station happening in the Power system (the originating system called System 1 in the figure). Cascading effects arise due to a dependency between the Power system and the Railway system (the dependent system called System 3 in the figure). If this impacted system gives rise to additional impacts to other system, there is a continuation of the cascading effect. The first resulting effects from directly impacted systems from the initiating event to dependent systems are defined as "**first-order cascading effects**". If this line of propagation continues, second, third, etc. order cascading effects arise.

1.2 Defining a Crisis situation

A clear definition of a crisis is necessary in order to differentiate it from other critical situations such as accidents and emergencies, because the aims of the simulation are not the same for these situations.

Existing literature provides a wide range of definitions for a crisis, which can cause confusion. For example, various authors have incorporated opposing components, including *threats* (Hermann, 1969; Kovoor-Misra, 1995; Nystrom and Starbuck, 1984) and *opportunities* (Fink and American Management Association, 1986; Milburn et al., 1983), as well as the concepts *surprising* (Hermann, 1969; Pearson and Mitroff, 1993) and *predictable* (Milburn et al., 1983). Flin (1996) and Sniezek et al. (2001) defined a crisis as a special situation with its own characteristics defined by uncertainties, a quick onset, temporal constraints, significant short-term losses (human and economic), a lack of controllability and a high level of stress. Despite these sometimes diverging definitions, Pauchant and Douville (1993) propose a definition that should be acceptable to most authors; for them, crises "are disruptive situations affecting an organization or a given system as a whole and challenging previously held basic assumptions;

they often require urgent and novel decisions and actions, leading potentially to a later restructuring of both the affected system and the basic assumptions made by the system's members" (Pauchant and Douville, 1993).

At first glance, the diversity of crisis characteristics suggested in the literature seems confusing. However, these definitions can be complementary and generally converge on two aspects when describing crises. Based on our literature review, two categories are proposed to define a crisis (Judek et al., 2017) (Table 1):

- The characteristics of a crisis situation;
- The characteristics of the state in which a crisis situation immerses a manager

Table 1. Characteristics pf the crisis identified based on literature review
(extracted from Judek et al., 2017)

Crisis situation	State of crisis
Chaos	Astonishment
Surprise / Unexpectedness	Time pressure
Important consequences	Disorder
Uncertainty	Relative nature of the crisis
Evolving nature of the problem	Anxiety
Irregular rhythm	Changes in relationship
Numerous stakeholders	
Information management issues	
Media involvement	

The nature of cascading effect implies that its aftermaths can lead to « chaos » since in its definition it is said that the consequences are more important at an order of cascade regarding the prior order of cascade. In addition, the cascading effects are also characterized by the involvement of « numerous stakeholders » and « important consequences ». These examples show the link with the concept of crisis situation since they are part of the characteristics of the crisis situation.

1.3 Emergency situation - not a crisis situation

While preparing a simulation, it is important to make the distinction between a crisis situation and an emergency situation.

This misunderstanding would lead to a fail of participants trying to apply a predefined plan, which would not be adapted to this specific situation. As a consequence, it would have a negative impact on their involvement since it would not have a positive effect on the situation. Indeed, coping with a situation without the appropriate tools would make the participant feel frustrated and give up thinking that the simulation is not realistic. One reason of tis confusion comes from the fact that both situations require a rapid response due to the aftermaths. For an organization, it is crucial to make the distinction the earlier possible since it will determine the adequate response.

This ambiguity must be clarified from the beginning since it will definitely influence the set-up, the design and the conduction of the simulation. The scenario will also be shaped by this early clarification of the high-level objective as mentioned by Borodzicz (2002) « crisis scenarios are, for any management structure, unique events that do not fit with an organization's history, policy or procedures, if they did, it wouldn't be a crisis ».

1.4 The concept of scenarios

A scenario can be described as a story of possible future events, with some degree of uncertainty[2]. The scenario can be based on real events, complemented with fictional story lines based on assumptions that are not necessarily predictive and thus differ from forecast and prognoses (Bishop et al., 2007; Meristö, 1991; Wack, 1985).

Scenarios can be used for many different purposes, such as: to illustrate alternative solutions and identify potential problems, to prevent certain effects (Laufer and Jung, 2010), to reduce uncertainty, to question existing assumptions (Pesonen et al., 2000), to indicate thinkable futures or desirable futures (Godet, 2000). They can also be used as a management tool to improve the quality of strategic decisions (Wilson, 2000).

Worth noting is that few of the definitions provided by theory include both aspects, content and purpose (Pesonen et al., 2000) or aim at testing a tool in an incident or crisis management environment. Only Walker (1995) covers all these aspects, making his definition and approach of key characteristics most fitting for the goal of this task. Walker defines a crisis management scenario[3] as: "**a description of the conditions under which the crisis management system or crisis management policy to be designed, tested or evaluated is assumed to perform**" (Walker, 1995).

Walker distinguishes two relevant components: **the context** and **the crisis**. The context is "the overall background or environment within which the specific crisis is to be considered. It is the state of the affected area at the time of the crisis" (Walker, 1995). This includes a specific timeframe or date stamp, demographics of a local population, geographical location, organizational relationships, availability of data etc. The context determines the framework into which a crisis is, or others might be embedded (for the purpose of the study).

The second component, the crisis, "includes the chain of (hypothetical) events that lead up to the crisis" or "the sequence of events to which the crisis management system must respond" (Walker, 1995). One context can thus embed different types of crises. Within the crisis script the chain of events can be altered, both leading to different scenarios (see further, multiple timeline development).

Walker identifies four criteria for scenarios to be adequate and qualitative:

- **Consistency**: Consistency refers to the script not being self-contradictory. For the CascEff scenarios, the internal consistency is assured by the fact that all scenarios are based on real events with fictional lines of development also inspired by real events.

- **Plausibility**: Plausibility means that the scenario needs to be likely to occur, i.e. it might happen (without necessarily being predictable). Extreme or worst case scenarios are not excluded, since some large scale historical incidents, such as the gas leak

[2] For more details, see D1.4 Report on scenarios to be elaborated for testing the incident evolution methodology

[3] Based on a more general definition suggested by Quade and Carter (1989)

incident in Bophal, India in 1984 and the Chernobyl nuclear accident in 1986, were considered unthinkable before they happened.

- **Credibility**: Credibility is closely linked to plausibility, according to Walker (1994). Circumstances, consecutive steps and any changes in them should be logical, and it is important to understand why they occur. The credibility is raised through the detailed analysis of interdependencies and impacted systems. It can be visualized with so called swim lanes for example.

- **Relevance**: This criterion relates to the purpose of the scenario and must follow a list of criteria regarding the defined objectives

2 A simulation methodology in four steps

As a general overview of this process, we propose four steps (also presented in Figure 2):

1) a preparatory and planning phase: **Design and development**
2) the actual running of the exercise: **Conduct**
3) the evaluation of the exercise: **Evaluation**
4) the integration of lessons learnt into the overall project or program: **Improvement Action Plan**

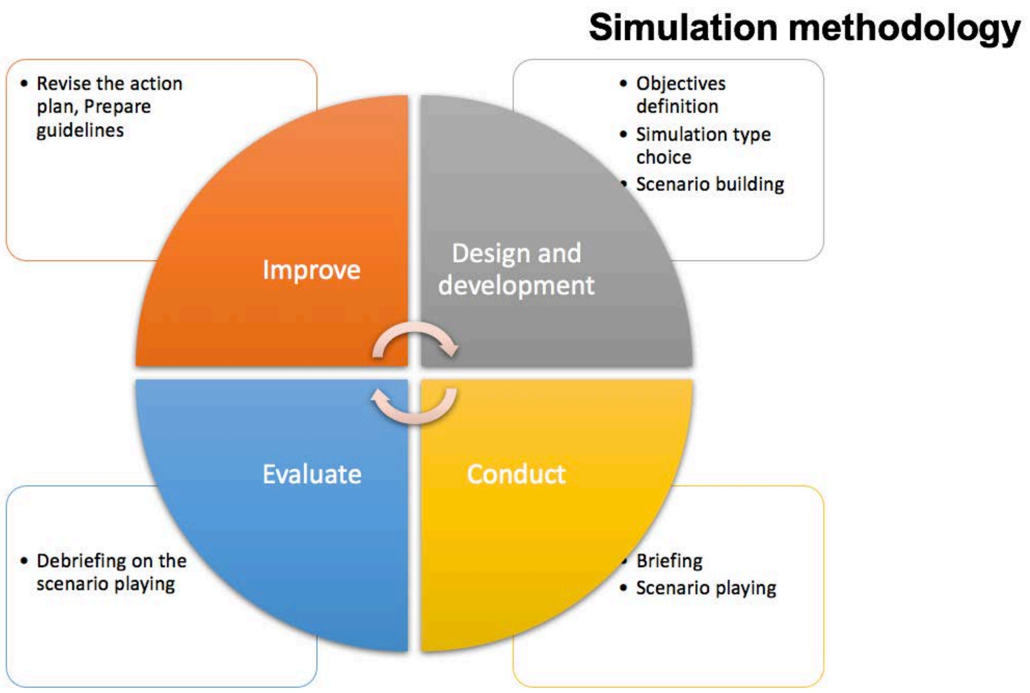

Figure 2. Simulation methodology steps

2.1 Design and development phases

Tasks included in the design and development phase are:

- Identifying the exercise goal (training, testing/validation, etc.);
- Setting SMART (Specific, Measurable, Achievable, Relevant, Time-bound) exercise objectives and define corresponding performance/evaluation criteria;
- Appointing the Exercise director and an Exercise project team (coordinator, operators, evaluators);
- Developing the exercise scenario and prepare all content e.g. build the scenario in XVR and/or iCrisis™ (see above: theme, incidents, actions, target group participants);
- Creating exercise documentation (test script for the key actors, evaluation template for the evaluators, etc.);
- Defining the type of activity: test, simulation, discussion-based or operations-based exercise, etc. and prepare for a test plan/exercise script accordingly. Elaboration of the test plan in parallel to the course of actions in the scenario:
    - Choice of location;

- Appropriate infrastructure;
- Required staff (exercise operators the day of the exercise, key actors and supporting actors, etc.);
- Preparation of the required resources and logistic plan; o Catering;
- Etc.

• Establishing a communication strategy.

2.1.1 Setting the objectives

The trainer needs to define the objective of the session. This stage is crucial in order to select the most relevant type of simulation and to design its format.

- **Training and testing of existing plans and abilities**

Training and testing can only be performed if there are elements to test. In other words, if the concept of cascading effects is already considered in a specific plan, then there is an interest in testing it. This test will be supported by a simulation that reproduces as accurately as possible the physical environment of the identified situation. For example, testing the capability of a command post to apply a specific plan considering cascading effects would be supported by a simulation that reproduces the situation through the regular organization, such as the real command post room with participants playing their own role and using regular tools for assessing and communication.

- **Raising awareness**

A crisis situation being by definition “unique”. An increase in awareness can help the managers to identify an emerging crisis situation at an early stage and to start considering possible cascading effects. It can also help session participants to avoid the pitfalls encountered in a crisis situation. Furthermore, raising awareness is a method that can be easily used and adapted by the targeted organization as it entails focusing on the characteristics of the situation. To achieve this, it must be made sure that they experience the situation and feel the state in which the situation immerses them in. If your objective is to raise awareness and participants are not evaluated, a scenario which is beyond the range of their skills can be used (participants must not feel judged). This will facilitate a process of auto-learning.

2.1.2 Four type of simulations

Basically, we identify four main types of simulation (see Figure 3). **On-field full scale simulations** generally deal with a catastrophic accident of great magnitude, of sudden appearance, requiring the mobilization of great means. This type of exercises allows the involvement of several organizations on a number of levels of management from tactics to strategic. Most of the time, it involves setting up a pre-defined plan at a large scale. As these simulations require a lot of work upstream as well as the mobilization of many stakeholders, they can be very costly and the organization of feedback is challenging.

Figure 3. Four different types of simulation

As a rule, **virtual full scale simulations** are simulations carried out in facilities whose objective is to operate as crisis units or command posts. Different categories of situations as well as different types of tools (plans or tools) can be tested, while at the same time trying to assess actors who are unfamiliar with situations of crises. Taking into account the objectives and the background of the participants, this type of simulation is implemented differently depending on if they aim at raising awareness or at testing the participants.

Scale-model simulations are the most common type of simulations. In many ways they are similar to a role-playing game. Many types of simulators exist, focusing on communication and on field operations for any type of hazards. They are typically computer based and appear similar to a video game. One example is the tool XVR (http://www.xvrsim.com).

Finally, the fourth simulation type consists of **simulations in kit,** adopting models of board games: type Monopoly (horizontal plane), or magnetic studs to move on tables (vertical plane). These simulations are led by gamemaster (an individual or a group), who is also master of timing. One example of this is the Swedish Emergo-train System (Crichton and Flin, 2001).

2.1.3 Scenario building methodology

The methodology of building a scenario presented here relies on the comprehensive and detailed process for developing and using scenarios proposed by Wilson and Ralston (2006). This involves eighteen steps (Table 2). Each step in this process is a critical point of adding value and exposing mental models and assumptions during the scenario project. These 18 steps are divided in four general phases of scenario planning, namely, "(a) getting started, (b) laying the environmental analysis foundation, (c) creating the scenarios, and (d) moving from scenarios to a decision".

- (a) Steps 1-6 are related to starting up the scenario project, and these steps are meant to define the scope of the project and assemble the scenario project team;
- (b) Steps 7-10 are concerned with exploring the internal and external environments and putting these together in a cohesive picture;
- (c) Steps 11-14 focus on developing the scenarios themselves, based on all of the work done in the previous steps;
- (d) The final phase includes steps 15-18, they cover the use of the scenarios to examine current strategies and decisions.

Wilson and Ralston provide a detailed roadmap through each of these steps with specific instructions and practitioner tips.

Table 2. Steps of scenario building (extracted from Wilson and Ralston, 2006)

Step 1: Develop the case for scenarios Step 2: Gain executive understanding, support and participation Step 3: Define the decision focus Step 4: Design the process Step 5: Select the facilitator Step 6: Form the scenario team Step 7: Gather available data, views and projections Step 9: Identify the critical forces and drivers	Step 10: Conduct focused research on key issues, forces and drivers Step 11: Assess the importance and uncertainty of forces and drivers Step 12: Identify key "axes of uncertainty" Step 13: Select scenario logics to cover the "envelope of uncertainty" Step 14: Write the story lines for the scenarios Step 15: Rehearse the future with scenarios Step 16: Get to the decision recommendations Step 17: Identify signposts to monitor Step 18: Communicate the results to the organization

Wilson and Ralstons' roadmap aims at elaborating scenarios as a strategic management tool to anticipate future evolutions, rather than decision making based on forecasting. Even if the starting point and angle are different, their roadmap is relevant for incident management scenarios, as shown by Moats *et al.* (Moats et al., 2008) who picked up this step by step plan for crisis management training. Therefore, the methodology proposed by Wilson and Ralston had been adapted. Finally, we assume that regarding our objectives, the main steps in scenario writing can be summarized by analogy with the steps proposed by VTT Technical Research Centre of Finland, (Nina Wessberg):

- **Scoping the scenario field**

- **Definition of the purpose**
  The first element to take into consideration when preparing a simulation is to decide upon its aim and purpose. This will influence the choices to be made when designing a simulation that will mimic the wanted situation.

- **Cascading effects**
  If the concept of cascading effects is considered in an existing plan, the objective of the simulation should be to test either the plan itself, or the capability of participants to apply it. To do so, the type of simulation suggested would be an exercise.

If the concept of cascading effects is not yet considered by the organization, the objective should be to sensitize participants to the issue.

- **Crisis situation**
  As the crisis situation by definition is a unique and unexpected situation, no specific plan exists for such situation. Regarding a crisis situation, the only type of objective is therefore to raise participants' awareness by sensitizing them.

- **Emergency situation**
  In an emergency context, a predefined plan is applied as a response to the problem. The objective should be to test whether the predefined plan is applied.

- **Strategical vs Tactical vs Operational level**
  The choice of objectives and the type of simulations to be conducted will be influenced by the targeted level of response for the exercise, mirroring the fact that different decisions are made on different levels and decisions are implemented on other levels of response.

- **Identification of problems to be addressed**
  At this stage one must define the problems that the participants will go through. This work is done jointly with an expert on the organization involved, in order to be realistic and aligned with the exercise objectives.

- **Theme**
  Defining the theme, involves creating the premises for the environment of the story that the participants will encounter in the scenario. For example, the theme can it can be in relation to a certain type of hazard such as natural or industrial etc.

- **Identification of key factors**
  - Key decision factors

  It is also important to think about the key factors that could play a role in the decision-making process. For example, the scenario building process may include the following question: "What are the key factors one should know in order to improve the quality of decisions?". Answering this question will allow to focus attention on these factors for performing decision-making in an efficient way.

  - Drivers and barriers

  Beside the key decision factors, contextual drivers and barriers (economic, social, political, regulatory issues, etc.) exist that will or could influence the decision-making process. The identification of these drivers and barriers and the cause-and-effect relationship amongst them will allow the inclusion of their potential impacts in the decisions; and these expected impacts can be fed into the scenario. The scenario building process may for example include the following questions: "What key drivers and barriers could underlie the decisions?" and "What could be their impacts on the decisions?". Following this, trends and uncertainties are identified by questioning one's assumptions about the determined driving forces.

- **Analyzing key factors and their dependencies: ranking the driving forces on the basis of their significance and degree of uncertainty and identifying logics to deal with uncertainty**
  The degree of importance of each of the driving forces for the success of the decisions needs to be identified along with the degree of uncertainty as to how it will develop for ranking the relative importance of each of these forces. The objective is not to rate how uncertain the impacts are that the driver will have on the decision. Rather is to rate how uncertain the future developments of the driver are. The most important and most uncertain driving forces should thus be identified. This allows targeting the aspects of the scenario that will or could need intensive attention.

  Based upon this rating, some factors must be chosen to provide the logics or the axes along which the scenario will differ. For the scenario to be a useful learning tool, the logics must rely on factors which are inherent to the success of the most significant decisions or highly important to the development of the focal issue, here in cascading effects.

- **Scenario script generation: writing the story line as a coherent and realistic scenario**
  Finally, the scenario can be written based on the collected information so far. First of all, an introduction needs to explain the environment and the context of the scenario. Then, based on a timeline, the storyline can be developed step by step. This will help following the story more easily. Important elements should be highlighted, such as the pitfalls, changes in the situation and the expected reactions of participants.

- **Scenario transfer to paths: linking the scenario to the initial purpose and communicate to the parties involved.**
  Once the scenario is written, it must be reviewed by the parties involved to verify that it is realistic and aligned with their expectations and their understanding of the objectives.

2.1.4 Scenario description template

To facilitate the description of scenarios, a template is proposed in Figure 4. It summarizes the main elements of a scenario and can be used for any type of scenario.

1 **Name** of the scenario

2. **Place** of the scenario

3. Overall **type** of the initial event and type of the impact

4. **Description of the initial system** including more details on the initial event

5. Description of the course of events

6. **Description of cascading effects**, types of dependencies, systems involved after the spread from the initial system

- Interdependencies in the chain of events:
  - Geographical interdependency
  - Physical interdependency
  - Logical interdependency
- Interdependencies relevant for the impact of the incident:
  - Physical interdependency
  - Logical interdependency

7. Real **consequences** and possible consequences

8. Is the scenario **local, regional, national or inter**national? Are there cross border effects?

9. Description of the different **organisations involved** and the relation between them

10. Is the scenario based on a **historic event?** If yes, please give references or information on where more detailed information can be found or obtained

11. Are there **similar real events** that are not exactly the same, but could be of interest?

12. If the scenario is based on a historic event, does the selected scenario differ in any sense from the historic event? If yes, in what way?

Impact

Describe the effect (usually negative on a system either from an initiating event or, where systems are dependent, through a system dependency. The impact may be measured in one or several of the six impact categories:

1. **Technical** impact (encompasses the damage and loss of technical components, physical assets, etc.)
2. **Organisational** impact (relates to the organisations and institutions that manage the systems; encompassing impacts in terms of organisational capacity, coordination, and information management, etc.)
3. **Social** impact (encompasses impacts on community such as political and civil unrest)
4. **Human** impact (encompasses impact on the population, such as health-issues, well-being, casualties and injuries)
5. **Economic** impact (encompasses impacts in terms of both direct and indirect economic losses)
6. **Environmental** impact (encompasses the effects on natural resources, flora, fauna)

Figure 4. Scenario description template

2.1.5 Library of CascEff scenarios

In this section, we present a library of scenarios with cascading effects, which could be used for any exercise focusing on cascading effects. Table 3 lists some suggested scenarios selected within the CascEff project framework and whose detailed descriptions are presented in D5.1.

Table 3. Description of CascEff scenarios

Criteria	Scheldt case	Mont blanc	Festival	Séchilienne	Nut ware-house blast	SkatåS wildfire	Black out
Nature of Initiating event[23]	Man-made Land-slide	Tunnel fire	Ship Fire	Landslide	Industrial fire	Wildfire	Critical component failure at a power distribution station
Type of initiating event	Accidental	Accidental	Accidental	Natural hazard	Accidental	Accidental	Accidental
Secondary events: first order cascading effect	Risk of explosion	Risk for a mega-fire	Risk of explosion	River flow and road transportation interruption	Environmental disaster and public health risks	Risk for polluting drinking-water reservoir; smoke affecting the city (especially hospital); risk for telecommunication; nearby infrastructure (highway, airport)	Power outage followed by a total black out
Secondary events: other cascading effects (second, third ... order)	Other explosions (Occupational) Safety risks	(Occupational) Health risks	Health & Safety risks Traffic impediment Socio-economical	Flooding (2nd), Pollution (3rd), Industrial accident (3rd), Toxic release (4st), ... + many people and goods transportation problems all-over the area leading to disruption in education, economical activities, etc...	Contamination of water supply Business and Industry Political and (psycho-) social impact	Risk for affecting municipal services as water supply, healthcare. Risk for effects on transportation and communication in the region	Geographical area and number of people affected, cross border and cross system impact, socio-demographic impact
Real/ fictional	Real event	Real event	Fictional, combination of 3 real events	Fictional but based on real data	Real event	Real event, with risks for cascading effects based on both real and fictional events.	Fictional but potential
Large scale impact	Geographical, Industrial, Economic, Social	Geographical Economic, Social	Geographical Economic, (psycho-)Social	Geographical, Industrial, Economic, Social	Environmental, Industrial, Economic, Social, Health	Geographical Technical Economic Social	Geographical Physical Technical Economic Organisational Social
Cross border effects	NL-BE	FR-IT	Any border	Internal borders	Internal borders	Internal borders	NL-BE
Multi/Single Agency	Multi	Multi	Multi	Multi	Multi	Multi	Single
Expertise of the partners	Campus Vesta BE	Ghent University BE	SCE, KCCE BE	UL and INERIS FR	NFRS UK	SP SE	XVR Simulation NL
EU Relevance	Every country	Every country	Every country	Every country	Most countries	Most countries	Every country
Time span	5 days – several weeks	several days /weeks	2 days- several months	1 week minimum	Several weeks	3 days	60 hours – several weeks
Realistic	✓	✓	✓	✓	✓	✓	✓

The Scheldt case: based on a historical event in the industrial port of Antwerp (Belgium, July 5-9, 2013). Construction works created a man-made landside that caused a risk of explosion of damaged pipelines. In case of an explosion, a cascade of possible risks for the surroundings and considerable impact would have been probable.

The Mont Blanc tunnel fire: a historical scenario (24 March 1999) with real cascading effects that had identifiable cross border effects (Italy and France). The actual impacts due to the accident were very severe and had both a short and long term effect.

The Festival case: a fictitious scenario based on a combination of three real events (two incident types) with potential cascading effects, which could occur anywhere in Europe:

- (1) a hazmat transportation incident (Wetteren, Belgium, 2013; Ostedijck schip, Spain 2007),
- (2) the evacuation of an outdoor music festival (Pukkelpop, Belgium, 2007).

The Séchilienne scenario: this is not a past event but a potential scenario, which may lead to huge consequences. It concerns a potential ground movement of more than 3 million m3 in a village named Séchilienne (France).

The Nut warehouse blast scenario: based on a real industrial fire that happened in Northampton, UK (June 26, 2013) In this scenario, the political dimension is important due to the risk of environmental pollution and the possible impact on the local population.

The Skatås wildfire scenario: based on an incident in the Skatås forest located around lakes Stora Delsön and Lilla Delsjön, east of the city of Gothenburg, on the west coast of Sweden (April 29, 2008). The actual consequences of the incident were limited, although possible cascading effects with considerable impact were probable (severe consequences for personnel safety, health, properties, infrastructure, businesses, societal services, transportation, etc.).

The Power Blackout scenario: a fictive case but the potential impacts are based on real-life large power outages in Europe and North America in recent years. It is a complex cross-border scenario, a combination of winter weather and a failure of a critical component causing an outage that affects two provinces in The Netherlands and after some time four provinces in Belgium.

2.2 Conducting the exercise

The Conduct phase consists of:

- Start up with a briefing by the exercise coordinator: briefing of the exercise operators, key actors and supporting actors and distribution of documents;
- Roll out of the test script and scenario;
- Termination of the exercise

2.2.1 Roles involved in a simulation

As the purpose of a simulation is to recreate an environment as accurately as possible and to do so, many roles will have to be involved in the simulation. The following exhaustive list of roles is divided into two categories: the *exercises roles* that are more generic, applicable to all exercises, independent of the scenario, and the *scenario roles* being more specific in relation with the scenario. They do not actively participate in the organization of the exercise.

a) Exercise roles

Role	Responsibility
Exercise director or manager	Has the overall responsibility for all aspects related to the organisation of the exercise. Has a clear mandate to do so. Manages and supervises the exercise team and the whole process.
Exercise (project) team	Depending on the complexity of the exercise, recurrent functions in the exercise team are: the exercise coordinator, operators, facilitators, evaluators, observers, (safety) controllers, etc.
Exercise coordinator	The person responsible for the concrete planning, conducting and evaluating exercise activities and for the cooperation between internal and external entities.
Evaluator(s)	Persons who observe and evaluate the exercise without taking an active part in it. They are chosen for their specific expertise related to the theme and the goals of the exercise. They use evaluation documents or templates to document their observations and feedback.
Observer(s)	Have a similar but narrower role than evaluators. Their task is to observe and share their observations, without interpretation or evaluation.
(Lead evaluator)	(If there are many evaluators, assigned for specific aspects of the exercise, a lead evaluator can be appointed. He is in charge of collecting all the feedback and their integration into a global evaluation.)
Exercise Operators	Operators are in charge of operational aspects of the organisation of the exercise. They play an important role in the logistic preparation of the exercise.
Safety controller	The person in charge of occupational safety and health matters, the day of the exercise and in the preparation phase.

b) Scenario roles

Role	Responsibility
Participants Key actors	Persons who participate actively in the exercise as players in the scenario. They can be key actor or supporting actor.
Supporting actors	Persons playing an active role in the prevention, response and/or recovery actions presented in the scenario. They initiate actions and by doing so determine the actual course of actions the day of the exercise. They participate in Discussion-based as well Operation-based exercises.
Participants Key actors	Mostly volunteers, simulating a specific role in Operation-based exercises and contribute to a realistic scenario (victims, neighbours, people passing by, etc.).

2.3 Evaluation of the exercise

The Evaluation phase consists of:
- Post exercise debriefing: feedback from the evaluators is gathered, shared and discussed in one or more debriefing sessions;
- Consultation of stakeholders: results of the debriefing can be shared with stakeholders.

2.4 Creation of an Improvement Action Plan

The last phase collects relevant information and prepares the follow up. Lessons learnt from the exercise need to be consolidated into an Improvement action plan, consisting of actions, guidelines and/or recommendations for improvement.

3 The iCrisisTM simulation approach: an example of a simulation set-up and conduction process

In this section, we present the set-up of the iCrisis^{TM} simulation approach. The objective of this section is to provide the reader with an example of designing the planned simulation.

The iCrisis^{TM} simulation approach that has been developed at University of Lorraine (www.icrisis.com) belongs to the category of virtual simulations in real size, involving only crisis cells (also known as crisis units). But, unlike some systems encountered in this category, it does not rely on any computerized modeling. Its implementation requires few means but places the participants in really stressful conditions. More generally, it is distinguished from other simulators by its flexibility, portability, modularity and high level of interactivity between players. The technical part of the system is only a communication tool between the cells, which allows the animation cell to monitor the events and interact with the participants.

3.1 Objectives of an iCrisis^{TM} simulation

Using iCrisis^{TM} as a training tool has the following objectives:

- Reproduce the atmosphere of crisis situations with a certain degree of realism so that participants experience a range of typical effects in link with the characteristics defining a crisis.
- Contribute to the understanding of decision-making in emergency or crisis management teams.
- Improve the conditions of cooperative learning of the participants involved in crises management within closed groups through the sharing of their experiences, knowledge and points of view.
- Draw the attention of professional trainees to the weaknesses of their preparedness capacity by helping to assess the efficiency of their organizations in crisis situations.
- Raise situational awareness of participants (professionals and students) about challenges crisis situations may pose and the various behaviours which the actors involved in a crisis management could have
- Let the participants develop some non-technical skills such as: ability to delegate, leadership, analytical synthesis, teamwork, communication, action in uncertainty, stress management, etc.
- Demonstrate crisis communication challenges (keeping in mind that communication has traditionally been the Achilles' Heel of crisis management operations) by placing participants under the pressure of media

3.2 Technical characteristics

iCrisis^{TM} is a flexible multi-player online system which could be simultaneously used on several networked laptop-computers. Based on html5, iCrisis^{TM} is an up to date web application which can be used anywhere without any installation. Thus, it can be used by decision-makers' groups physically far from each other (even in different countries if necessary). The only requirement is the configuration of the simulation settings. It can be set by the simulation administrator for any number of groups of decision-makers involved in each simulation. Last generation web browsers (chrome or safari) are required to make iCrisis^{TM} work with comfort.

Moreover, because it is a web-based tool, iCrisis™ can make use of or interact with any web-based platform. The use of iCrisis™ does not require any specific computing knowledge and skills: participants need to have only a basic knowledge on using computers for chatting with virtual speakers.

The tool records and stores all the messages exchanged between participants' groups, thus allowing the simulation team to track messages in real-time as well as to make a dynamic analysis in order to adapt the on-going scenario the actions/decisions taken by the participants.

3.3 Routine use process

Running a simulation with iCrisis™ is a three-stage process:

- Constructing the scenario to be used
- Running the simulation
- Debriefing with participants to share their experience and to analyse the outcomes of the simulation

3.4 Scenario building

The iCrisis™ approach begins with a given scenario but then allows for adaptation of the story depending on how the participants chose to cope with the situation. A key feature of the approach is to make simulations very adaptive and responsive. Thus, the facilitators can easily implement the characteristics of their chosen scenario. The context of the scenario and the role-playing methodology both allow the crisis situation to be established. The simulations run using iCrisis™ execute an open scenario; that is, only the context of the scenario remains fixed. The story itself is left flexible to fit with the behaviour of the participants, which is not foreseeable. Since the objective is to sensitize the participants about the crisis situation and state characteristics, the management of the scenario is not a crucial point for the players. In comparison, for an emergency situation simulation exercise the scenario is very precise since the objective in such exercise is to assess the response of the players.

Through the imagined events of the scenario, the story includes the *evolving nature of the problem*; for example, starting with a snowfall warning that evolves through the snowfall event. It initially includes slight problems such as people falling, but eventually much larger problems occur, such as severe weather conditions. These problems have *important consequences* that can be both structural (blocked roads and power outages) and organizational (regular plans and procedures becoming ineffective). This main storyline is supplemented with routine incidents, forcing the participants to cope with the larger events as well as dealing with everyday problems. The accumulation of both regular and extraordinary events creates an element of *surprise* for the participants. The increasing number and diversity of events requires the involvement of *multiple stakeholders*, who are progressively included. The combination of everyday incidents that cause delays due to the lack of available resources, in addition to rare or unusual events that require innovation to design an adequate response, contributes to a situation characterized by *complete disorder and confusion* among the participants. This is the definition of chaos (from the Oxford dictionary).

The iCrisis™ platform implements some crisis situation characteristics by the addition of information depending on the scenario and on participant reactions. The content of the message influences the nature of the information, conveying uncertainty. To increase the *uncertainty* in the minds of the participants, the nature, extent, duration and consequences of the events must remain unclear. A message sent by the animation team could be perceived as urgent because it describes a situation as requiring an urgent response; this could be exacerbated by repetition or by giving shocking details. In addition to message content, the tempo of messaging is important as it makes the participants experience a rhythm of events that is irregular and unpredictable, alternating between slow periods and rapid sequences of events. The creation of an *irregular rhythm* relies on the storyline as well as on the cadence of messaging. Careful control of the information given to participants in a noisy room can help induce *information management issues* for the participants. Without being erroneous, some messages are intentionally ambiguous and/or have information that is not appropriate to the person who is receiving the message.

3.5 Running the simulation

An iCrisis™ simulation involves one to several (at least three) physically separated crisis cells, a media office and an animation team; all of which are connected by internet messaging. The three crisis cells generally consist of a Prefecture command post (at the county level), a Municipality command post and a Company command post (Figure 4). However, any configuration at a strategic level is possible. In each crisis cell, there is an observer who takes note of the functioning of the players as crisis cells members: iCrisis™ simulations are based on an observation methodology of the decision-making processes implemented in the groups. Observers are given observation forms to be used for observing players and giving feedback of the decision-making process in the group during the debriefing.

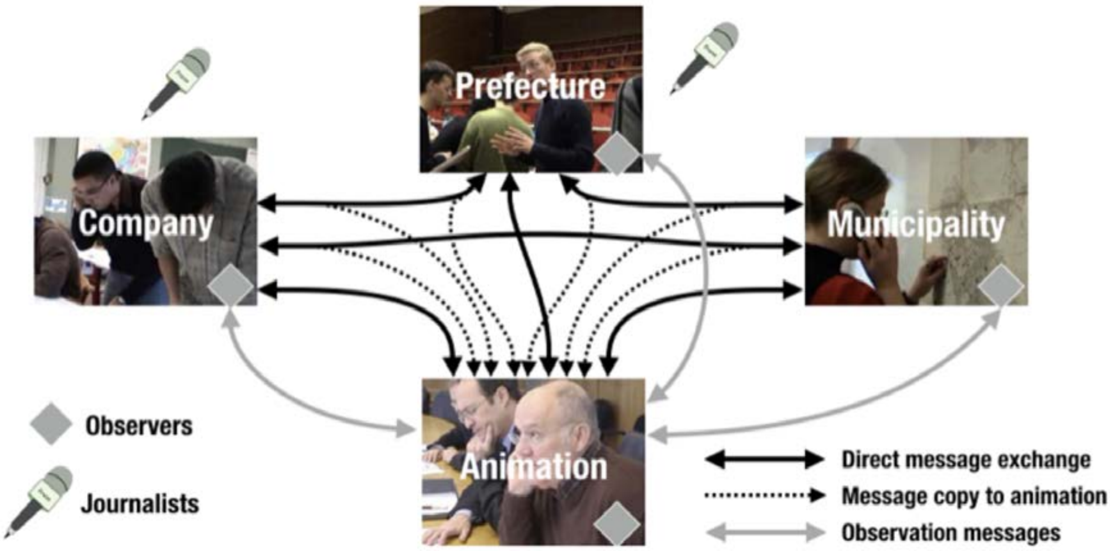

Figure 4. General overview of the iCrisis™ simulation approach (arrows represent the flow of information via text messaging)

To implement *media involvement* (incorporating social media) in the iCrisis™ simulation, some participants are chosen to play the role of journalists for media coverage purpose. A facilitator briefs them on behaviour characteristic of journalists, including tenacity, aggressiveness and scrutinizing the situation. In the iCrisis™ simulations, journalists are free to move between groups and ask questions of anyone. The participants in the crisis cells can then react as they wish. Journalists act as free agents and can visit the different crisis cells to gather information. Their role is important since their interactions with the players and their interpretation of the information they gather can create disturbances. These interactions make the information in the simulation evolve. The reason for including media as an actor is that crisis situations may worsen if inadequate responses are given when dealing with media contacts. Thus, communication skills also need to be trained besides other competencies in crisis management. Another key objective of including journalists in the scenario is to create a press article and/or a video record for a TV report, retransmitting interviews performed during the simulation to be shown during the debriefing period.

3.6 The iCrisis™ user interface

The iCrisis™ user interface mainly consists of a chatting window. The iCrisis™ chatting window (Figure 5) looks like a regular mailing box through which the different players interact. It is their only interaction channel, apart from phone communication initiated by the animation team only. Exchanging information through written messages during the iCrisis™ simulations allows the creation of a database that can be used to analyse the process during debriefing. Each message is highlighted in a colour that represents the group that has sent the message and different types of filters can be applied to display the needed information.

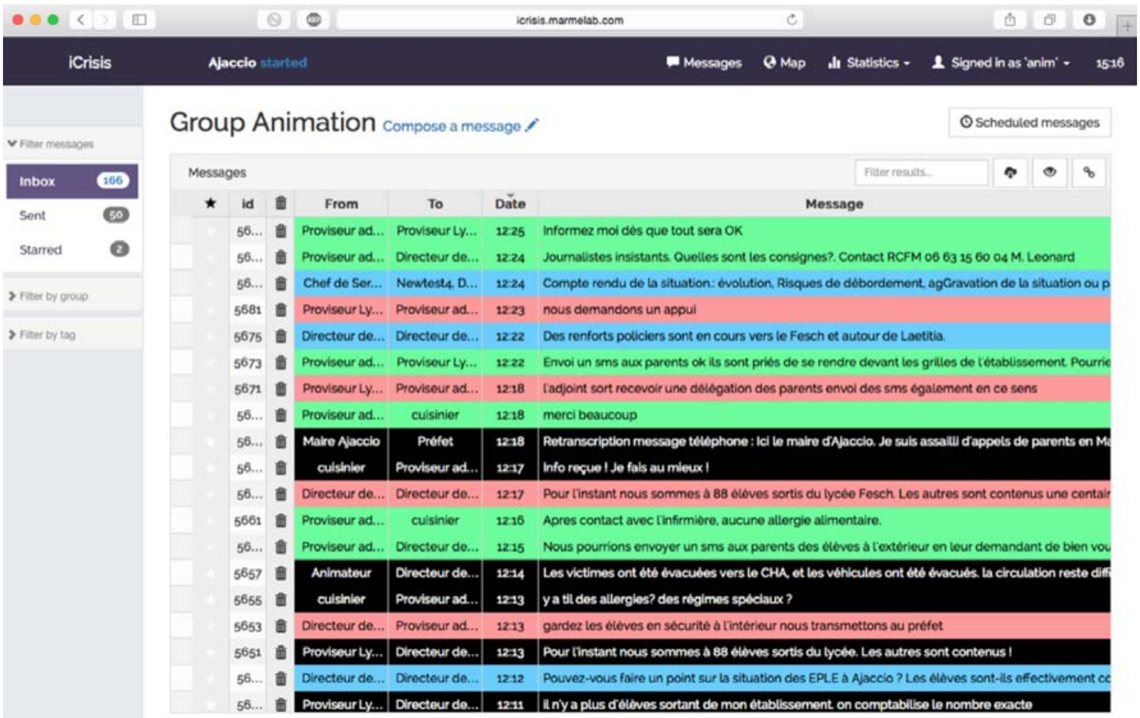

Figure 5. iCrisis™ chatting window interface

Participants are also provided with a map view window displaying a map of the location of the events. This map view window (Figure 6) is a geographical support for the players as well as for the animation team. It helps the participants by creating an overall visualization of the geographic environment of the entity to which their roles belong to. It consists in a MyMap view (drawn using Google Maps Application Programming Interface) that allows the animation team to populate the simulation with geographic information.

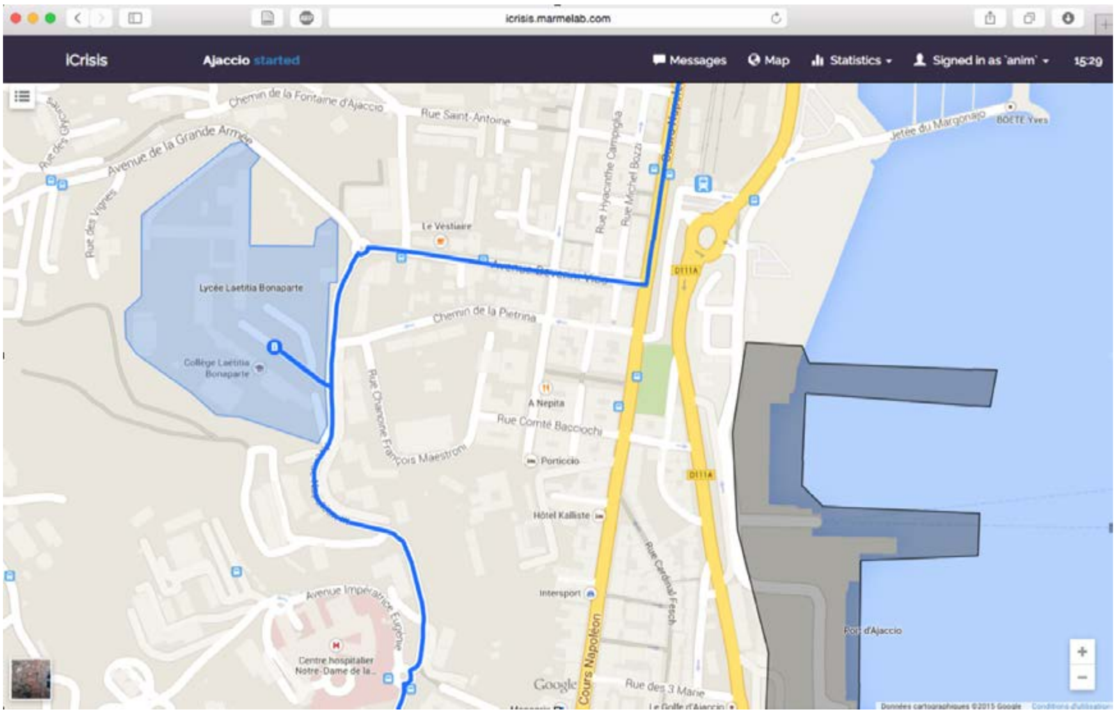

Figure 6. iCrisis™ map window interface

3.7 Simulation proceeding

Generally, a whole training session (running simulation and debriefing) is full-day session. At the beginning of the training session all the participants are in one room for briefing on the objectives of the training session and on the use of the iCrisis™ platform. Then they move to separate rooms to initiate the simulation. From the start of the simulation, each crisis cell receives scenario injects from the animation team as well as the media office. Groups can exchange messages (see full line arrows in Figure 3). The animation team can exchange messages with all groups and receives copies of all messages exchanged between the playing groups through the iCrisis™ application (see dashed arrows in Figure 3). This helps the animation team to follow, in real-time, the interactions between the groups and interact itself with the groups in order to introduce new events. These interconnections and the presence of observers (see solid grey arrows in Figure 3) allow the animation team to adapt the storyline based on the participants' reactions.

A simulation starts with an unspecified length but is usually run for a duration corresponding to approximately two to three hours. The duration is dependent on the responsiveness of the players and the simulation ends when the animation team judges that the crisis reaches a supercritical level so that it could not be resolved by the players. Once this state is reached, the animation team sends a message notifying the players of the end of the simulation.

3.8 Debriefing with participants

At the end of the simulation participants reconvene for the debriefing. Each simulation is followed by a debriefing that lasts for approximately two hours. The debriefing is the opportunity for the participants, the facilitators (from the animation team) and the journalists to share their experiences of the simulation in a frank and honest manner.

Participants from each crisis cell speak first to relate the key events they have faced and how they have coped with these events. Observers then share what they have watched regarding the team organization in the crisis cells. The journalists present a press article and/or a TV news report based on the information they gathered during the simulation. The debriefing also gives the facilitators the opportunity to talk about the potential “mistakes and misunderstandings” made by the participants in a non-judgmental way as well as about the difficulties involved in dealing with the crisis situation and increase participants’ awareness.

iCrisis™ also offers a set of statistical tools which will help the animation team during the simulation itself or during the debriefing.

4 Conclusions

Before starting the process of designing a simulation, it is crucial to define the concepts utilized in the domain. This is to avoid misunderstandings and enable to the creation of a common vision. The reflection on the level of preparation will allow to determine the main objective of the organization involved in the training process. This step will permit to design the simulation’s objectives, which can, for example, aim at sensitizing or training through an exercise.

The assessment of the training session depends on the objectives as the basis for making an evaluation during an exercise. If sensitizing the participants (organisation) has been chosen as an objective of the simulation, it is important to note that there cannot be an evaluation of the participants.

Based on these preliminary steps the choice of simulation type can be made in regards with the objectives and the development of the scenario that must take into account the identified targeted participants.

The presented methodology on design of a scenario proposes the main steps needed to build it. However, they must be adapted to the context of the chosen “story” as well as the defined objectives.

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