ELICITING KNOWLEDGE ABOUT CRISSES FROM THREE DIFFERENT PERSPECTIVES

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Abstract

Crises can be analyzed through different perspectives, regarding their scope and time horizon. This paper presents the results compiled in three different workshops corresponding to the same European project. This project deals with the analysis of large crises originated due to problems in the power network, causing major disruptions in Society.

The first workshop focused on the peak of the crisis and dealt with issues like how to respond to the crisis triggering event. Mechanisms that make possible the cascading effects amplifying the crisis impact were also identified. As crisis response is not the responsibility of a single agent, the performance of coordination mechanisms in these stressful situations was also analyzed in this workshop.

The second workshop paid attention to the relation between the efforts applied on the pre-crisis phase and the impact on the crisis peak and post-crisis phases. Its objective was to develop holistic models that allow determining all the impacts of a crisis from a long term perspective, as crises may have a long series of consequences which are not immediately observable. During the second workshop, the preventive measures that can be developed during crisis preparation and the outcome of these efforts on crisis impact reduction were analyzed.

The third workshop analyzed the inter-crisis learning process, that is, the learning process that happens from one crisis to another. This process can contribute to improving organizations resilience and crisis management capacities. However, despite organizational learning from crisis episodes is considered a key aspect to improve the preparation for future crises, there are still some learning barriers which condition this learning process that were analyzed during this session.

Each workshop led to the identification of relevant policies, the definition of potential behaviours of the crises and the characterization of the involved agents and variables.

Introduction

Currently, Society's welfare is largely dependent on the effective performance of Critical Infrastructures (CIs) since they are responsible for energy, water supply, health services, telecommunications, etc. This high dependency causes serious problems when a failure
affects one or more of these critical systems; consequently, how can current Society be ready to deal with breakdowns in CIs?

In the aftermath of recent events such as terrorist attacks (New York, London and Madrid) or natural disasters (hurricane Katrina, Indian Ocean Tsunami or Japan earthquake), Society has increased its concern about the high vulnerability of CIs against different types of threats such as natural incidents, human or technical failures and even terrorist attacks.

Understanding the long term evolution of crises covering the whole lifecycle of a crisis is necessary to face them appropriately, to diminish their consequences and to guarantee the resilience of organizations and services. However, the process of building knowledge about how to manage in the face of such unpredictable and uncertain events is not an easy issue. The increasing complexity of CIs leads to interdependencies and feedbacks which make it more difficult to distinguish causes and effects. Additionally, one of the biggest difficulties is that crisis research requires a high level of cooperation throughout different stakeholders: CIs owners, customers, first responders, governments, etc.

The need for improving Critical Infrastructure Protection (CIP) due to its high societal impact has led to an increase in the budget assigned by governments to research in this field; an incipient area of knowledge where several questions still need to be answered, such as: which are the interdependencies between different CIs? How does a society achieve a suitable commitment between investments in crisis preparation and the losses due to a crisis? How do we avoid repeating the same mistakes all over again?

Modelling and simulation methodologies provide tools that may help answering these questions through the development of simulation models. Actually, these models are useful tools to train crisis managers since they enable the identification of areas of interest for improving strategic orientation, providing insights into the necessity of cooperative actions, supporting awareness on initial and subsequent crisis effects, and providing test scenarios that can be repeated under modified conditions.

Gathering information from different experts is a crucial process to guarantee that these simulation models compile and integrate the fragmented mental models of different stakeholders. So, this process requires the use of a collaborative methodology that encourages consensus building among the different agents involved.

This paper presents a practical case to illustrate the use of a collaborative methodology in a European research project called SEMPOC (Simulation Exercise to Manage POwer cut Crises). The following sections describe the information gathering process using Group Model Building (GMB) collaborative methodology.

State of the art

CIP requires crisis managers to understand system vulnerabilities, the interaction among directly or indirectly involved sectors and how the decisions taken under stress may influence the impact of a crisis. Regarding the electrical power sector, current complexity of interconnected grids and cross border trade makes this sector particularly vulnerable to cascading effects due to natural disasters, terrorist attacks or technical failures. Actually, Europe and North America have suffered in recent years a significant number of blackouts where millions of people were affected (CRE and AEEG, 2004, Johnson, 2008, U.S.-Canada Power System Outage Task Force, 2004). This fact, in addition to the severe consequences that a power outage might have on Society, forces crisis managers to develop not only reactive strategies but also proactive ones that enhance the crisis managers' awareness to predict that a crisis is going to occur.

Due to the severe consequences that a power outage might have on Society, crisis management needs both proactive and reactive strategies to improve CIs resilience (Boin
et al., 2007, Schulman and Roe, 2007, Schulman et al., 2004). In addition, reviewing and applying lessons learned from previous crises even occurred in other sectors may be an useful approach to enhance the crisis management process (Crichton et al., 2009). Nevertheless, aspects such as the lack of coordination between public and private organizations, managerial ignorance on system vulnerabilities and inadequate training of crisis managers complicate the achievement of a high level of preparedness (McConnell and Drennan, 2006, Roux-Dufort, 2007, Somers, 2009).

The development of simulation models allows gaining an overall view and a better understanding of complex systems, and provides crisis managers with environments for training and decision support {Lyons, 2003 #304}. In the bibliography, several simulation paradigms can be found. However, no modelling method is suitable for every purpose (Sarriegi et al., 2009). System Dynamics (SD) encourages not focusing on the isolated events but rather on the behaviour patterns that these events lead to (Forrester, 1961, Sterman, 2000). This high aggregation level makes it easier to analyze crises as evolutionary processes that are affected by the degree of prior preparation and post-event consequences, lasting for long periods of time. Changing parameters of this model generates different simulated behaviours, which analysis allows a deeper understanding of the system. Policy recommendations can then be built based on those results.

Additionally, a significant body of literature links simulation modelling with collaborative modelling methodologies where modellers work on the problem jointly with multidisciplinary domain experts. SEMPOC project has selected the Group Model Building (GMB) methodology since it has achieved a long record of successes integrating fragmented knowledge, initially residing in the minds of different agents, into aggregated SD models in similar circumstances (Andersen et al., 1997, Rich et al., 2009, Vennix et al., 2007). Furthermore, the participation of the model beneficiaries during the early stages of its development also increases their understanding, confidence and acceptance of the model.

**SEMPOC Project**

The main objective of SEMPOC project is to assess the European power production and distribution systems' ability to deliver service and mitigate damage in the face of a major power cut. This objective is achieved by developing simulation models that allow crisis managers to simulate outages with different severity, and test policies in order to deliver recommendations to mitigate damage and improve recovery for future crises.

The scope of these simulation models does not concentrate on the technical details of power system sector, but rather try to embrace the big picture of the crisis including other sectors that may also be affected by the outage. This means inclusion of not only quantitative variables (hard variables), but also aspects that, although they cannot usually be precisely measured (soft variables), are known to be critical for decision making. These soft variables are usually related to human behaviour or abstract concepts such as socio-political effects or public anxiety during the blackout, which are indirectly estimated.

The complexity of CIs and their interconnections forces the research team to take an integrated and multi-disciplinary approach which includes interdisciplinary knowledge and cooperation. Three two-day workshops, which addressed the crisis issue gradually and from different perspectives, were arranged in order to gather useful information to build the simulation models. Fourteen international experts from several organizations such as crisis managers, first responders, national agencies and people from the power sector participated in these workshops which took place in San Sebastian (Spain).

The structure of the workshops was based on the three different and complementary units of analysis used in several reports which analysed crises. The first unit of analysis focused on the peak of the crisis explaining all the details about the main causes of the triggering event and the immediate response phase (ASCE, 2007, UCTE, 2004). The second unit of
analysis covers the whole lifecycle of a single crisis covering the pre-crisis, peak of the
 crisis and post-crisis phases (Kahan et al., 2009, Rose and Lim, 2002). The third unit of
 analysis covered the learning process from one crisis to another bearing in mind more than
 one crisis (Crichton et al., 2009, Elliott, 2009).

Following sections explain the specific exercises developed using GMB methodology
 which allows efficient cooperation between modellers and experts. During these
 workshops, the modelling team’s main objective was to gather information needed to
 develop the simulation models ensuring that all mental models were considered.

**Workshop 1: Crisis event**

The first workshop focused on the short term perspective of an energetic crisis covering
 an interval of a few days, from the time of the event strike until it is under control. In our
 case, this period covered sixteen days; two previous to the outage and fourteen after the
 event. The workshop paid special attention on the interplay between technical,
 organizational, human and cultural factors. Following subsections explain the exercises
 which allowed gathering information from experts.

**Stakeholders identification**

The stakeholder analysis exercise consists of identifying the main agents affecting or
 influenced by the researched problem. Firstly, domain experts were divided in different
 groups and each group worked on the identification of the stakeholders that were
 presented later in a plenary session.

Participants were also asked to classify these stakeholders in the most appropriate position
 on a two dimensional grid characterized by "Interest" in the problem on the horizontal
 axis versus ability to "Influence" on the problem on the vertical axis. The "Influence" of
 the stakeholders measured their level of impact on the problem, while the "Interest"
 represented their motivation to solve the analyzed problem. Figure 1 shows all the
 stakeholders identified during this exercise, where the key stakeholders are those located
 in the upper right corner of the diagram (inside dashed box).

![Figure 1: Stakeholders](image)

**Behaviour over time**

The second exercise focused on the identification of the most relevant indicators that
 efficiently represented the nature and evolution of a crisis caused by a power outage. The
 set of variables identified by experts as the most relevant for the scenario was composed
 by the following eight variables (their units are shown in brackets): Performance of the
 grid [number of affected customers], Communication availability [percentage],

...
Anticipated repair time [h/day], Casualties per day [number of people], Public disorder [dimensionless], Trust on decision makers [dimensionless], People working solving the crisis [number of people] and Crisis management resources [percentage of resources].

The dimensionless indicators are soft variables which cannot be measured in an accurate way so that a range of values between 0 and 1 is used. For example, for the variable “Trust on decision makers” 0 means total absence of trust while 1 value represents total confidence.

Experts were also asked for drawing the behavior of these indicators based on their experience and intuition in two opposite situations. The first one showed the evolution of these indicators when the crisis was efficiently managed and the second showed the worst case when crisis was poorly managed. Figure 2 shows the behaviours of two variables (best case in green and worst case in red), where it can be seen the increase of Crisis Management Resources as the duration of blackout is prolonged and the trust on decision makers decreases.

The information gathered during this exercise is a key input for the simulation model development, as the model should reproduce these behavior modes.

**Figure 2: Behaviour over time**

![Figure 2: Behaviour over time](image)

**Policy analysis**

The third exercise consisted of identifying the most appropriate policies that can diminish the impact of the crisis. These policies are in fact degrees of freedom that can be modified in the simulation model to obtain different behaviors. For example, a poor communication policy might damage customer trust on government and power companies, increasing the public disorder indicator if the information provided by media is not reliable. As a consequence of a high public disorder level, government and power companies may be forced to increase the deployed resources to solve efficiently the crisis.

**Workshop 2: Single crisis lifecycle**

The main purpose of the second workshop was to analyse the crisis from a long term perspective, covering the whole lifecycle of a crisis. The exercises carried out in the second workshop sessions concentrated on identifying the relationship existing between pre-crisis planning and effective response to a crisis. This approach allows evaluating the behaviour on the pre-, peak and post-crisis, providing a more holistic evaluation of long term consequences.

**Pre-crisis and Post-crisis Indicators**

The aim of this exercise was to identify the most important issues that crisis managers should take into account during the pre- and post-crisis periods. The analysis of the pre-crisis phase involves the development of measures and policies related to different areas
that enhance the preparation level of organisations to deal with any crisis. On the other hand, the post-crisis phase is a period for analysis and reflection. Crisis managers evaluate the effectiveness of crisis management, identifying the threats and vulnerabilities and errors made during the crisis peak.

Workshop participants were asked first to identify pre-crisis and post-crisis indicators and to subsequently cluster them into sectors (see Figure 3).

**Figure 3: Main indicators of pre-crisis and post-crisis grouped by sectors**

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Pre-crisis</th>
<th>Post-crisis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis preparation and</td>
<td>Number of cross border crisis exercises</td>
<td>Assumption of responsibilities</td>
</tr>
<tr>
<td>coordination</td>
<td>Number of trained responders</td>
<td>Coordination of protocols</td>
</tr>
<tr>
<td></td>
<td>Coordination protocols</td>
<td></td>
</tr>
<tr>
<td>Legislation and</td>
<td>Cross border agreements and regulation</td>
<td>Review of existing agreements</td>
</tr>
<tr>
<td>Regulation</td>
<td></td>
<td>Development of new agreements</td>
</tr>
<tr>
<td>System state</td>
<td>Infrastructure improvement</td>
<td>Infrastructure adequacy</td>
</tr>
<tr>
<td></td>
<td>Dependency on foreign providers</td>
<td></td>
</tr>
<tr>
<td>Society awareness</td>
<td>Country reputation</td>
<td>Confidence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public behaviour</td>
</tr>
</tbody>
</table>

**Policy recommendation**

This exercise enables the modelling team to close a crisis loop linking the pre-crisis and post-crisis stages. The investments made during the pre-crisis phase to enhance preparation will determine the crisis impact afterwards. In the same way, the crisis impact analysis made in the aftermath may bring to light the strengths and weaknesses in the handling of the crisis providing feedback to correct mistakes for future crises.

Therefore, the development of policies is necessary to go from the worst to the best scenario (see Figure 4). The worst scenario would be the one where none of the indicators had been properly managed out whereas in the best scenario all indicators had been effectively developed.

For example, performing a good training to CIs staff and first responders may help to respond to the crisis in a faster and more efficient way. The existence of agreements increases the availability and productivity of available resources to respond to the crisis. The development of a suitable level of maintenance in the system or designing a redundant grid may help to cushion crisis impact. Finally, the information given to Society through the media about the crisis solving process should be reliable and constant to avoid loss of trust on decision makers or an increase of public anxiety.

**Figure 4: Policies to build system resilience**

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Crisis preparation and coordination</th>
<th>Legislation and Regulation</th>
<th>System state</th>
<th>Society awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policies</td>
<td>Internal training</td>
<td>External training</td>
<td>Legal and regulatory issues</td>
<td>Infrastructure adequacy</td>
</tr>
</tbody>
</table>

**Workshop 3: Inter-crises learning process**

The last workshop focused on the organisational learning process from previous crises or incidents. The early detection, comprehension and use of crisis indicators provided new insights concerning dangers, enhancing the crisis preparation and response. Actually, an exhaustive detection of precursors, analysis of occurred crises and information exchange among different institutions may help to learn from crises and to avoid previous mistakes.

The detection of these precursors leads to an increase in the level of crisis managers' awareness what can diminish the crisis impact and the system weaknesses. Perception of precursors requires the ability to distinguish significant information from noise; actually it
requires that crisis managers are aware of incidents or events that may cause a crisis (Shaw et al., 2009)

Identification of awareness precursors and barriers

The goal of this exercise was to shed light about the precursors that may help to predict crises. Some of the most relevant precursors identified were the following:

- **Redundancy of power load capacity**: The power production and power demand must be kept in equilibrium to avoid severe frequency and voltage disruptions which ultimately cause outages. A lower degree of redundancy reduces the power system's ability to handle unexpected occurrences which may cause blackouts.

- **Trust in government**: It can be measured by media reports, complains and interviews with focus groups. It is necessary that governments not only base their decision on the technical details of an incident but also on the soft factors, such as organizational preparedness.

- **Type of threat detected and interpreted** by intelligence agencies, which impact can be diminished by contingency plans.

The crisis managers’ awareness may influence the severity of future crises. For instance, a high level of awareness can make managers act proactively in order to diminish the probability of an outage occurrence. However, the ignorance of incidents in the system can lead to high severity consequences. Experts identified the following barriers which limit awareness levels and may influence crisis management.

- **Lack of information or its incorrect management**: The quality and quantity of the information to analyze when a crisis occurs is crucial. Divergent information from different sources may distort the situation and delay the crisis managers’ response as they must analyze the reliability of information and decide which one is relevant.

- **Lack of economical funding**: it conditions the available resources for crisis managers and first responders to enhance their training and develop new skills. Scarce resources also limit the number of experts in crisis management field.

Indicators to measure awareness

As the crisis managers’ ability to detect precursors could prevent or mitigate a crisis, the experts were asked to think how different levels of awareness affect the system over time. For the following exercises, domain experts were divided in three groups, mixing people from previously defined different sectors obtaining in this way contribution from different perspectives and expertise to the same problem.

Three different scenarios were presented in order to analyze these alternatives (see Figure 5). The first scenario, called “No detection”, represented a situation where many events were taking place but none of them were detected, so that as consequence two large crises occurred. The second scenario named Poor detection & limited resolution showed that some of the occurred events were detected, so that crisis managers acted upon them consequently and one of the two crises was avoided. In the third scenario, Detection & resolution, most of the events were detected and managers acted upon them, preventing both crises to occur. As the events are detected and analyzed, the number of future events is reduced enhancing system resilience for future crises.
Once the scenarios were validated by experts, they proposed several indicators that crisis managers should concentrate on in order to go from “No detection” scenario to “Detection & Resolution” scenario. Then, experts proposed some indicators that could be consolidated between the stories to analyze the different indicators that influence the system’s behaviour. Figure 6 shows the indicators identified during this exercise and the most voted ones are emphasized in grey.

**Figure 6: Indicators extracted from dynamic stories (number of votes in brackets)**

- Capacity for regulation (0)
- Coordination of stakeholders (0)
- Number of lessons learned (0)
- Number of small incidents (6)
- Level of regulation (2)
- Ability to use resources (training) (0)
- Quality of crisis management (2)
- Quality of infrastructures design (2)
- Knowledge of emergency operations
- Ability to respond to an event/crisis (0)
- Budget for crisis management (1)
- Number of detected incidents (2)
- Perception of risk
- Vulnerability consequences (2)
- Resources for analysis + design (9)
- Threats to power (0)
- Crisis Planning Capability (0)

**Behaviour over time graphs**

The most voted set of indicators were used as inputs for this exercise, which consisted of drawing their evolution over time. Experts relied on their experience and intuition in the three mentioned scenarios, identifying also the most suitable units to measure the indicators.

**Work after the workshops**

During the ensuing months to each workshop, the modelling team turned the data collected during the workshops into simulation models. The validation of each model was performed by teleconferences engaging the experts who took part in the workshops. Experts clarified some technical questions and verified the simulation model performance.
providing modelling team with useful information and comments to refine the models. This validation process is also important to build confidence in the developed simulation models.

The developed models enable managers to test a range of options for alleviating the crisis situation, and to test them against different environmental and structural scenarios. This will increase insight in the consequences of some policies enhancing in this manner their crisis management skills. The simulation model enables crisis managers to analyse the influence of each policy on the overall crisis impact.

Discussion

One of the most important drawbacks in the crisis management enhancement process is that relevant knowledge about crises in CIs is fragmented in several stakeholders’ mental models distributed in various sectors and countries. SEMPOC project has used a collaborative methodology to elicit initially fragmented knowledge from experts and make it explicit finally integrating it in a more coherent way in simulation models.

However, further research is still required to calibrate these simulation models properly. During the workshops, many qualitative data were gathered but there are not enough quantitative data to establish for instance the influence of a proper training in improving the response during a crisis or the effect of a high level of maintenance in diminishing the crisis impact.

References


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