From pre-crisis to post-crisis going through the peak

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ABSTRACT: Managing crises is an uninterrupted process. Before the crisis peak strikes, managers must concentrate on developing preventive measures as during crisis time there is no opportunity if they have not been implemented in advance. Therefore, it is essential to understand that the crisis does not only involve the triggering event but also pre-crisis and post-crisis periods. When crises are observed from this holistic perspective, the evaluation of crisis management should take into account the whole crisis lifecycle perspective. This paper presents a compilation of different policies that may be applied along the crisis lifecycle in addition to a simulation model, which allows analysing the evolution and effect of the used resources and the diverse potential impacts of the crisis.

1 INTRODUCTION

As Coombs states a crisis does not just happen it evolves (Coombs 2007). A crisis does not start when the triggering event occurs; there is a long process before its occurrence and also after. Thus, there is a need of a holistic overview when managing crises. Crisis management must consider the Crisis Lifecycle (long term evolution of crises) in order to respond them properly and diminish their consequences. The life cycle of crises encompasses three phases (Coombs 2007): pre-crisis, crisis event and post-crisis. In other words, the relationship among precursors and mitigation, the manifestation of the crisis and the restoration process that returns the system to its previous state.

It is also necessary to be aware about the complexity of crises. The existing connections and interdependencies among several sectors spread cascading effects from one to another. Furthermore, these cascading effects can transcend international borders affecting more than one country. For example, during the last decade there have been several international large scale power cuts such as the 2003 blackouts in North America (U.S.-Canada Power System Outage Task Force 2004) and Italy (CRE & AEEG 2004, Union for the Coordination of Transmission of Electricity (UCTE) 2004) as well as the 2006 blackout in Europe which spread to Morocco (Union for the Coordination of Transmission of Electricity (UCTE) 2007, Johnson 2008).

Therefore, international and multidisciplinary experts’ participation is required to obtain a holistic perspective. Thus, there is a need of gathering the initially fragmented knowledge residing in the minds of the experts.

This paper presents the results obtained from a two days workshop carried out during an European project called SEMPOC (Simulation Exercise to Manage POwer cut Crises). SEMPOC project’s objective is to assess the European power production and distribution system’s ability to deliver service and mitigate damage in the face of a major power cut. This objective is achieved through the development of simulation models which represent the behaviour of a large crisis on the energy sector. These simulation models allow us to run different scenarios in order to analyse the effect of developing policies related to crisis management. When designing and implementing those policies on these models, the simulation’s behaviour will be different and this will let crisis managers learn how their decisions can affect the evolution of future crises.

The following sections of the paper present the state of the art about simulation modelling as well as the process, methodology and results of a SEMPOC workshop conducted with the participation of several international experts. We explain the workshop’s objective and the different exercises carried on during the two days workshop. We also present the indicators that were identified by the domain experts as most relevant for crisis management. Subsequently, we explain the policies that crisis managers might develop in order to bring those indicators to their optimal level. After that, through the explanation of a simulation model’s structure, we describe the strategy followed to implement those policies. Finally, we present the different behaviours of the simulation model when applying those policies and its usability to improve future crises’ management.
2 METHODOLOGY

Modelling and simulation let to obtain an overall perspective for a better understanding of complex and dynamic systems such as crises. Crisis managers can use simulation as a training tool where they can observe how their decisions and policies development affect to crises’ evolution. In dynamic complex systems, variables change over time as they interact and some of these changes are not straightforward to predict, as there are time delays involved between causes and effects and between actions and reactions. When a policy is applied at sector A in the model with an expected immediate result at sector B, this result may never be obtained and furthermore, some unintended effect may be observed at a distant another sector C. Thus, policies are the degrees of freedom that can be modified in the simulation model to obtain different behaviours that enable observing the consequences of each policy in the overall system in addition to understanding the causes of undesirable and unpredictable dynamics.

We have chosen System Dynamics computer simulation in combination with Group Model Building collaborative methodology as these methodologies are the most suitable to achieve SEMPOC’s purposes and have been successfully combined before.

System Dynamics focuses on the behaviour that the combination of several events leads to and not only on isolated events (Forrester 1961, Sterman 2000, Maani & Cavana 2007). This high aggregation level allows the analysis of crises as evolutionary processes where the activities carried out on pre and post-crisis stages have significant influence during the whole crisis lifecycle. Furthermore, System Dynamics allows considering not only crises’ technical aspects but also social ones such as public disorder. This means the inclusion of not only quantitative variables (hard variables), but also aspects that, although usually they cannot be empirically measured (soft variables), are known to be critical for decision making as they may have significant side effects during a crisis that can even influence the crisis duration (Lindell & Prater 2003).

Group Model Building collaborative methodology is a process designed to develop consensus and support for organisational interventions (Richardson & Andersen 1995, Vennix 1996, Andersen et al. 1997, Vennix et al. 2007). Group Model Building has been successfully applied to many different complex and interdisciplinary problems (Vennix 1996, Sterman 2000). Group Model Building allows the modelling team to work together with international experts integrating and making explicit their fragmented knowledge in order to develop simulation models.

3 SEMPOC WORKSHOP

As commented before, there is a need of gathering experts’ knowledge to improve future crisis management. Thus, fourteen international experts from several organisations such as crisis managers, first responders, national agencies and people from the power sector (Table 1) were invited to take part on the SEMPOC workshop which took place in San Sebastian (Spain).

The main objective of this workshop was to focus on identifying the main issues for the development of a whole crisis lifecycle simulation model in order to analyse large power crises evolution over time. This simulation model takes into account the long term perspective; from the pre-crisis stage going through the crisis peak and ending by the post-crisis phase. This long term perception allows crisis managers to have a holistic view of the crisis giving them the opportunity of evaluating how prevention and preparedness activities influence on crisis’ evolution and its impact. Furthermore, they can analyse with hindsight their management to avoid making the same errors again improving for future crises management.

During the pre-crisis period, crisis managers’ main goal is to identify threats and vulnerabilities, reduce weaknesses, and prepare plans for dealing with the future risks. Afterwards, the crisis peak phase is the visible manifestation of the crisis caused by a trigger-

| Table 1. SEMPOC workshop participants. |
| Organisation | Country |
| National Operations Centre | Netherlands |
| Sjöland & Thyselius | Sweden |
| Swedish Civil Contingencies Agency | Sweden |
| REE (Spanish energy company) | Spain |
| Gas Natural—Fenosa (Spanish electric and gas company) | Spain |
| Faculty of Criminal Justice and Security, Gjøvik University College | Slovenia Ljubljana |
| CNPIC (Critical Infrastructure Protection National Centre) | University of Spain |
| Argonne National Laboratory | USA |
| Directorate for Civil Protection and Emergency Planning | Norway |
| Danish Emergency Management Agency (DEMA) | Denmark |
| SAMUR (Emergency and Rescue Service) | Spain |
| Eles (Elektro Slovenija) | Slovenia |
| EPES (Public Emergency Health Organisation) | Spain |
3.1 Workshop activities

The exercises carried out during the two days workshop were focused on these long term issues, linking the three stages of crises from the prevention activities carried out during the pre-crisis phase to the evaluation on the post-crisis stage. Some of the outcomes achieved in those exercises are explained in the following sections.

Before starting with the exercises the SEMPOC project’s objectives were explained to the experts and the modelling team established the experts’ work teams and the expectations for those workshop days. Afterwards, pre and post-crisis stages and crisis lifecycle concept were explained.

The outcomes from these exercises were translated into a simulation model where crisis managers and institutions may obtain the necessary knowledge that allows them to establish suitable measures and policies in order to improve crisis response for future incidents.

3.1.1 Story building exercise

To develop the holistic crisis simulation model there is a need of identifying the most important issues that crisis managers’ should bear in mind during the pre and post-crisis periods. For that reason, the work teams were firstly asked to think about narratives in order to explain which type of events or incidents must take place to provoke a large crisis in the power sector. After all teams presented their stories, the experts decided to combine their most relevant aspects to have one consolidated story.

The consolidated story included two countries, A and B. There was a failure in Country A’s power net but the triggering event had not yet been identified. This failure had lead to a fire in a nuclear power plant, therefore some cross border lines were not working and due to an inadequate infrastructure the Country B was not receiving power from Country A. Furthermore, as each country was prioritising their own needs there was not coordination among both countries so the assistance that Society should receive was not the proper one.

This story was used as a base to make experts think about the main indicators during the whole crisis lifecycle. Firstly, experts worked in small teams and then they presented their indicators to all participants. After that, they identified the most influential crisis management indicators and linked them with the crisis phases.

3.1.2 Consolidation of pre-crisis indicators

In order to properly face and manage crises, it is necessary to be prepared investing time and resources and trying to prevent future crises to occur. Thus, the purpose of this exercise was to focus on the identified indicators related to the pre-crisis stage. The experts were asked to cluster the pre-crisis indicators and the following groups were created: Crisis preparation & Coordination, Legislation & Regulation, System state and Society awareness.

Afterwards, a voting exercise was carried out where each expert was given a number of votes in order to let them decide which indicators were the most relevant ones (units are shown in brackets):

1. Crisis preparation and coordination
   - Number of cross border crisis exercises [Number of exercises]: Crisis managers’ preparation for such large crises should include the performance of, at least, one cross border exercise per year.
   - Number of trained responders [Number of people]: Having enough well trained crisis responders will improve crisis management.
   - Coordination protocols [Number of protocols]: When a crisis occurs there must be a good coordination among managers therefore, there should be coordination protocols to establish procedures and responsibilities.

2. Legislation and Regulation
   - Cross border agreements and regulation [Number of agreements]: During the pre-crisis stage existing agreements and regulation must be reviewed and updated. In some cases, new agreements and regulation should be developed.

3. System state
   - Infrastructure improvement [€ invested]: Before the crisis triggering event the infrastructure must be in a proper state, this means that the system owners have to invest in maintenance and renovation of infrastructures and components.
   - Dependency on foreign providers [KW provided]: It is necessary to analyse country’s dependency in foreign providers as a problem in a provider country may spread to ours.

4. Society awareness
   - Country reputation [Country’s position in the reputation index]: Having a good country’s
reputation is an important factor to avoid public anxiety. Society is very sensitive and people starts to worry when they know that country’s reputation is not good. Therefore, any kind of crisis is more likely to occur if Society is overly anxious.

3.1.3 Consolidation of post-crisis indicators
In the same way we did for the pre-crisis indicators, the indicators identified for the post-crisis stage were first clustered and then ranked by a voting exercise. In this phase experts clustered the indicators in one more group than what they did for the pre-crisis stage so the identified groups for post-crisis were: Crisis preparation & Coordination, Legislation & Regulation, System state, Society awareness and Crisis learning.

In this post-crisis stage some of the identified indicators were soft variables which cannot be empirically measured so they were established from 0 to 1. For example for “Public Behaviour” indicator 0 means that there is no public reaction, while 0.5 is when Society is worried and a significant amount of phone calls are being made to the involved organisations asking for information. Finally, the value 1 will be the situation where Society is overly anxious and they start to demonstrate on the streets to show their disagreement with the crisis management.

This time, the most voted indicators for the post-crisis stage were (units or the way to measure indicators is on brackets):

1. Crisis preparation and coordination
   - Coordination protocols [Number of protocols]: After the crisis peak the coordination protocols have to be reviewed and updated.
   - Assumption of responsibilities [soft variable from 0 to 1]: It is necessary that all the organisations involved in the event assume their responsibility to face the crisis appropriately.

2. Legislation and Regulation
   - Review of existing agreements [Percentage of reviewed agreements]: There has to be a complete review of agreements during the post-crisis to see which aspects have to be modified.
   - Development of new agreements [Number of agreements]: In some cases it will be necessary to develop new agreements to improve future coordination among the affected sectors.

3. System state
   - Infrastructure adequacy [soft variable from 0 to 1]: The crisis could have affected the infrastructure so there is a need of restoring the damage and also of thinking about the current state of the existing infrastructure.

4. Society awareness
   - Confidence [soft variable from 0 to 1]: If Society feels that they are receiving reliable information about what is happening they will be more confident on the organisations or government. However, if they feel that the information is distorted their will not trust managers.

   - Public behaviour [soft variable from 0 to 1]: When a crisis strikes Society can help to better manage it or even can make it worse. This is related to confidence as if Society loose trust on decision makers, public anxiety and disorder will increase making crisis management much more difficult.

5. Crisis learning
   - Information exchange [Percent of age shared information]: During the post-crisis stage managers have to exchange all the information they have to the rest of involved organisations.
   - Quality of triggering event’s analysis [soft variable from 0 to 1]: Having all the information, crisis managers can make a proper analysis of the crisis development deeply analysing the triggering event and drawing lessons learned for future events.
   - Quality of Incident Commission [soft variable from 0 to 1]: An incident commission should be established to analyse and evaluate the development of the crisis taking into account the developed procedures.

3.1.4 Policies identification
Until that moment, the experts had been working on the pre-crisis and post-crisis stages independently, without thinking of the relationships or connections between both phases.

By means of this exercise, the modelling team wanted to close the loop by linking those phases through the implementation of several policies in order to go from the worst to the best scenario. 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. This process made feared situations become hoped issues.

The experts worked in groups thinking about these policies and also about how long it would take to improve those issues. After that, they presented their results in plenary in order to consolidate what all have considered.

Finally, domain experts agreed to cluster all the identified policies into the following ones:

1. Crisis preparation and coordination
   - Internal training (Power Company’s workers): Internal training refers to the training that staff of power companies carries out in order to know how to solve and respond efficiently to a crisis. Performing a good train-
ing to workers for crisis response can help to solve the crisis in a faster and better way.

External training (first responders, Society, etc.): External training refers to the training that first responders have to perform in order to be able to act efficiently once the crisis has happened. It also includes how Society is prepared to face the crisis.

2. Legislation and Regulation
– Legislation and regulation issues: The existence of agreements increases the number and productivity of available resources to solve the crisis and it also reduces the time needed to allocate those resources.

3. System state
– Infrastructure adequacy: It refers to the quality of the technical system, that is, the robustness and redundancy level of our system to face any problem that can damage the system and to prevent a crisis to occur.
– Infrastructure maintenance: It includes lines repair, renewal of old equipment with reliable components, etc. If the power lines are robust and are well maintained the probability that a crisis occurs is lower than if they are in a poor state. Even if they do not avoid the occurrence of a crisis, a good maintenance of the lines can reduce the severity of the impact.

4. Society awareness
– Communication to Society through the media: Society has to be properly informed about what is happening to avoid loss of trust on decision makers, public anxiety and/or demonstrations. For this reason, it is important to give correct information to mass media.

5. Crisis learning
– Precursors’ detection: Precursors detection and analysis can help decision makers to avoid a crisis occurring.
– Information exchange: If there exists a good information exchange, crisis managers can know about all the issues that are occurring and through its analysis they will improve their management.
– Lessons learned: If crisis managers develop proper crisis learning they will be able to improve their management for future crises.

3.1.5 Baby model
As final exercise of the workshop the modelling team showed to the experts a first draft of the causal loop diagram developed taken into account the identified policies (Fig. 1).

Through this causal loop diagram the domain experts could see the connections and influences among the policies that were identified as the most relevant ones for crisis management. Afterwards, the modelling team used this diagram as a basis for the development of the simulation model’s structure.

Causal loop diagrams consist of variables connected by arrows (causal links) denoting causal influences among them. Each causal link is assigned a polarity either positive (+) or negative (−). On the one hand, a positive link means that if the cause increases the effect also increases above what it would otherwise have been, and if the cause decreases the effect also decreases. On the other hand, a negative link means that if the cause increases the effect decreases below what it would otherwise have been, and if the cause decreases the effect increases. Regarding the loops, if the feedback effect reinforces the initial variable it is a reinforcing loop (R) and if it opposes the original variable it is a balancing or control loop (B).

Each of the identified policies corresponds, at least, to one of the causal loops included into the simulation models’ diagram:
– R1 loop “Damaged system through impacts”
  Any “Impacts” affecting the system can produce damages on it. Higher the impact higher the damage. Thus, if the “System State (Adequacy)” is poorer its robustness will be lower and, consequently the system will be more vulnerable to face subsequent “Impacts”.
– B1 loop “System improvement after impacts”

![Causal loop diagram developed during the SEMPOC workshop.](image)
This loop tries to reduce the effect of the R1 loop. When “Impacts” occur, crisis managers deploy some “Resources” from the available ones to improve the “System State (Adequacy)” as it could have been damaged. Having an appropriate “System State (Adequacy)”, future “Impacts” can be avoided or at least reduced.

- **B2 loop** “Mitigation quality improvement through system state”
  It also reduces the effect of R1 as when “Impacts” arise “Resources” are deployed to get a better “System State (Adequacy)”. Therefore, a good “System State (Adequacy)” will improve “Mitigation Quality” reducing next “Impacts” severity.

- **B3 loop** “Resolution quality improvement through legislation”
  After “Impacts” some “Resources” are deployed to develop new “Legislation and Regulation” or to review and update the existing one. This “Legislation and Regulation” will improve crises’ “Resolution Quality” as in those legislations resources deployment will be captured. Thus, in future events the resources will be deployed faster and efficiently. Therefore, future “Impacts” harshness will decrease.

- **B4 loop** “Resolution quality improvement through preparation and coordination”
  It refers to the awareness of Society when “Impacts” occur, higher the impact bigger “Society Awareness”. If Society is not well informed about the situation they will lose trust on managers and will start to get overly anxious. This reaction will put pressure on managers who will have to solve impact’s consequences in a more efficient way improving “Resolution Quality” to try to recover Society’s trust on them and reducing future “Impacts” severity.

- **B5 loop** “Resolution quality improvement through preparation and coordination”
  The loop illustrates how after the occurrence of “Impacts” the deployment of “Resources” to improve “Crisis Preparation and Coordination” will get a better “Resolution Quality”. When power company workers and first responders receive a good training (“Crisis Preparation and Coordination”) they will be able to react better and faster improving “Resolution Quality” and also avoiding the occurrence of next “Impacts” or lowering their consequences.

- **B6 loop** “Resolution quality improvement through learning, preparation and coordination”
  This loop represents that after “Impacts” managers deploy “Resources” for “Crisis Learning”. When agents review their management and procedures developed during past impacts they learn (“Crisis Learning”). The efficiency of the invested time on learning will improve their “Crisis Preparation and Coordination” and therefore, they will be able to increase their “Resolution Quality” what will decrease future “Impacts” severity.

- **B7 loop** “Mitigation quality improvement through preparation and coordination”
  After the “Impacts” some “Resources” are applied to properly train company workers and first responders (“Crisis Preparation and Coordination”). Thus, they will be able to perform better mitigation issues (“Mitigation Quality”). Consequently, next “Impacts” harshness will be reduced.

### 4 SIMULATION MODEL

During the following months after the workshop, the modelling team analysed all the materials obtained in the workshop and started to develop the simulation model. The developed simulation model represents a situation where some events take place provoking damages on the power system. The first event is a small one and occurs in month 40 whereas the second one happens in month 80 and is a 400 times bigger impact.

In the following graphs (Figs. 2–4) different simulation runs are represented in order to see the effect of accomplishing the policies commented before. The “Base Run” scenario (line number 1 in graphs) shows how the model behaves in good conditions, where suitable investments are made to develop a good level of policies. However, in the “Low Level of System Adequacy” scenario (line number 2) there are not enough resources to improve the state or adequacy of the system. Something similar happens with the “Low Level of Crisis Preparation” scenario (line number 3) where there are not sufficient resources to improve crisis preparation and coordination.

Figure 2 shows the evolution over time of “Impacts” variable which measures the economic losses caused by the events. The first event cannot
be distinguished on the graph due to its scale as the big events’ impact is of some billions whereas this event has an impact of millions.

As it can be seen in the graph, the impact is higher in “Low Level of System Adequacy” and in “Low Level of Crisis Preparation” scenarios than in the “Base Run”. This occurs since, as commented before (see Section 3.1.5), having a good system state can reduce future impacts but having the opposite situation, a low level of system state can also increase future impacts’ severity. Moreover, a similar effect happens with crisis preparation and coordination.

In Figure 3 the evolution of “System State (Adequacy)” variable can be seen. In the “Base Run” scenario the initial level of system state is higher than in the “Low Level of System Adequacy” as from the beginning there are not enough resources to maintain that level. Furthermore, the effect of the small event occurred in month 40 can only be seen in the “Low Level of System Adequacy” as the system is more vulnerable.

After the impact, crisis managers understand that a better system state is needed and therefore, they deploy resources to increase this state. However, after month 150 there is a relaxation effect as no events are occurring. Crisis managers start to forget past events and the pressure to increase the system state’s level decrease. Consequently, the system level decreases until the level that they consider as sufficient.

In the “Low Level of Crisis Preparation” scenario the relaxation effect is delayed in comparison with “Base Run” because the consequences of the event have been higher and crisis managers need more time to forget.

In Figure 4 “Crisis Preparation and Coordination” variable is represented and its behaviour in the three runs is similar to the behaviour of “System State (Adequacy)”. In the “Low Level of Crisis Preparation” scenario the effect of the small event is almost inappreciable because, as the system state level is good, the impact is lower.

Once having developed the simulation model, the modelling team performed a validation process through a series of teleconferences with the domain experts who participated on the workshop. The aim of the validation process was to let experts to analyse the simulation model and the different behaviours obtained when developing several scenarios and to guarantee that they agree on its usability for crisis management improvement.

5 CONCLUSIONS

The collaborative methodologies such as Group Model Building are especially useful when there is the need of involving several agents from different expertise into the process. Group Model Building in combination with System Dynamics allows the integration of each piece of the problem at hand into a holistic simulation model that permits a more complete view. The advantage of this kind of simulation modelling is that it makes explicit tacit assumptions about the causal structure of the system which are often misjudged making difficult for crisis managers to realise about them. Based on our initial experiences with this process, we believe that it is a useful method for scenario development and design to test different policies application in order to train crisis managers.

Throughout the process the results obtained are several. On the one hand, the exercises carried out during the workshop provide us with information about the most important issues involved into the crises. On the other hand, the final outcomes of the workshop are the simulation models which allow us to test different scenarios and policies application. Through the analysis of these simulations managers can learn how their decision making influences the crisis’ evolution in order to improve crisis management.
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