# Using GMB Methodology on a Large Crisis Model

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**ABSTRACT**

Mitigating, detecting, evaluating, responding and recovering from crises are highly complex tasks that involve many decision makers (agents). As a consequence using collaborative methods that allow the cooperation among these agents during the crisis management strategy and procedures design is of significant importance.

Group Model Building (GMB) is a robust collaborative methodology that has been successfully used for modelling several complex socio-technical problems, where different agents may have diverse perspectives or interests in the problem under analysis. Through the development of a series of exercises, GMB allows the integration of these initially fragmented perspectives. Modellers translate the knowledge elicited from experts during GMB workshops into simulation models that reproduce the behaviour of the problem. This paper presents the use and adaptation of the GMB methodology in a research project about large pan European crises due to outages in the electricity sector.

**Keywords**

Crisis management, collaborative modeling process, Group Model Building (GMB), collaborative methods

**INTRODUCTION**

Society today is totally dependent upon secure generation and distribution of electrical energy. A stable supply of electricity allows us to flick a switch and have light in the middle of a dark night, turn on the air conditioner when it is too hot, or send an email to the other side of the world in the blink of an eye. To ensure availability of supply, the electricity generators and consumers are not connected in a fashion where one generator serves a specific set of consumers. Instead, all generators and consumers are connected to the same meshed grid. Thus, if one generator or one power line fails, redundant components can take over the job of the failed component.

Connecting everything together obviously increases the complexity of the grid. Advanced protection mechanisms and command and control systems have therefore been created to make it possible to manage the integrated power system in a reliable manner. However, adding those mechanisms make the grid even more complex. In the last decade, malfunctioning protection mechanisms and breakdowns in the command and control of power systems have led to several serious and large scale outages such as the ones that occurred in Italy and North America in 2003 and the blackout in Europe in 2006 (CRE and AEEG, 2004, Johnson, 2008, U.S.-Canada Power System Outage Task Force, 2004). These incidents although affected millions of people had relatively low due to their short duration. Fortunately, the energy sector has not yet experienced coordinated attacks that have resulted in long outages with international consequences. Due to our dependency on electrical energy, an important question arises: What would happen if several countries suffered from a long time blackout? How would their critical infrastructures (hospitals, logistics, transportation, water and food supply, etc.) behave? Which might be the sociopolitical consequences of such a crisis?

Our society has many critical targets that can potentially be attacked. We cannot assume that all terrorist attacks or other security incidents can be prevented. Consequently we have to improve our ability to mitigate, detect, evaluate, respond and recover from such severe crises. Since we are considering a large scale event which has a larger scope compared to the mostly national crises that have occurred so far, real experience nor documented

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reports about this type of events exists. Consequently the process of building in advance knowledge about such unpredictable and uncertain events requires a high level of cooperation throughout different sectors: private industry, institutions and governments. A difficult issue since the cooperation not only must transcend organizational boundaries, but also international borders. Increasing concern about the security of Critical Infrastructures has prompted the European Union to launch the European Programme for Critical Infrastructure Protection (EPCIP). The general objective is to improve CI protection and reduce the EU's vulnerability to severe attacks. Our project SEMPOC (Simulation Exercise to Manage Power Cut Crises) is funded by the EPCIP Programme and focuses on the specific framework of "Prevention, Preparedness and Consequence Management of Terrorism and other Security related risks".

## THE SEMPOC PROJECT

The aim of the SEMPOC project 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. The recommendation to mitigate damages and improve recovery is achieved through simulation exercises that assess the degree to which:

1. Agents in an interdependent system are able to deliver society critical services and mitigate damage in the face of a severe power cut.
2. Crisis lifecycles, cascading effects and their associated recovery times affect the system.
3. The system is able to detect precursor events.
4. The system is able to respond to crises and the effectiveness of the response.

Once the simulation exercises are developed, robust policies will be designed and tested to improve detection of precursor events, mitigating damage, preventing cascading effects and subcrises and delivering critical services.

During the course of the SEMPOC project (finishing in March 2011) three workshops of two days duration each are conducted where the modeling team and domain experts work collaboratively to develop a series of models addressing the objectives of the project. Each GMB workshop is carefully prepared using smaller preparatory workshops involving the core team of SEMPOC.

To understand the lifecycle and dynamics of large scale power cut crises the SEMPOC project uses Group Model Building (Andersen and Richardson, 1997, Vennix, 1996) in combination with System Dynamics computer simulation. We establish causal influences between and within the man-technology-organization system based on facilitated elicitation sessions with domain experts from several EU countries. The resulting aggregated model that focuses on the information and material flows among sectors and over time can be used to analyze this problem and design effective policies.

## METHODOLOGY OF THE PROJECT

SEMPOC targets a credible simulation model of the crisis evolution that reflects the external characteristics and verisimilitude without the internal details. System Dynamics (SD) encourages not focusing on the isolated events but rather on the behavior 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. Additionally, in SD models, the system's feedback structure is explicitly represented, which gives them an advantage with respect to visual representation. Changing parameters of this structure generates different simulated behaviors which analysis allows a deeper understanding of the system. Policy recommendations can then be built on those results.

Additionally, a significant body of literature links simulation modeling with collaborative modeling methodologies where modelers work on the problem jointly with multidisciplinary domain experts. This participation of the beneficiaries of the model during the early stages of its development also increases their understanding, confidence and acceptance of the model. We selected GMB, instead of other alternatives such as Delphi or CIA because this methodology was the one which best matched the characteristics of the problem and the project. Initially, knowledge about this problem resided fragmented in the minds of the different agents involved, each one having a different perspective. GMB has a long record of successes integrating knowledge into aggregated SD models in these circumstances (Andersen et al., 1997, Vennix et al., 2007).

## USE OF GMB METHODOLOGY IN THE SEMPOC PROJECT

One of the key steps of this model building process is integrating and making explicit the initially tacit and fragmented knowledge of domain experts. GMB has specific exercises that support this process. During the workshops, the modeling team's main objective is to capture information needed to develop a simulation model that provides a better understanding of the outage and its consequences and allows reproducing different behaviors depending on the selected strategy. One of the main advantages of GMB is that an early involvement of domain experts allows the modeling team to show them the relevance of their knowledge when building simulation models. As a result, domain experts' confidence in the model increases and the feeling of model ownership is achieved. Two exercises carried out during the first SEMPOC workshop and their results are presented next: The stakeholders' analysis and the behavior over time exercises.

The stakeholder analysis exercise consists of identifying the main agents affected or influenced by the researched problem. Initially, domain experts taking part in the GMB process are divided in different groups and each group works on the identification of the stakeholders. All the list of the stakeholders is presented in a plenary session. During the presentation the list is filtered to avoid invaluable duplicates.

Once the complete list has been presented, stakeholders are classified according to their interest in improving the problem and their capacity to influence the problem behavior. During this discussion the domain experts explain how each stakeholder might affect the problem behavior. The elicited information is used in subsequent exercises to define different strategies and policies that could be used to manage the problem.

Assessing the influence and interest of identified stakeholders allows identifying the leverage points that can determine the evolution of the problem. Figure 1 shows the outcome of this exercise, in which the dashed box represents the agents with stronger interest and influence to solve the problem.

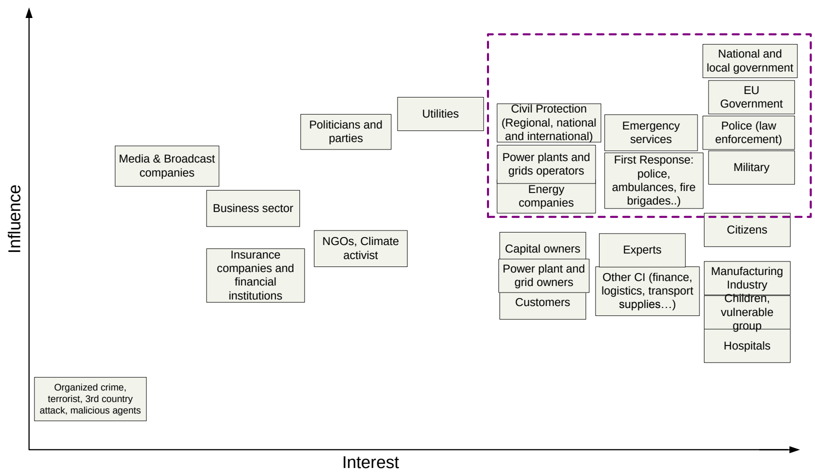


**Figure 1. Stakeholders**

The behaviors over time exercise deals with the evolution of the variables which best represent the behavior of the analyzed problem. During some previous exercises, domain experts identify which is the set of variables that according to them more efficiently represents the evolution of a large pan European crisis originated caused by problems in the electric net. In the case of the SEMPOC project, this set of variables is composed by the following eight variables (units are mentioned 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 [incidents per day], Trust on decision makers [Some value between 0 and 1], People working solving the crisis [people] and Crisis management resources [% of resources].

Then, domain experts were asked to draw the over-time behaviour of this set of variables in the best (the crisis is efficiently managed) and worst (the crisis is poorly managed) scenario based on their experience and intuition. The used scenario related a few days lasting crisis with successive blackouts happened in the first and fourth day caused by overload in the power net and unexplained failures in distribution grid respectively. The combination of these breakdowns and an ineffective coordination between different sectors caused that the crisis is not solved six days after the first failure. After a plenary presentation of these behaviors experts agreed on some behaviors that could be used as a reference for the best and the worst case. These some days lasting blackout is crucial, because expected phenomena would differ significantly from so far gained experience in "ordinary" blackouts in Europe.

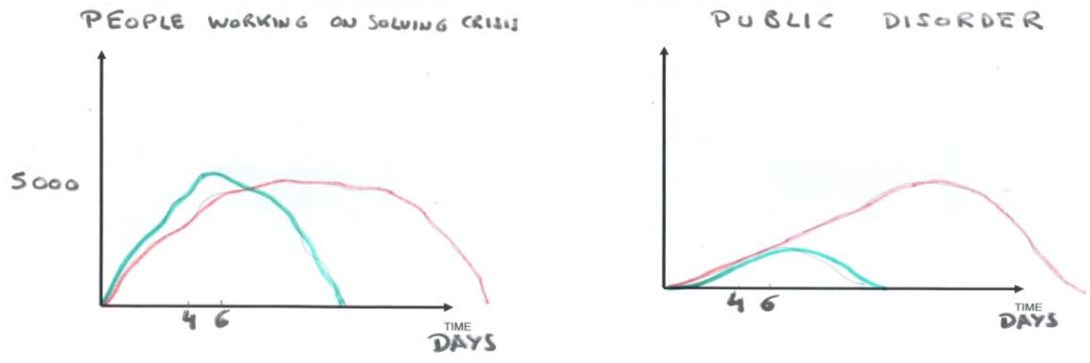


**Figure 2. Behavior over time**

Figure 2 shows the behaviors of two variables (best case in green and worst case in red), where it can be seen the evolution of the number of resources that would be deployed to respond to the crisis and the public disorder caused by the blackout. The information gathered during this exercise is a key input for the simulation model development, as the model should be able to reproduce these behavior modes. Additionally other validation tasks are discussed in the following section.

## THE MODELING PROCESS

After the workshop, the modeling team spent several months turning the knowledge gathered in GMB sessions into a simulation model. The collected information allowed identifying the most relevant sectors and variables involved in energetic crises and developing a detailed simulation model of a national crisis validated by an exhaustive process. This validation process consists of several tests such as performing sensitivity analysis and running the model under extreme conditions in order to detect errors and test its robustness. This internal validation process is complemented with a set of phone interviews with all workshop participants where the domain experts clarified some technical questions, elicitated the links between the variables and verified the simulation model performance. However, its final tuning (and complete model validation) is planned to be done after the last workshop, which is planned to take place in June 2010.

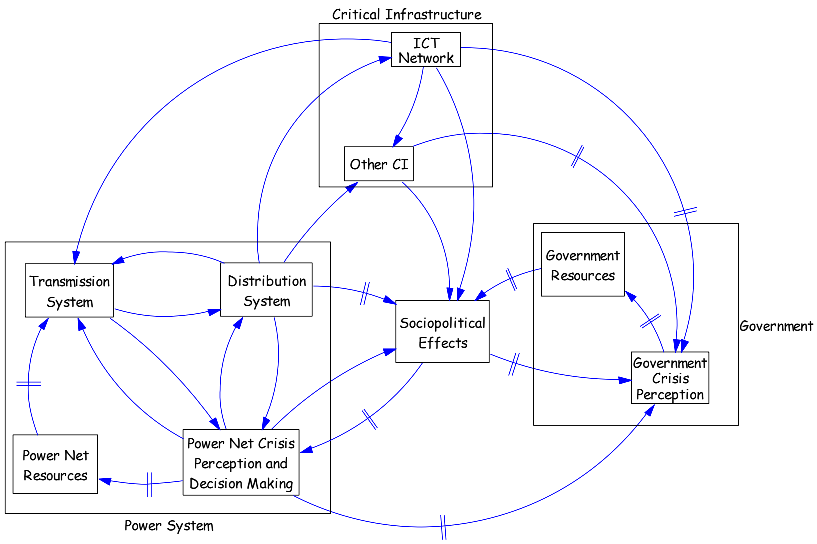


**Figure 3. Sector diagram (double lines crossing an arrow denote time delays)**

Figure 3 shows and aggregated view of the structure of the developed simulation model. As it can be seen, this structure includes the main stakeholders identified by experts during the workshop (see Figure 1). Some of them are explicitly included while others have been renamed or aggregated (for example, Emergency services and first responder have become Government Resources). Likewise, Figure 4 shows the results obtained running the simulation model for the variables showed in Figure 2. As it can be seen, the obtained behaviors are well aligned with the ones provided by domain experts.

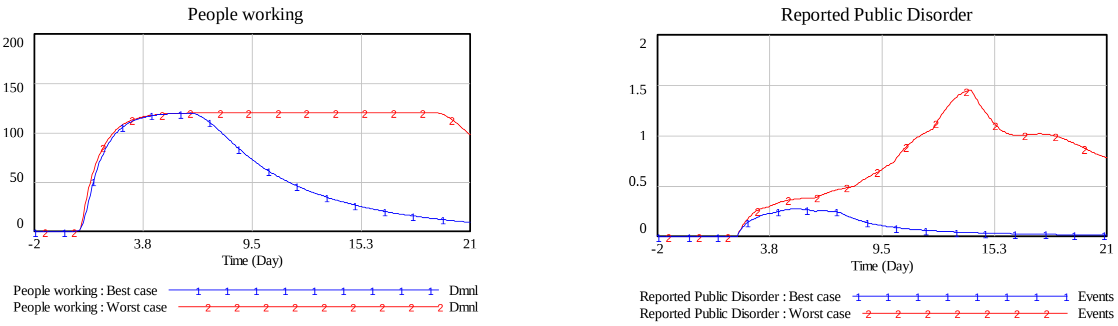


**Figure 4. Example of results obtained with the simulation model**

The next challenges for the following workshops are to study in depth the international perspective regarding international coordination protocols and pre-crisis and post-crisis aspects. At the end of the SEMPOC project we will end up having a validated model that will be used to design, test and communicate robust policies for the whole international crisis lifecycle. The meaning of "validated" is that domain experts have enough confidence on the results extracted from it; so they will take into account what they have learnt from the model when making their decision.

## CONCLUSIONS

The novelty of SEMPOC project is the application of GMB to the crisis management field. GMB has proven to be an excellent collaborative methodology when modelling this complex problem. Its use has allowed the modelling team to gather the knowledge from domain experts. The use of GMB has eased the process of integrating the initially fragmented domain experts' perspectives. In addition, domain experts who took part in the GMB workshop were satisfied with results obtained during the process. This is proven by the fact that all of them volunteered to take part in the subsequent model validation process and future GMB workshops.

## ACKNOWLEDGEMENT

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