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Sandro Moscatelli **Omar Viera**

Libertad Tansini

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Disaster Management and Operation Research in Uruguay

Magíster Ing. Sandro Moscatelli
Instituto de Computación, Facultad de Ingeniería
Universidad de la República
moscatel@fing.edu.uy

MSc. Omar Viera
Instituto de Computación, Facultad de Ingeniería
Universidad de la República
viera@fing.edu.uy

Dr. Ing. Libertad Tansini
Instituto de Computación, Facultad de Ingeniería
Universidad de la República
libertad@fing.edu.uy

Abstract

Disasters are events of huge magnitude and negative impact on society and environment. Disaster Management is a discipline that tries to deal with disasters. In this Technical Report we give a short introduction to these two issues from the operational researcher's point of view and focusing on the situation in Uruguay.

Keywords: disaster, disaster management, operation research.

2009

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1. INTRODUCTION

Disasters are events of huge magnitude and negative impact on society and environment. They affect communities and nations, causing human life losses and material damages.

One classification of disasters includes the following four causes [1]: (a) by human error and technological failures; (b) by intentional malevolence; (c) by acts of nature (earthquakes, tornados, hurricanes, etc.) and (d) combinations of some or all the previous ways (for example, bird flu pandemics are the results of acts of nature in conjunction with human errors). They are considered, generally, low probability-high impact events. That is, they are events with low probability of occurrence but with high impact on the community or the environment.

Because of that, they require assignment of important resources to predict, mitigate and recover from. This implies the need for effective, often real time cost reducing techniques.

Operation Research can provide up to date knowledge and experience in order to reduce the overall costs for all these activities.
This potential is even greater in Uruguay due to the lack of research and applications in this field.

2. DISASTERS

Analyzing the literature about disasters, the conclusion is that it does not exist only one definition of what a disaster is, therefore some possible definitions are presented below; trying to offer a better understanding of what disasters are.

The *World Health Organization* (WHO) [2] defines disaster as any occurrence that causes damage, ecological disruption, loss of human life, deterioration of health and health services on a scale sufficient to warrant an extraordinary response from outside the affected community or area.

The *International Federation of Red Cross and Red Crescent Societies* [3], an international humanitarian movement, defines disaster as a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources.

In the *Emergency Events Database* [4], a database of disasters maintained by the *Centre for Research on the Epidemiology* (CRED), a disaster is defined as a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance.

In the *Business Dictionary* [5], an online dictionary of business terms, a disaster is defined as a calamitous, distressing, or ruinous effects of a disastrous event of such scale that they disrupt (or threaten to disrupt) critical functions of an organization, society or system, for a period long enough to significantly harm it or cause its failure.

The *Federal Emergency Management Agency* [6], an agency of the United States government that is part of the *Department of Homeland Securities*, defines disaster as a non routine occurrence that has resulted in property damage, deaths, and/or injuries to a community that requires the use of resources from outside the affected community.

Analyzing the previous definitions we can conclude that the definitions of disasters have in common the following aspects:

- That they are possibly sudden.
- Have a hard negative social impact (human life losses, material and environment damages, associate costs, etc.).
- Disrupt the normal functioning of communities, societies, etc.
- Exceed the local available resources.

The most common types of disasters [3] [6] are shown in the Table 1.

Type of Disasters
Drought
Earthquakes
Epidemics
Famine/food insecurity
Floods
Hurricanes
Cyclones
Typhoons
Man-made disasters
Population movement
Technological
Volcanic eruption
Chemical emergencies
Dam Failure
Fire or Wildfire
Hazardous material
Heat
Landslide
Nuclear power plant emergency
Terrorism
Thunderstorm
Tornado
Tsunami
Winter Storm

Table 1 - Types of disasters.

3. DISASTER MANAGEMENT

Disaster Management is basically trying to deal with disasters. Again, there is not a unique definition of what disaster management is. Therefore some of them are presented below, trying to offer different points of view about the subject.

Haddow et al. [7] define disaster management as the discipline of dealing with and avoiding risks. It is a discipline that involves preparing for disaster before it happens, disaster response (e.g. emergency evacuation, quarantine, mass decontamination, etc.), as well as supporting and rebuilding society after natural or human-made disasters have occurred.

Drabek [8] defines disaster management as the discipline and profession of applying science, technology, planning and management to deal with extreme events that can injure or kill large numbers of people, do extensive property damage, and disrupt community life.

The *Federal Emergency Management Agency* [6] defines disaster management as a range of measures to manage risks to communities and the environment.

The *International Federation of Red Cross and Red Crescent Societies* [3] defines disaster management as the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters.

In common for all the previous definitions is the search for a scientific approach to handle disasters.

We can also see that disaster management is, by its nature:

- Social and political.
- Multi-organizational.
- Multi-functional.

3.1 General Approaches

Kelly [9], states that there are four main reasons why a disaster model can be useful. These are as follows:

1. A model can simplify complex events by helping to distinguish between critical elements. Its usefulness is more significant when responding to disasters with severe time constraints.

2. Comparing actual conditions with a theoretical model can lead to a better understanding of the current situation and can thus facilitate the planning process and the comprehensive completion of disaster management plans.

3. The availability of a disaster management model is an essential element in quantifying disaster events.

4. A documented disaster management model helps establish a common base of understanding for all involved agents. It also allows for better integration of the relief and recovery efforts.

Based on the above reasons, a well defined and clear model is highly beneficial in the management of disasters because it facilitates the (securing of) support for disaster management efforts.

Therefore as disaster management can be viewed in a number of ways, we present alternatives approaches to model the disaster management process and explain the key elements of disaster management, its operations and activities.

The more traditional approach [10] [11] has been to regard disaster management as a number of phased sequences of action or a continuum. These can be represented as a cycle as show in Figure 1.

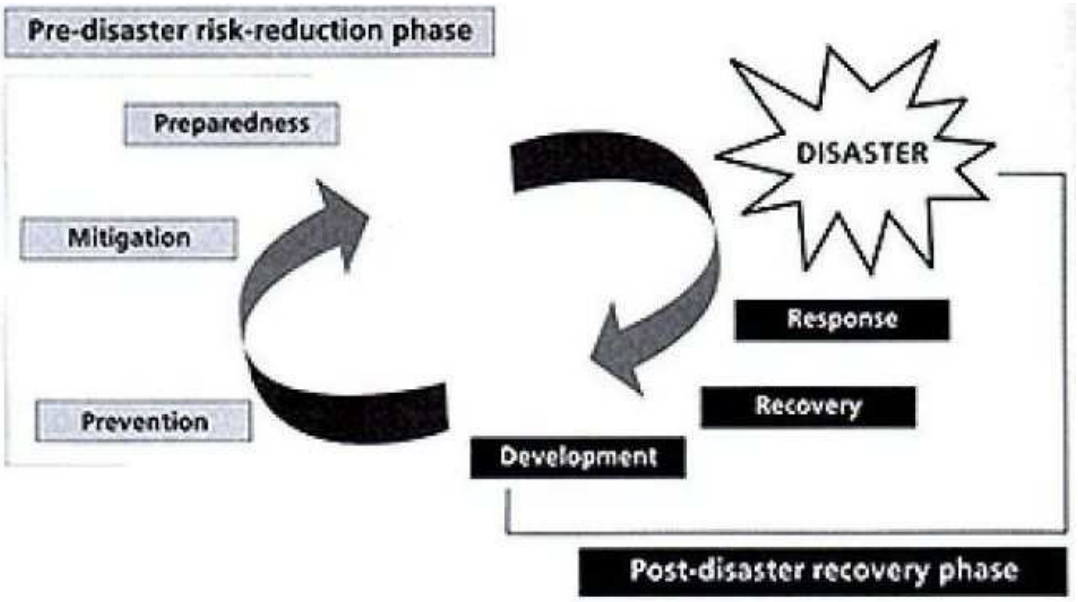

Figure 1 - Traditional model.

The assumption on which this model is based is that disasters are inevitable and the focus of the disaster management cycle is more on activities immediately before and after the disaster event.

Prevention [12] includes all measures aimed to avoiding the occurrence of a disaster.

Mitigation [13] is the process of designing and implementing procedures and measures that will prevent or reduce the risk associated with the occurrence of a disaster, by reducing either the likelihood or the impact of them.
The mitigation phase focuses on long-term measures for reducing or eliminating risk due to disasters [7].
Typical activities [14] included in this phase are: land use controls, barriers, tax incentives or disincentives, risk analysis, insurance, etc.

Preparedness [15] involves the activities that prepare the community to respond when a disaster occurs. Generally it implies developing plans of action for when disaster strikes and providing relevant information to help individuals and organizations to prepare themselves for the occurrence of disasters.
Typical activities [14] in this phase include: recruiting personnel, emergency planning, training, budgeting resources, maintenance of emergency supplies, communications systems, etc.

Response [14] take place only during a disaster event and immediately after the disaster happens. This phase typically implies the employment of resources and procedures, usually guided by plans, to preserve life, property, the environment, and the social, economic, and political structure of the community.
In general, some of the following tasks have to be performed in this phase: activating planes, opening shelters, fire fighting, evacuation, search and rescue, etc.

Recovery [15] is the process of minimizing the long term effects of a disaster situation and facilitating restoration to conditions that are as good, or better, than

those before the disaster occurs. It differs from the response phase in its focus: recovery efforts are concerned with issues and decisions that must be made after immediate needs are addressed [7] in the response phase.
The Recovery phase is, generally, subdivided in the following phases:

- Rehabilitation, it is any activity with the objective to restore normalcy in conditions caused by the disaster.

- Reconstruction, it is the repair and construction of a property undertaken after a disaster.

Common actions [14] in this phase include: cleanup, financial assistance, rebuilding facilities, full restoration of lifeline services, etc.

The inclusion of the development phase [12] in the disaster cycle is intended to ensure that following a disaster, countries incorporate hazard factors and vulnerability considerations into their development policies and plans, in the interest of national progress.

Although the traditional model is prevailing in disaster management, new models are emerging. Such models include the Expand-Contract Model (Figure 2) [10] [11] and The Crunch and Release Models (Figures 3 and 4) [10] [11] [16]. These models will be explained next.

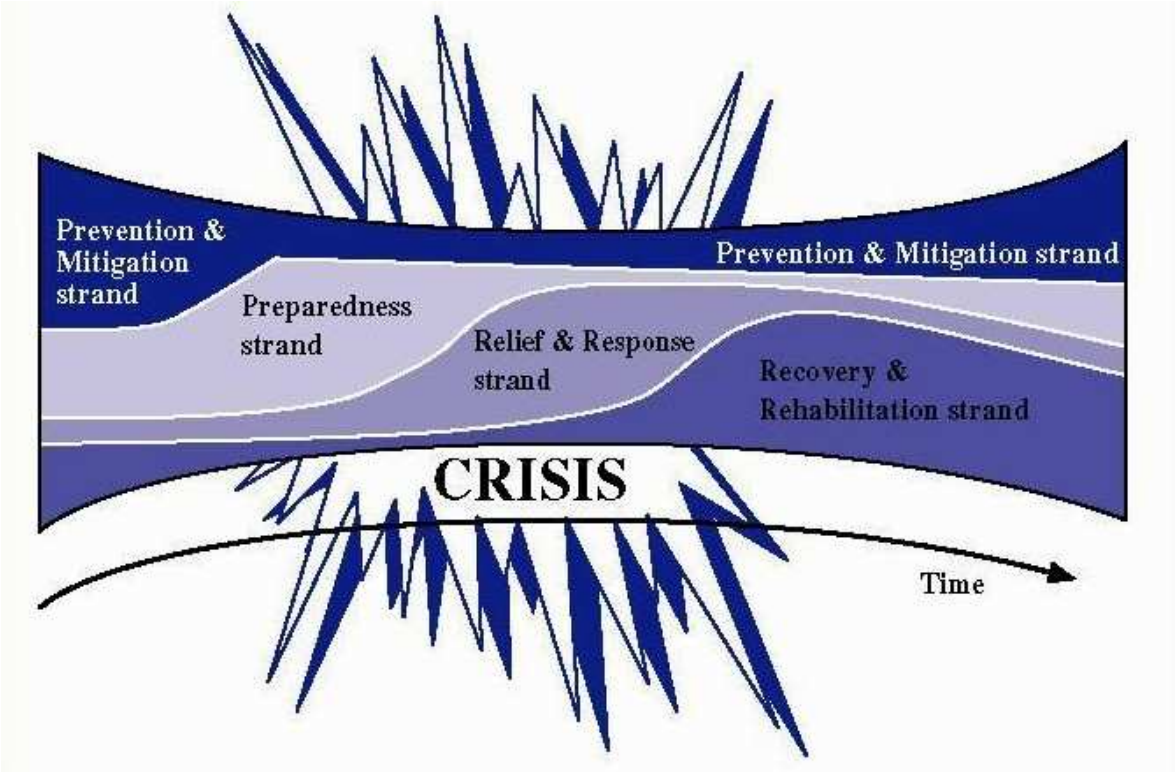

Figure 2 – Expand-Contract model.

In the Contract-Expand model [10] [11], disaster management is seen as a continuous process. The different disaster management phases, rather than in a sequential manner, run parallel to each other, albeit with varying degrees of emphasis.

Activities continue side by side, expanding or contracting on demand. As an example immediately after a disaster the “relief and response strand” will expand, but with time this activity would reduce and the “recovery and rehabilitation strand” will expand.

This model recognizes that disaster management includes a number of actions that may be occurring at the same time and not always one after the other, for example, in the case of droughts, drought relief, recovery and mitigation may often occur simultaneously.

The Disaster Crunch and Release Models [10] [11] [16] are useful to understand and explain the causes of disasters and adopt a cause-effect perspective.

These models [11] look at what could be done to prevent hazards from progressing into disasters. Also the human aspects of vulnerability are given more attention through social analysis.

The Crunch model (Figure 3) shows that vulnerability [10] (which is seen as rooted in socio-economic and political processes) has to be addressed (released) for disaster risk reduction. It also shows that a disaster happens only if hazard impacts on a vulnerable community.

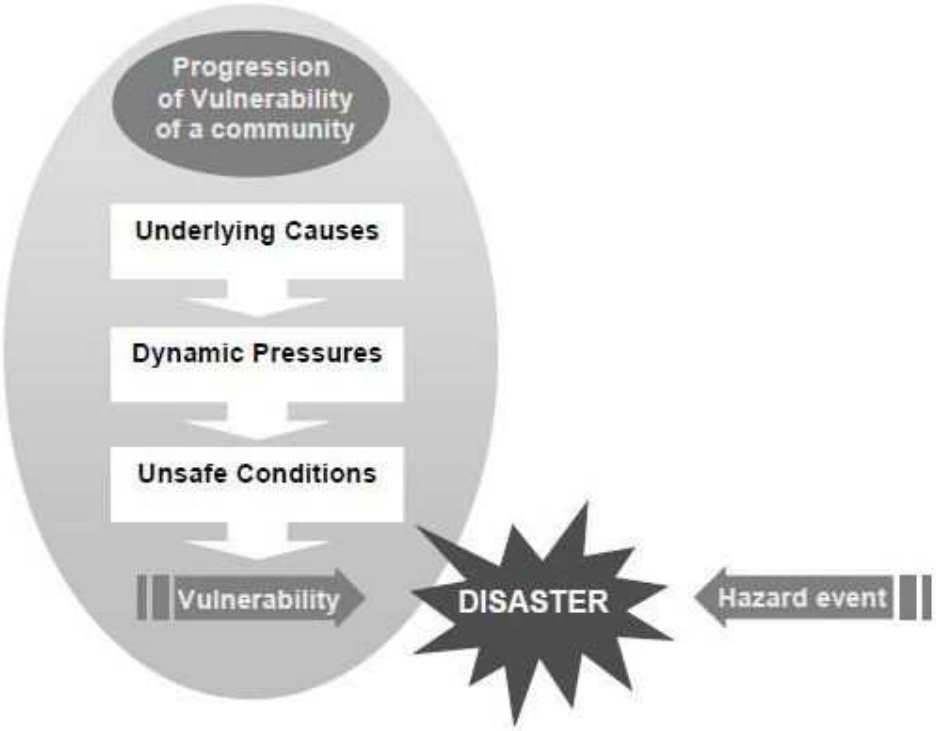

Figure 3 – Crunch model.

The model reveals a progression of vulnerability [10], beginning with underlying causes (poverty, limited access to power structures and resources, ideologies, economic systems, and general pre-conditioning factors). The underlying causes are translated, by dynamic pressure (lack of local institutions, education, training, appropriate skills, etc., as well as population expansion, urbanization and environmental degradation), into unsafe conditions.
The unsafe conditions are the vulnerable contexts where people and property are exposed to risk of disaster. They may be:

- Fragile physical environment, such as: disaster-prone locations or dangerous locations, unsafe buildings, unsafe infrastructure, etc.

- Fragile local economy, such as: livestock at risk, low-income levels, low health status, etc

Through the reverse of the Crunch Model, the Release Model shows how the risks of disasters can be reduced addressing the factor that cause these risks [11]. This means working against all the components of the Crunch model, as it showed in Figure 4.

Figure 4 – Release model.

3.2 Conclusions

Until a few decades ago, disasters were viewed as one-off events and responded to by governments and relief agencies without taking into account the social and economic implications and causes of these events [17].

Gradually this attitude has changed to an emphasis on preparedness measures, such as stockpiling of relief goods, preparedness plans, and a growing role for relief agencies such as the Red Cross [17].

In recent years, more comprehensive approaches and models have emerged as an evolution from putting the emphasis in the response phase, assuming that disasters are inevitable, to focusing on the pre disaster activities (prevention, mitigation, preparedness, etc.).

As a result of this new models have been proposed, such as the Expand and Contract model (which assumes that disaster intervention measures of disaster prevention, mitigation, response and recovery can be carried out at all times in a disaster-prone community and the relative weighting of each component “contracts” or “expands” depending on the relationship between the hazard and the vulnerability of the community) and the Crunch and Release models (which concentrates in the prevention of hazards, so that they do not become disasters).

4. OPERATIONS RESEARCH AND DISASTER MANAGEMENT

In this section we give a short comprehensive approach to Operations Research (OR) and reasons why OR has a great potential in addressing and optimizing the difficult tasks that are involved in disaster management.

4.1 Operations Research

For the *Institute for Operations Research and the Management Sciences* (INFORMS) Operations Research is defined as the discipline of applying advanced analytical methods to help make better decisions [18].

The *Association of European Operational Research Societies* says that OR can be described as a scientific approach to the solution of problems in the management of complex systems. In a rapidly changing environment an understanding is sought which will facilitate the choice and the implementation of more effective solutions which, typically, may involve complex interactions among people, materials and money [19].

In the course of *Introducción a la Investigación de Operaciones* of the Faculty of Engineering (UdelaR), OR is defined as the research on operations to achieve the optimal objective of a system or the improvement of it [20].

According to the above definitions OR can be described as a scientific approach that uses advanced analytical methods to obtain optimal solutions for complex decision problems.

Considering that disasters are problems that test the ability of societies, nations or regions to:

- protect populations an infrastructure
- reduce human an property losses
- recover rapidly

the management of disasters requires support from a discipline capable of:

- accurate forecasting
- managing risks
- “scientific” decision making for short and long terms
- improving the response
- reduce the overall costs.

So, we can see that OR is well suitable for all the activities and structures involved in Disaster Management.

4.2 Operations Research in Disaster Management

In disaster relief operations [21], local and national public officials and social organizations face critical questions related to the safety and well-being of the people who are affected by these emergencies.
After a disaster occurs, that is in the post disasters phases, some of the most important of these questions is how to respond in the most efficient manner to minimize the loss of life and maximize the efficiency of the rescue operations.
Also before a disaster occurs, that is in the pre disasters phases, there is a need of tools and techniques to analyze different scenarios and develop suitable plans that allow responding in the best possible way when disasters happen.

Given the challenges of disaster management, the application of OR has an enormous potential and could play an important role in addressing and optimizing the difficult problems generated in the complex situations arising by the occurrence of disasters. For example, and without being exhaustive:

- Risk and vulnerability assessment.
- Robust planning and strengthening of infrastructure networks.
- Emergency response logistics.
- Information systems for post-disaster coordination and decision support.

The apparent randomness of impact and problems, and the uniqueness of incidents, that generates disasters, demands dynamic, fast, effective and efficient solutions, thus making disaster management a good candidate for applying some of the OR techniques.

OR can provide the scientific approach required by disaster management by means of the use of the different techniques and tools that are used systematically and naturally in OR, that can help to improve the disaster management discipline.

Disasters offer a plethora of extreme problem situations that require decision making in complex situations [22]. The decisions makers have to face with a, possibly, great number of feasible alternatives. A wide variety of OR techniques can be used for better decision making as a planning tool in the field of disaster management. Some of these OR techniques are [14] [23]:

- Decision theory
- Multiple attribute utility theory
- Mathematical and stochastic programming
- Optimization models
- Probability and statistics analysis
- Simulation
- Queuing theory
- Soft OR (problem structuring)

.

4.3 Applications of OR Techniques in Disaster Management

Altay et al. [14] have collected, classified and studied a great number of OR publications in the different stages of disaster management.

Some of the relevant literature on the subject of pre disasters phases, for example regarding floods and earthquakes, are Tamura et al. [24], Coles et al. [25], Lian et al. [26], Viswanath et al. [27] and Wei et al. [28].

In the post disasters phases for floods and earthquakes other important articles are Barbarosoglu et al. [29], Ozdamar et al. [30] and Shim et al. [31].

It is more atypical to find papers on OR techniques applied to pre or post disasters phases for disasters such as Wars [32], or Terrorism [33].

5. OPERATIONS RESEARCH APPLIED TO DISASTER MANAGEMENT IN URUGUAY

In 1995 “Sistema Nacional de Emergencias” (SNE), or in English, National Emergency System was created in Uruguay. It is a government agency [34] whose mission is:

“To plan, coordinate, execute, lead, evaluate and act in the prevention and in the necessary actions in all the situations of emergency, crisis and exceptional disasters or similar situations, that happen or are imminent, in within the national territory, its airspace and/or its fluvial and marine jurisdictional areas and that directly or indirectly affect in a significant and profound manner, the State, its habitants and/or their goods, and when they exceed the capacities of the organizations originally assigned to deal with them.”

Figure 5 shows the current organizational structure of SNE.

In Uruguay the most common disasters are floods, wildfires, draughts and windstorms according the *Sistema Nacional de Emergencias*. Table 3 and 4 show some data regarding the effects of some of these types of disasters, taken from SNE.

Table 3 shows data about the number of people evacuated and dead, for floods occurred between the years 1997 and 2005, classified by the geographical districts of Uruguay. This data was obtained from the web page of the *Sistema Nacional de Emergencias*.

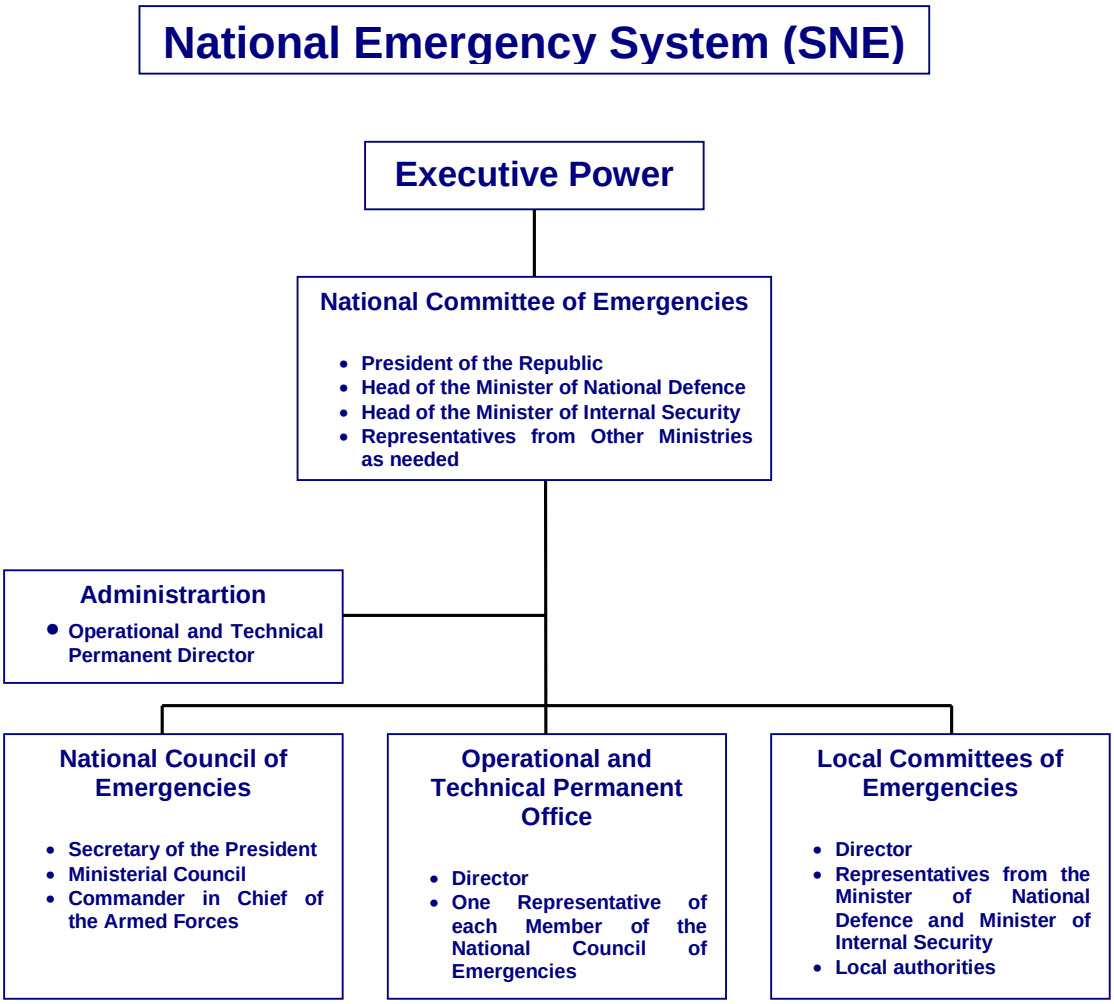

Figure 5 – National Emergency System.

Table 4 shows the number of interventions made by firemen in case of wildfires.

Department	#Evacuated	#Dead
Artigas	12979	1
Canelones	2941	3
Cerro Largo	1227	-
Colonia	556	-
Lavalleja	611	-
Durazno	7170	1
Flores	159	-
Florida	545	-
Maldonado	1.156	-
Montevideo	782	2
Paysandú	3.770	-
Rio Negro	109	-
Rivera	1.333	-
Rocha	246	-
Salto	4.608	-
San José	447	1
Soriano	991	-
Tacuarembó	5337	2
Treinta y Tres	2.214	-
Totals	47.181	10

Table 3 - People evacuated and death.

Year	#Interventions
2005	3247
2006	2232
2007	3262

Table 4 - Number of interventions in wildfires.

Due to the types of disasters that occur in Uruguay, the topography of the country and the social and economic profile of the people affected we believe that there is a need to adopt a disaster management model that emphasizes in pre disaster measures, reducing vulnerability. We also believe that the potential of OR applied to disaster management is even greater in Uruguay due to the lack of research and applications in the field. Basically OR techniques will help to:

- Minimize risks of natural disasters and others types of disasters.
- Maximize the capacity to handle disasters.
- Make decisions makers aware of the need to quantify damages
- Save lives.
- Reduce overall costs.
- Contribute to the creation of state policies.

6. CONCLUSIONS AND FURTHER RESEARCH

As we have seen, the occurrence of a disaster implies huge costs, disrupts the normal functioning of communities and societies and exceeds the local available resources.
Disaster management is the discipline of handling disasters. Due to the characteristics of disasters, disaster management is multi-organizational and multi-disciplinary.

OR is a scientific approach that uses advanced analytical methods to obtain optimal decisions for problems in the management of complex systems and is well suited for all the activities and structures of disaster management.

In Uruguay the disaster management as a discipline, the use of a model as a guide for managing disasters (eventually adequate at the reality of the country and the types of disasters that can occur) and the application of OR techniques for disaster management is not exactly widely spread.

We believe that the applications of OR to disaster management is a novel field in Uruguay that can and must be developed.

The application of OR models and methods can improve and help to develop the effectiveness of disaster management in Uruguay.

A possible first step in the right direction could be to establish contact with decision makers and convince them of the potential cost savings. Making decision makers conscious about the need to quantify damages is an important and necessary step in order to further interest them in the employment of scientific approaches to disaster management, such as those offered by OR.

Uruguay needs to better integrate disaster management and OR techniques at all levels. We are convinced that this integration requires investments for which the benefits are far greater than the overall costs.

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