FLOOD DISASTER MANAGEMENT WITH THE USE OF AHP

Zoe Nivolianitou* and Barbara Synodinou
System Reliability & Industrial Safety Lab,
INTR-P, NSCR "Demokritos", GREECE
E-mail: zoe@ipta.demokritos.gr

Davide Manca and Sara Brambilla
Chemical Engineering Department,
CMIC Politecnico di Milano, ITALY
E-mail: davide.manca@polimi.it

ABSTRACT

The present paper focuses on the developing of a decision-making tool for emergency planning and response and in particular for flood incidents. The proposed tool is a simulator (i.e. computer based software) capable of identifying the "emergency machine" lacks, allowing also for improvement of specific areas of the emergency system, such as technical equipment, human factors, protocols, response time and sequence. There is an ongoing effort for better ways of protecting human life, land, property and the environment by improved flood management techniques. The present work has been elaborated within the Pre-Emergencies EC funded project, which aimed at the construction of a tool that would evaluate in a single measurable index the actual response level of a disaster management system in the case of both sudden and mounding risks. This tool can be used as a technical instrument to simulate the organisational and inter-organisational asset of a multi-actor civil protection group with the aim of highlighting strong and vulnerable elements of civil protection structures thought the use of a number of indices pertaining to characteristic parameters on four sub-layers of detail. By recognising that not all parameters have the same relevance in determining the performance of the emergency response, the categorization allows for the discarding of the least important ones by singling out a weighed scale of indices, through the use of the Analytical Hierarchy Process (AHP). The AHP approach supports decision making in Emergency Preparedness through alternatives structured into a weighed multi-criteria framework.

Keywords: flood incidents management, AHP

1. Introduction

Flood damages are increasing in recent years, mainly as a result of exceeding frequency in the occurrence of large floods all around the world (ICSU, 2005), but also of existing and continuing encroachment on flood plains through unplanned development and of aging of flood protection structures. Under such circumstances, there is an ongoing effort for better ways of protecting human life, land, property and the environment by improved flood management techniques. Flood management is already difficult in river basins controlled by a single authority, and becomes challenging when dealing with transboundary floods, which may originate in one country of jurisdiction and then propagate downstream to another (Akter & Simonovic, 2005). Thus, the demands on communications, information and data sharing, compatibility of forecasting methodologies, and, eventually close collaboration in disaster flood management are particularly strong and important.

* Corresponding author

The present work has been elaborated within the Pre-Emergencies EC funded Project (Grant Agreement for the action Nr 07.030601/2005/42374/SUB/A5), which aimed at the construction of a tool that would evaluate in a single measurable index the actual response level of a disaster management system in the case of both sudden and mounding risks. In our case the risk of a flood disaster has been considered.

In the remainder of this paper the reader can find: the tool development in section 2, the case study application in section 3, the results from the application in section 4 and last, the conclusions in section 5.

2. Tool development

2.1 General

The decisions that need to be taken by civil protection authorities, should an accident happen, are swift and often based on incomplete and ambiguous information about the unfolding event and its location (Paton & Flin, 1999). The mobilisation of multiple stakeholders is also a non-trivial task. In that sense, the use of an emergency management system that can control the possible dangerous effects of the incident by supporting the emergency staff against high stress components is indispensable. Plans should be based on a detailed and comprehensive analysis of operational demands and connected actions, by organising the multidisciplinary competences, while sharing the available means and human resources. To facilitate the development of emergency response systems assisting performance during a crisis, organisational and inter-organisational coordination must be improved, by focusing on internal and external vulnerability elements for each organisation. This includes the proper definition of emergency preparedness activities, such as areas of responsibilities, roles of participating bodies, means availability and sharing and good knowledge of the incident scene both regarding the geomorphology and the population distribution. In this perspective, software tools can be of paramount importance in supporting the actors to consider the multifaceted factors characterising the emergency response.

2.2 Description of the tool

The dedicated tool developed within the Pre-Emergencies Project by the POLIMI staff, under the code name "Evaluator" aimed at being used as a technical instument to simulate the organisational and inter-organisational asset of a multi-actor civil protection group with the aim of highlighting strong and vulnerable elements of civil protection structures. This has been done by analysing a series of parameters that pertain to the:

- Physical area of the incident, such as the characteristics of the flooded region,
- Organisational area, such as the organisational aspects of the institutional groups involved in the emergency response, and
- Contextual area, such as resources available in the areas surrounding the incident location.

The work has led to the development and definition of a four levels hierarchy, achieving a good characterisation of criteria. The macro-criteria of interest are at the higher lever of the hierarchy, i.e. the criteria that the decision maker will finally take into consideration, while at the lower level there are the questions to reply for evaluating the system under consideration. Physical, organisational and Contextual features are collected to manage the emergency response by identifying a "final score" that expresses the quality of intra- and inter-organisational coordination.

2.3 The Analytic Hierarchy Process as a tool for Decision making

As described above, the software tool acting as an emergency preparedness instrument should be able to address and judge several distinct features of risk element and its correlated emergency response. To be clearer, if one concentrates to the flooding risk, one would like to assess the importance of different topics such as, the geomorphology of the area, the population density, the organisational characteristics of civil protection authorities, etc. Moreover, one would like to understand not only qualitatively, but also quantitatively the effectiveness of the emergency preparedness structure so as to assess its efficiency and to identify some feasible and valuable improvements.

However, not all features or actors have the same relevance in determining the performance of the emergency response. To that end, a number of indices pertaining to the parameters described above (on four sub-layers of detail), have been identified and categorized through the grouping of similar characteristics, so as to compare features related to the same areas. This categorization, grouping and comparison have been done based on the principles of Saaty's (2007) Analytical Hierarchy Process (AHP) and allow for the discarding of the least important ones by singling out a weighed scale of indices, through its use. In that sense, the AHP approach supports decision making in Emergency Preparedness through alternatives structured into a weighed multi-criteria framework.

3. The flooding incident case-study

3.1 General setting

In this section, we will demonstrate the profitable application of AHP methodology to a selected case study: the evaluation of the emergency response performance in the case of flooding (Montz & Gruntfest 2002) of a greater area owing to the excess effluent waters of a river in Northern Greece (Nivolianitou et al. 2007), where the coordination among three states is needed, as this river is a tri-national one.

In order to apply the AHP methodology, the hierarchy for categorising the criteria involved in the decision process was analysed, discussed and proposed through the interviews (Montagna & Spano 2006) that have been held with the officials of the civil protection in the area. Additionally emergency protocol analysis and literature review have been also deployed to identify key-parameters. A scheme was sketched to assist in collecting data and in identifying the aspects to investigate. The main topics discussed in the interviews were the description of the "on-scene" operating groups during the crisis and the most likely incident scenarios

This preliminary work led us to the development of a four levels hierarchy for the specific case-study (note that different incident situations can lead to a completely different structure of the hierarchy), by which we achieved a good categorisation of criteria without exceeding either in simplicity or in detail. At the first level of hierarchy, we identified three main areas of interest, involving Physical, Organisational and Contextual criteria. Table 1 describes each of these categories.

Table 1. Description of the first level of the hierarchy.

Level 1	Description
Physical Features	Related to the technical and physical aspects of risk in a flooded area (soil morphology, dikes, dams, alternative routings)
Organisational Aspects	Related to the organisational factors of inter-organisation coordination and communication
Contextual Features	Related to external artificial and natural "structures" (retentions measures, helipads, medical services, emergency communication system)

The second and third levels of the hierarchy go deeper in detail by analysing different aspects related to the main topics of each previous level. As far as the Physical features are concerned, the second level of the hierarchy takes into consideration factors about the flooded area physical structure and soil morphology, the measuring/signaling system and the announcement/notification systems. Further on in detail, the third level considers issues related to water flow formation, the flooding conditions and the means availability. Table 2 reports the complete characterisation of the branches of the hierarchical tree related to Physical features.

Table 2. The hierarchical tree of the Physical features.

Level 2	Level 3
Flooded area physical structure	-Flooding conditions -Means availability
Soil morphology	-Water flooding information -Flooding conditions

Organisational aspects relate to the emergency protocol updating, the emergency communication and information systems (especially among the neighboring countries) and the participating actors training for emergency response. The third level involves the analysis of rescuers' experience, the communication with flooded area Users, with the Public, with the Mass media, with external authorities and with the Neiboughring countries. It deals also with the use and updating of procedures used, with the profile specification of competent authorities and the identification of roles among the intervening group.

Similarly, the Contextual features in the second level of the hierarchy take into account the presence of additional resources, the parallel traffic management in the flooded area and the emergency communication system established. Within these features, the first aid support, the water resources that may aggravate the situation, the viability and the communication system are the features considered in the third level.

All these features are investigated through specific sets of questions asked in fourth level, as the ones presented in Figure 1, that permit the elicitation of information needed. These questions are being given univocal identification numbers directly related with the parameter and level of analysis associated.

Level 1 **ORGANIZATIONAL**
Level 2 EXTERNAL EMERGENCY PLAN
Level 3 Coordination Procedures
Level 4

5010	Presence of the flooded area map in the external emergency plan
5020	Are there safety installations/equipment marked on the map in the flooded area?
5030	Indication of the flooded area physical features in the emergency plan
5050	Presence of a flooded area map in the safe places
5060	Is there a periodic checking of safety equipment in the safe places?
5070	Are voluntary organisations invited ny competent authorities to participate in the crisis?

	5010	5020	5030	5050	5060	5070
5010	1	3	5	3	1	3
5020	1/3	1	5	1/3	3	3
5030	1/5	1/5	1	1/3	1/3	1/3
5050	1/3	3	3	1	1	1
5060	1	1/3	3	1	1	1
5070	1/3	1/3	3	1	1	1

Figure 1. An Excel snapshot with the indexes and their pair wise comparison in level 4.

3.2 Calculations

Within the questions characteristics, the question typology distinguishes among qualitative and quantitative indices, i.e a) questions that do not assume any quantitative values (length, number of elements, etc.) or when a finite number of choices are allowed (yes/no, low/medium/high, etc,), and b) questions that assume a quantitative value (length, number of elements, etc.).

When at level 1 we have 3 elements, at level 2 we have 15 and at level 3 we have 48, the number of questions at level 4 depends a lot on the branch of the analysis. So, there is a maximum of a thirty questions belonging to the Physical branch, at least seventy eight belonging to the Organisational branch and seventy five questions related with the Contextual branch. It should be noted that not all the branches or questions are equally active, as some terminate prematurely not leading to a deeper level of detail.

Once the hierarchical structure has been defined, it is time to evaluate the relative importance of criteria pertaining to the same level (weights evaluation, see Figure 1), so as to express the emergency response performance with the most relevant features in the evaluation of the final score. The pair wise comparisons were carried out by experts assisted with all the material mentioned previously (such as interviews, literature, etc.). Using a scale from 1 to 9 the experts were asked to judge, for instance, the relative importance of Physical against Organisational criterion, etc. From these comparisons the Physical and Organisational areas resulted to be more relevant than the Contextual one. This type of analysis was repeated for each branch of the hierarchy to weigh the different criteria involved in the final judgment. Once the hierarchy was set up and the weights determined, the emergency performance Evaluator is ready to be used.

4. The use of the Evaluator

The Pre-Emergencies team developed a user-friendly interface (see Figure 2) for the final users, allowing the performing of the emergency response analysis. The user can load an accident scenario (e.g. a flooding episode), answer to the questions related to the macro-areas of interest (Physical and/or Organisational and/or Contextual), and run the Evaluator engine evaluating the performance of the emergency response. It is evident that, as the participating stakeholders in an emergency response scheme are multiple, equally multiple may be the users that simultaneously run a scenario in order to evaluate a response scheme, e.g. the chief of the civil protection troupes together with the head of communications and the mayor of the flooded area. Their answers are needed in order to rate their cooperation, coordination and communication degree.

When the questionnaire is completed, the AHP evaluates some performance indices, such as an overall performance index, three indices, one for each first level category (the sum of which is the overall index) and three relative scores, measuring the goodness of the system in each specific first level category, different from the previous ones, as the latter are not weighed. The indices take values from one to one hundred. The software is useful for either performing a sensitivity analysis or monitoring the risk management dynamics. The former is achieved by multiple runs of the Evaluator changing each time one or more input data to understand the dependency of the output data from each input so as to optimise the investments/actions. Monitoring of risk management dynamics is achieved by running the Evaluator at predefined time intervals to track the dynamic evolution of the system according to the modifications introduced by competent authorities.

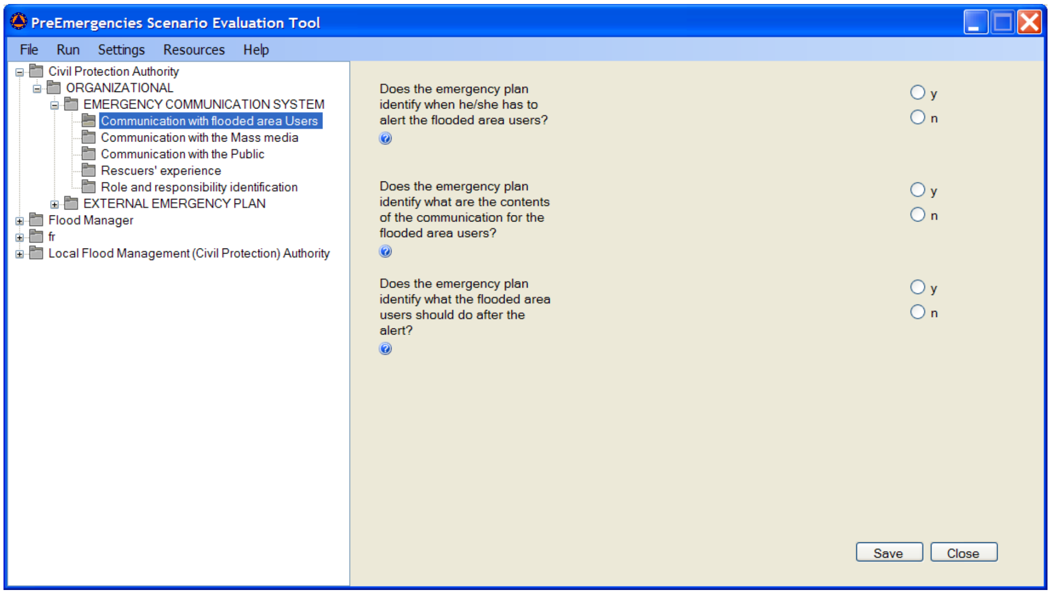

Figure 2. A snapshot of the Evaluator GUI.

5. Conclusions

The present paper focuses on the developing of a decision-making tool for emergency planning and response and in particular for flood incidents. The proposed tool is a simulator (i.e. computer based software) capable of identifying the "emergency machine" lacks, allowing also for improvement of specific areas of the emergency system, such as technical equipment, human factors, protocols, response time and sequence of events in both a pro-active and dynamic way.

REFERENCES

Akter, T., Simonovic, S.P. (2005). Aggregation of fuzzy views of a large number of stakeholders for multi-objective flood management decision-making, *Journal of Environmental Management*, *77 (2)*, 133-143.

International Council of Science (ICSU), 2005. Science and natural hazards. (cited 2011 February 20). Available at:http://www.icsu.org/6_memberzone/GA_documentation/9_Hazards.pdf

Montagna S., Spano M. (2006). *Procedure to code the interviews*. PRE-EMERGENCIES Phase –2 report. University of Torino.

Montz B.E., Gruntfest E. (2002). Flash flood mitigation: recommendations for research and applications. *Environmental Hazards 4*, 15-22.

Nivolianitou Z, Synodinou B., Paralikas A. (2007). *Flooding prevention and emergency response: national protocols and action plans in Greece*. In. Pre-Emergencies. Preparedness, management, communication and lesson learnt in emergencies. Edited by Croce Rossa Italiana. ANANKE, 155-186.

Paton D., Flin R. (1999). Disaster stress: an emergency management prospective, *Disaster prevention and Management*, *8(4)*, 261-267.

Saaty, T.L. (2007). Fundamentals of Decision making and priority theory with the Analytic Hierarchy Process, vol.VI of AHP Series, Pittsburgh, PA: RWS Publications.