HAL open science

# A Decision Support Framework for Crisis Management

Daouda Kamissoko, Pascale Zaraté, François Pérès

## To cite this version:

Daouda Kamissoko, Pascale Zaraté, François Pérès. A Decision Support Framework for Crisis Management. 3rd Euro Working Group Workshop on Decision Support Systems: Impact of Decision Support Systems for Global Environments (EWG-DSS 2013), 2013, Thessaloniki, Greece. pp.1–10, 10.1007/978-3-319-11364-7_1 . hal-03246613

**HAL Id: hal-03246613**

**https://hal.science/hal-03246613v1**

Submitted on 10 Jan 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# A Decision Support Framework for crisis management

Daouda Kamissoko[1], Pascale Zaraté[2], François Pérès[3]

[1]IRIT / SMAC, 118 route de Narbonne, F-31062 Toulouse Cedex 9, France
daouda.kamissoko@irit.fr
[2]47 Avenue d'Azereix 65000 Tarbes, France

**Abstract.** This paper deals with the development of a Decision Support System (DSS) for infrastructure network vulnerability analysis in the natural disaster context. The developed DSS named VESTA supports dynamic modelling and interdependence modelling. The issues in this particular decision context are identified. Characteristics to be respected and the software architecture are also presented. The strengths of the DSS and its functionalities are highlighted. It calculates parameters by a simulation based on a vulnerability model. This paper discusses the implementation granularities of and the use of such a DSS.

Keywords: Decision Support System, UML, Database, Disaster, Infrastructure, Network, Vulnerability

## 1 Introduction

Natural disasters have always been societies' destabilization sources since the beginning of the human societies. In the past, they were attributed to divine wrath sign. Much later their manifestations were explained scientifically. Actual knowledge allows the disaster description through models more or less established. Although the causes of such events are most often known, it turns out to be very difficult to prevent natural disasters. At most it is possible to think about protection systems.

Disaster affects many stakes including infrastructure networks. Through interdependence, a failure of one component might lead to those of the others by cascading failures. This situation can quickly lead to a complex crisis.

One of the challenges in the crisis management is the responsiveness of decision makers. The use of a Decision Support System seems to be primordial to meet the challenge. Indeed, every second counts and decisions must be taken quickly. Consequently, the use of simulation systems in such context seems essential.

The objective of this paper is to present a Decision Support System for

infrastructure network disruption in the context of natural disaster. First of all the issues of the DSS are presented. Features to overcome these issues are then shortlisted. Following on, the used architecture is described before presentation of the resulting software.

## 2 Issues

Decision making is one of the human being's main cognitive activities. In fact, man is a being who doubts. Through the doubt mechanism, it is in constant reflection in every decision process. This situation is further emphasised when there are several possible options. In general decision making, [1] pointed out some elements which make the decision process difficult:

- Uncertainty of the problem;
- Several different objectives;
- Different conclusions that may derive from different perspectives.

In the particular area of infrastructure failure many other difficulties indices could be added to the above enumerated:

- Decision maker's emotional state instability;
- Consequence extent;
- Interdependence between networks;
- Interdependence between feared events;
- The need of justification;
- Multiples actors.

For illustrative purpose, the 2010 volcanic eruption in Iceland affected about 20 countries because of the interdependences in air transportation networks. Because of this number of decision maker implied in the decision process, actions synchronisation is harder and time consuming. This kind of situation is source of stress and anxiety for decision makers which judgment could be affected. The stress erasing from this situation leads to the instability of decision maker emotional state. In addition, the justification of every action is very different from a normal situation.

It follows that a normal decision context is different from a crisis one. Currently everyday routine decisions are less complex, their consequence scope is limited, and the decision makers' emotional state is quite stable. On the contrary, in a crisis situation, decisions are more

complex, the consequence scope is high, decision justification needs are different, and the decision makers are emotionally instable.
Whatever the consequences, a decision has to be justified and in the case of natural disasters, maybe more than any other context, it is crucial to explain what is intended to be done. Natural disaster decision context varies greatly according to the decision-makers emotional states, the consequences extent, the need of justification, and the decision subject complexity. Thus, in natural disaster situations, the need of support seems to be obvious for decision making.
The previous example highlights the need of justification of every decision. In fact this is not specificity of infrastructure failure but in disaster situation in general. Stakes represented by the travellers has to be informed about why theirs flights was cancelled, diverted, delayed etc. Using computer software (Decision Support Systems) is therefore valuable.
In the following sections, we will describe the architecture of a DSS to overcome these issues and take efficient and effective actions according to crisis management phases. The aim of an effective action is to fulfil objectives in the assigned time, while that of an efficient action is to fulfil objectives with the assigned means.
We have identified some phases in natural disaster crisis management. They consist of:

- Investigation: To identify the feared events and the stakes: This is the phase of ignorance which aims to identify risks;
- Awareness of the situation: In this phase, the risk is known, stakes are awarded of the situation which means the beginning of cognitive processes to integrate the risk culture;
- Simulation: Aims to evaluate different scenarios through models more or less elaborated;
- Warning: This is the phase where we assist to the appearance of the hazard's signs;
- Event: Occurrence of the hazard;
- Replication: The event is over but the risk of recurrence is high. Replicas are seen especially when it comes to earthquakes;
- Post-event: The crisis is over, but it remains to rebuild and repair damages;
- Stability: This is the last phase. Choices are evaluated and feedback formalized.

The next section presents definitions of DSSs and some of their features.

## 3 Definitions and Features

A Decision Support System is a computer-based system for decision support [2]. It is defined as an integration of computer hardware and software that is designed to complement the cognitive processes of humans in their decision making [3]. In this paper, the designed system can be used in many phases. It is called VESTA.
DSS features as those of classical software depend on the use. They were described by Sprague and Carlson through the ROMC approach [4]: Representations, Operations, Memory Aids, Control Mechanisms. With regard to decision support systems in a disaster management, they have to be flexible, adaptive, responsive, interactive [2], progressive and controllable [3]. In addition to these features, we have also identified other parameters like: response time, geographical distribution, ease of use, portability, ergonomic and efficiency.
Next section introduces the architecture that incorporates these features.

## 4 Architecture

As recommended by Sprague [5], the architecture adopted is composed of three parts namely: a Human Computer Interface, a Data Base, and a Model Base. William A. Wallace in [3] added to these parts a data analysis capability. In our approach, this module is managed by the Data Base Management System. In some situations like those related to territorial management, a spatial DSS can have prominent spatial components [6].
Data Base is devoted to data analysis capability performed by a Data Base Management System (DBMS). The Model Base is related to a normative model implemented in a Model Based Management System (MDBS). The Human Computer Interface is related to a Dialogue Management System.
Next section presents these components.

### 4.1 Human Computer Interface

A Human Computer Interface (HCI) represents all windows accessible

to users. The nine windows of the application have been prototyped with Balsamiq [7]. At the encoding time, the GUI was drawn by WindowsBuilder - an Eclipse IDE plug-in [8]. The dialogue management system related to the Human Computer Interface is implemented through Java Classes.

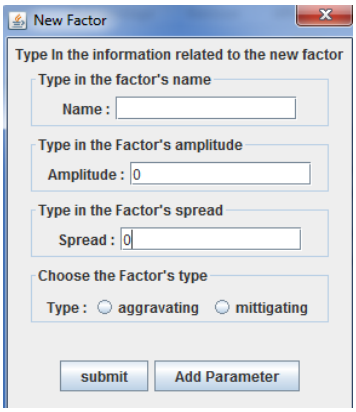


**Fig. 1.** Human Computer Interface of VESTA

A feared event like a flood can be aggravated or mitigated by some natural or artificial factors (like a dam for instance). As an illustration, Fig. 1. presents this particular HCI.

## 4.2 Database

Decisions emerge from the performed data processing. Data are located in a database. The Unified Modelling Language (UML) is used for the data description. We used a methodology inspired from that presented in [9] This approach included actors identification, building the static context diagram, relationships between use cases, use cases for human actors, sequence diagrams, activity diagrams and class diagrams.

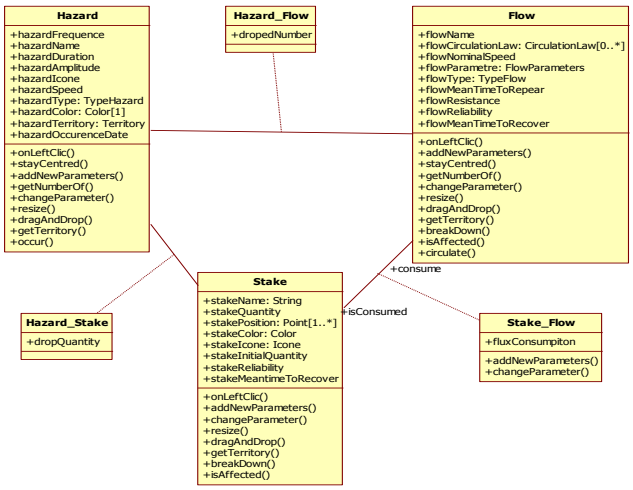


**Fig. 2.** Class diagram with StarUML [10]

Fig. 2 resents part of the class diagrams in UML. At its occurrence, a feared event (Hazard) affects circulating flows in the network and stake. The real data base implements 30 classes and 12 relations.

## 4.3 Model base

The model base is managed by a Model Base Management System (MBMS). The functional and dynamic modelling of MBMS are performed through the object approach.

Several kinds of actors are identified: International, National, Regional, Infrastructure Manager, Local Operator, Emergency, Citizen and the Analyst. For each of them several use cases are defined. We have defined 14 scenarios. The example in Fig. **3.** shows that a local actor can determine among others critical components, effective actions, feared events etc.

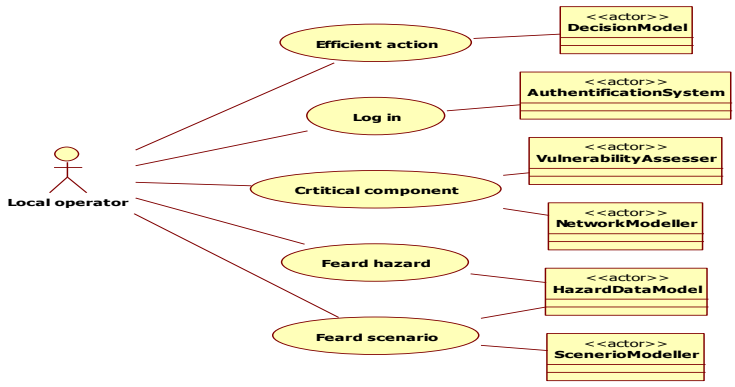


**Fig. 3.** Use case for local operator

Use cases in Fig. 3. are based on the vulnerability model [11] presented in the next section.

## Vulnerability model

Vulnerability is "a stake's inability to resist the hazard's occurrence and to recover effectively its nominal functioning for a given period of time" [12]. Vulnerability depends on the hazard and the system state. It is given by:

$$V = P(Hazard) \times (1 - \prod_{n=1}^{N}(1 - \vartheta_n)) \quad (1)$$

N is the number of component. $\vartheta_n$ is the intrinsic vulnerability of a single component n. It is given by:

$$\vartheta_n = (1 - R_b)(1 - R_s) \quad (2)$$

$R_b$ is defined as the robustness and $R_s$ the resilience. The reader may refer to [11] for more information.
The originality of the DSS is also in the implementation of this model.

## Model implementation

Because of its portability Java was retained as development language to implement the model in the previous section. In addition, Java is free and can run on different computer environments without any change.
The system is fully implemented by using swing as an API for graphics and JUNG to represent the network [13].

## 5 The Decision Support System: VESTA

Many terms are related to Decision Support System in the literature: artificial intelligence, data mining, on-line analytical processing, knowledge management [14], Group Support System (GSS), Executive Information System (EIS). In general, a Decision Support System is a computer-based system for decision support [2]. There are many definitions in the literature. We divided these points of views into three groups:

- Definitions focusing on the characteristic [2], [15];
- Definitions on the objective [3], [14];
- Definitions on the architecture [5], [16].

A recapitulative is given by[17] and [14]. The developed DSS complements shortcoming of the existing. Its functioning is presented in the following section.

### 5.1 Functioning

In the literature there are several Decision Support System for disasters management. Their applications are related to many disciplines: pollution control, water resource management, flood, forecasting, prevention of epidemic etc. [14]. A recapitulative is given by [17] and [14]. None of these systems take into account the vulnerability calculation in a generic way. The Decision Support System for Interdependent Network Vulnerability Analysis realized in this study contains an ergonomic graphical user interface which allows the user to choose different possibilities depending on his/her rights. The functioning is composed of five phases: Characterization, Modelling, Simulation, Decision, and Evaluation.

The first step of this approach is to describe the decision context in the characterization phase. After this description, networks and interdependences modelling would be performed in the modelling phase. The simulation will allow best actions determination. Determined actions are evaluated in the Evaluation step.

VESTA is able to calculate the vulnerability of a geographical region or a network. The region must first of all be modelled by the analyst. Next parameters as feared events and stakes have to be estimated and the system can assess the vulnerability of the defined target. Its strengths

are presented in the next section.

## 5.2 Strengths

**Dynamic Network drawing**

The strength of VESTA resides in the dynamic network drawing. The software enables the user to import a map as a picture or to select an area from a real map (using Google maps for example). Then, specify the boundaries of the geographic area to work within. If the user does not find a map, the software offers the possibility to draw the territory and represent it by its boundaries on the zone. Territories are resizable (zoom, extension...).

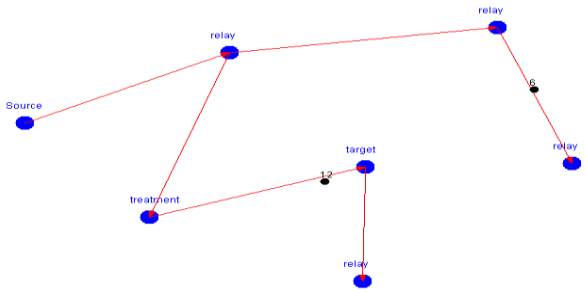


**Fig. 4.** Network drawing

During the simulation, the user can draw the network by a drag and drop function. He/She can add and remove component dynamically. The Fig. 4. shows an example of network drawing.

**Vulnerability-based Simulation**

VESTA simulates network functioning and determines the vulnerability according to the model presented in [11]. This model takes account of interdependence among networks, flow circulation, the impact of a feared event such as an earthquake, the component failure due to its unreliability etc. VESTA could determine other parameters which are described in the next section.

## 5.3 Results representation

The system has been used in two cases study. The first is a generic one.

The reader is invited to see [11] for more information. The second is real situation. The analysis is performed for Lourdes, in the "Hautes-Pyrénées" (France). Indeed, the Hautes-Pyrénées lies in the highest seismic area in the French metropolitan country. Lourdes is a pilgrimage city since 1858. As an illustration the city hosted during the 150th anniversary of the Virgin apparition nearby 70,000 pilgrims per day. This may amplify the dramatic character of the consequences in case of the occurrence of a seism. Among the different topics of concern, the city wishes to analyse the vulnerability of the sewage network. The simulation was performed with our DSS and we proposed some actions. The details of the analysis and the methodology are available in [18].

For a single element (single network, territory, network component, stake, flow, factor, feared event), the application calculates the vulnerability and shows the result in the form of Pareto chart. This chart provides information on the importance of the considered element to the global vulnerability. The system could also calculate the part of vulnerability induced by interdependence. For now, it is a prototype and must be improved.

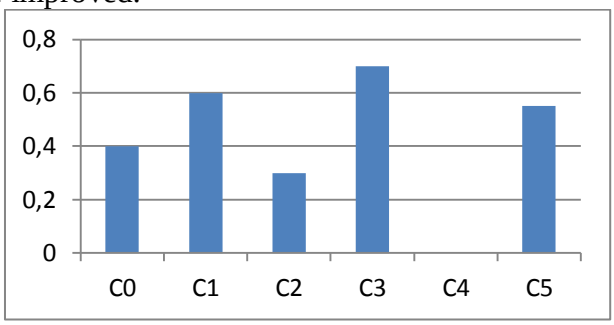


**Fig. 5.** Parameter calculation

Fig. 5. represents the vulnerabilities of six components. It shows that the component C4 is the least vulnerable with respect to the feared event. Conversely C3 is the most vulnerable. Let us remark that the user could also select more or less components and choose to display resilience instead of vulnerability for example.

## 5.4 Functionalities

The approach used in the DSS is to minimize the effects of interdependences and detect the vulnerable elements. The main

developed functionalities are presented in the following.

- Evolution of the parameter: The user can follow the evolution of one or more parameters during the simulation time (vulnerability, robustness, resilience etc.).
- Feared event or scenario: One of the aims of vulnerability analysis is to determine the consequences of feared events and scenarios. The DSS is able to provide the decision maker with some information about one parameter of a selected component in the case of different possible scenarios.
- Effect of interdependence: Interdependence when activated could change the behaviour of the system. The user can select a parameter of a component and see the effect of one or more interdependences on it.

But the following functions are still under implementation: Estimation of the Time to break down of a single component, the minimum value on one parameter (reliability, Mean Time To Repair…), Determination of the worst feared event occurrence point.

## 6 Conclusion

The objective of this paper was to present a vulnerability model-based Decision Support System. Every component of the architecture has been described. The obtained DSS allows an estimation of infrastructure network vulnerability taking interdependences into account. The main contributions are in the following:

- Characterisation of a natural disaster decision context;
- Identification of DSS features in this context;
- Description of the DSS functionalities;
- Proposition of a DSS for natural disaster management.

Thus it is possible to deduce among others vulnerable areas, critical components and the most threatened stakes.

Our model takes into account interdependences only between systems of the same type. So we did not investigate the interdependences between feared events and infrastructure networks. But in our simulation, we implemented a model (out of the scope of this paper) to assess the impact of feared events on infrastructures. In the future our perspective is to deploy this application on the internet and on mobile devices (smartphone, tablet).

# 7 References


[1] P. Hellstom et T. Kvist, « Eval-u-a-tion of deci-sion sup-port mod-ules and human inter-faces using the Top-Sim sim-u-la-tor », presented at the 5th World Con-gress on Rail-way Research (WCRR 2001), Cologne, Ger-many, 2001.

[2] Y. Leung et N. T. Shatin, *Intelligent Spatial Decision Support Systems*. Springer-Verlag Berlin and Heidelberg GmbH & Co. K, 1997.

[3] W. A. Wallace et F. D. Balogh, « Decision Support Systems for Disaster Management », *Public Administration Review*, vol. 45, p. 134‑146, janv. 1985.

[4] R. H. Sprague et E. D. Carlson, *Building effective decision support systems*. Prentice-Hall, 1982.

[5] R. H. Sprague, « A framework for the development of decision support systems », *MIS Q.*, vol. 4, n° 4, p. 1–26, déc. 1980.

[6] D. E. Snediker, A. T. Murray, et T. C. Matisziw, « Decision support for network disruption mitigation », *Decis. Support Syst.*, vol. 44, n° 4, p. 954–969, mars 2008.

[7] « Balsamiq Mockups ». [Online]. Available: http://www.balsamiq.com/. [Accessed: 09-avr-2013].

[8] « Eclipse Java EE IDE for Web Developers ». [Online]. Available: http://www.eclipse.org/. [Accessed: 09-avr-2013].

[9] P. Roques, *UML 2 par la pratique: études de cas et exercices corrigés*. Eyrolles, 2009.

[10] « StarUML, The Open Source UML/MDA Platform ». [Online]. Available: http://staruml.sourceforge.net/en/. [Accessed: 10-avr-2013].

[11] D. Kamissoko, F. Pérès, et P. Zaraté, « Technological networks robustness and resilience assessment », presented at the 5th International Conference on Industrial Engineering and Systems Management, Rabat, Morocco, 2013.

[12] D. Kamissoko, F. Pérès, et P. Zaraté, « Infrastructure Network Vulnerability », presented at the 20th IEEE International conference on Collaboration Technologies and Infrastructures, Paris, 2011.

[13] « JUNG, Java Universal Network/Graph Framework ». [Online]. Available: http://jung.sourceforge.net/index.html. [Accessed: 10-avr-2013].

[14] M. Cioca et L.-I. Cioca, « Decision Support Systems used in Disaster Management », *InTech*, janv-2010.

[15] J. P. Shim, M. Warkentin, J. F. Courtney, D. J. Power, R. Sharda, et C. Carlsson, « Past, present, and future of decision support technology », *Decision Support Systems*, vol. 33, n° 2, p. 111‑126, juin 2002.

[16] S. Eom et E. Kim, « A survey of decision support system applications (1995–2001) », *Journal of the Operational Research Society*, vol. 57, n° 11, p. 1264‑1278, déc. 2005.

[17] Asghar, A. Damminda, et L. Churilov, « A dynamic integrated model for disaster management decision support systems », *International journal of simulation systems science technology*, vol. 6, n° 10‑11, p. 95‑114, 2005.

[18] D. Kamissoko, « Decision support for infrastructure network vulnerability assessment in natural disaster crisis situations », Doctorate, University of Toulouse, University of Toulouse 1 Capitole, 2013.