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# Decision Support Systems used in Disaster Management

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## 1. Introduction

The informational society is emerging as a new stage in the development of human society, by intense use of information in all fields of activity. The technological support of the new society is being built through the convergence of three major sectors: information technology, communication technology and digital content production. The development of new communication and information technology means is crucial to increasing competition, improving services and communication between institutions (Bizoi, 2007).

The initial concept of **Decision Support System (DSS)**, even though it was coined before the PC era, focused on the use of interactive calculation in semistructured decision-making (Alter, 2002).

The decision support systems are a distinct class of information systems. They integrate specific with general-use decision support information devices to form a constitutive part of the organizational global system (Filip, 2004).

In 1995, Clement identified four factors which determine the difficulty degree of the decision-making process (Hellstom & Kvist, 2003). The first, and altogether the most important factor is the *complexity of the problem*. The human factor has a limited capacity of perceiving and solving complex problems and, therefore, builds simplified mental models of real situations. Even if these models are applied in the best way possible, any simplification may lead to defective decisions. The second factor is given by the *uncertainty degree of the problem*, and the third is the fact that, in most cases, *several different objectives are set*. A certain decision may be right in the short run, but may prove wrong in the long run and vice versa. The last factor presented by Clement and which we should also consider refers to the *different conclusions that may be derived from different perspectives*, especially when several people are involved in the decision-making process.

In order to make good decisions, the decision maker must be well informed, must have access to high-quality models (from simple, implicit models to sophisticated mathematical models) and to "adequate" information. A decision support system may make all these conditions achievable (Hellstom & Kvist, 2003).

Considering the activities that the DSS supports, the elements of the decision-making model are (Demarest, 2005):

- a *decision maker* – an individual or a group responsible for making a particular decision;
- a *set of inputs of the decision-making process* – data, numerical or qualitative models for interpreting data, previous experiences with similar data sets or decisional situations

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and diverse rules of a cultural or psychological nature, or constraints associated to the decision-making process;

- the *decision-making process* proper – a set of steps, which are more or less clearly defined, for transforming input data into output data as decisions;
- a *set of output data of the decision-making process*, including the decisions proper and (ideally) a set of evaluation criteria for the decisions which take into account the needs, problems or objectives at the root of the decision-making process.

### 1.1 A short history

According to (Keen & Scott, 1978), the concept of Decision Support System has emerged from two main areas of research: theoretical studies focused on organizational decision-making conducted by the researchers of the Carnegie Institute of Technology during the 1950s and 1960s and the technical work on interactive computer systems carried out at the Massachusetts Institute of Technology in the 1960s. The concept of Decision Support System became an area of research on its own in the mid - 1970s before gaining in intensity during the 1980s.

Executive Information Systems, Group Decision Support Systems and Organisational Decision Support Systems emerged in the mid - and late 1980s from single user and model - oriented Decision Support Systems.

According to (Aggarwal, 2001), the evolution of the DSS may be divided into four generations: the first DSS generation focused on data; the second DSS generation focused on improving the user interface; the third DSS generation focused on models and the fourth, the present-day generation, was obtained by introducing new analytical web-based applications.

As a short conclusion, the Decision Support Systems belong to a multidisciplinary environment, including database research, artificial intelligence, human-computer interaction, simulation methods, software engineering and telecommunications.

Thus, the concept of Decision Support Systems is an almost established concept, but which is still growing due to the integration (incorporation) of several individual and relatively newer technologies (object orientation, expert systems, advanced communications), from which it "extracts" new valences and strengths. Concurrently, the vitality of the concept is stimulated by the growing tendency of integrating processes and functions with all industrial systems, environment management systems, etc. (Filip, 2004).

### 1.2 Definitions

The definitions provided during the last 30 years for DSS show, according to (Keen, 1987), "both what DSS is and what it is not", with consequences on both the scientific basis, and the credibility of the decision support applications.

Essentially, a DSS is a computerized system which improves the activity of decision-makers situated on different levels in the chain of command (from supervision of different processes to leading positions in politics). At the same time, DSS stimulates the decision-maker to improve the decisional process and make the right decisions in order to obtain high and quickly visible performances (decision effectiveness) (Filip & Bărbat, 1999).

As early as 1980, (Sprague, 1980) observed that the initial definition of the Decision Support Systems – computerized interactive systems which support decision-makers in using data and models to solve unstructured problems was too restrictive, and thus, the definition was expanded to include any system involved in the decision-making process.

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This expansion of the definition made the concept of Decision Support Systems an umbrella term for different types of systems, many of which having no connection with the initial idea of Decision Support Systems (Alter, 2002). If, initially, Decision Support Systems were instruments for large companies, today, they also address small companies too. These instruments have changed and will change considerably the way in which decisions are made. They enable the individual or organisational decision-maker to manage more effectively the volume and complexity of information and better co-ordinate activities.

### 1.3 DSS characteristics and functions

The characteristics specific to a DSS depend on the type of decision the systems have been designed for (Bellorini & Lombardi, 1998). However, numerous authors have suggested a series of "standard" characteristics any DSS should possess. Considering the results obtained by (Parker & Al-Utabi, 1986) after studying 350 sources on the same subject (Bellorini & Lombardi, 1998) and the essential characteristics emphasized by (Filip, 2004) we may synthesize a list of DSS characteristics:

- to provide support and improve, not replace, human reasoning; the user maintains control over the DSS at all times.
- to assist managers in the decision-making process connected with unstructured and semi-structured problems, which cannot be solved through simple reasoning and judgment, or through any other classes of information systems;
- to be flexible and adaptable in relation to the changes in the context of the decision and support as many (or even all) decision process stages as possible;
- to be focused on characteristics in order to make it more user-friendly to less proficient users (managers on all levels, a single decision-maker or a group) and not be limited to the computerisation of some methods of working used before the implementation of the system, but to facilitate and stimulate new approaches (to ensure support for a variety of decision processes and for different styles);
- to combine the use of analytical models and techniques with data access functions; the data and information in the system should be obtained from various sources;
- to improve the efficiency of the decision process, rather than its effectiveness, focusing on the increase in productivity and the quality, suitability and applicability of decisions, rather than on the time and cost of decision.

In conclusion, the main characteristics of a DSS are:

- it alleviates efforts, amplifies decision-makers' capacity and its purpose is not to replace them or transform them into mere agents who adopt mechanically solutions provided by the computer;
- its purpose is to approach semi-structured problems, in which sections of the analysis effort could be computerised, but the decision-makers use their own reasoning to control the decision process.

### 1.4 DSS classification

The systems that used to provide support in the decision process have been named by specialists Decision Support Systems or Decision Management Systems. Recently, terms such as artificial intelligence, data mining, on-line analytical processing, knowledge management have been used for systems whose objective was to inform and assist managers in the decision process (Muntean, 2003).

Because of the existence of a huge number of terms, which have caused many problems to DSS research, several criteria, have been proposed for a classification of Decision Support Systems (Suduc, 2007).

Undoubtedly, numerous DSS classifications have been developed in time, but we shall restrict below to those classifications which are enough relevant and encompassing to the subject in discussion.

Donovan and Madnick (1977), quoted by Turban (1998), divided DSS, according to the nature of the decisional problem, into two categories:

- institutional DSSs facilitate solving structured problems within an organisation;
- ad-hoc DSSs facilitate solving semi-structured problems, which are not usually anticipated.

Hackathorn and Keen (1981), quoted by Turban (1998), identified three categories of DSS:

- single-user DSSs;
- group DSSs;
- organisational DSSs.

Steven Alter, quoted by Muntean (2003) proposed in 1980 a classification of the Decision Support Systems according to "the degree to which the system's output can directly determine the decision", independently from problem type, functional area or decisional perspective. Thus, seven categories of Decision Support Systems were proposed, divided into two super-classes:

- Data-oriented DSSs
  - File Drawer Systems, whose purpose is to automate certain manual processes and provide access to data items. They address people who have operational responsibilities (operators, clerks, workshop supervisors). Currently, this category includes simple query and reporting instruments which access transactional systems;
  - Data Analysis Systems, which facilitate the analysis of current and historical data, in order to produce reports for managers. Data analysis is required for budget analysis, business opportunities analysis, investment effectiveness analysis, etc. Today, this category includes a large number of data warehouse applications;
  - Analysis Information Systems, which provide access to a multitude of support databases for the decisional process, as well as a series of simple models in order to supply information necessary for solving particular decisional situations. This category includes today the OLAP systems, frequently used in sales forecasting, competition analysis, production planning, etc.
- Model-oriented DSSs
  - Systems oriented on Accounting and Financial Models. The models employed are "what-if" and "goal-seeking" and they are frequently used in producing profitability estimates for new products, estimative balances, etc.
  - Systems oriented on Representational Models, which use simulation models to estimate consequences; they are used extensively in risk analysis, in production simulation etc.;
  - Systems oriented on Optimisation Models which help producing optimal solutions for different activities;
  - Systems oriented on Suggestion Models, which carry out the logical process that leads to a suggested decision for activities with a certain degree of structuring (such as determining the rate of updating insurance, models for the optimisation of bond supply, etc.).

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### 1.5 Advantages and limitations

Filip (2007) identifies four advantages and six limitations, as shown below:

- advantages
  - direct (or intermediated) work with the decision support system may contribute to improving the individual's decisional capacity;
  - increase in work productivity by extending capacity of decision-makers to directly process information;
  - expanding decision-makers' individual capacities leads to improved decisions, as a result of a better analysis;
  - being an artificial object, the decision support system is objective and impartial;
- limitations
  - the system lacks human traits: creativity, intuition, imagination, responsibleness or the instinct of self-preservation;
  - because of hardware and software limitations, there could be consequences which lead to insufficient qualities (regarding correctness and completeness) of knowledge accumulated within the system and in the limited possibilities of communication between decision-maker and the DSS;
  - in order to be effective and efficient, the system must be designed with a specific purpose in mind, for a specific field of use and a specific type of relative decision problems;
  - the DSS is designed as a component part of the global computer system of the organisation, from which it derives the necessary data. Thus, there may be compatibility problems between computer systems;
  - terminological issues and problems related to the significance of certain aspects approached by DSS may arise because of the cultural differences between developers and users;
  - the system may be used only partially and terminological issues may arise if the system documentation is cumbersome or poorly structured.

### 1.6 Disaster prevention DSSs

DSSs are extensively applied in environmental protection. They are used in pollution control, in water resources management and rationing, in flood control and forecasting, in agriculture for pest control, in forestry, in the prevention of epidemic diseases, etc.

The following are examples of systems used in activities related to ensuring the balance of ecosystems and in environmental protection:

- the TELEFLEUR (TELEmatics-assisted handling of FLood Emergencies in URban areas) funded by the European Commission, for the development of an operational system for the prevention and management of floods, which combines telematic technologies with advanced meteorological and hydrological forecasting encapsulated in a decision support system. The DSS was tested in the following areas: Liguria, Italy and Greater Athens, Greece;
- in Italy, the "Dipartimento di Informatica" (the Department of Informatics), at the "La Sapienza" University in Rome, have developed a DSS for flood control and prevention, based on Web technologies. The computer system has a distributed architecture, collecting data from distant sources. The decisional system simulates scenarios using the collected data and makes quantitative and qualitative predictions. The system also

provides a decision risk analysis for flooded areas. The DSS integrates an expert system in its architecture which uses experience and data accumulated from previous similar situations to make decisions;

- the L-THIA (Long-Term Hydrologic Impact Assessment) developed by Purdue University, United States of America, is one of the best systems used for monitoring and controlling the hydrological impact of climate change. It is integrated with GIS, a database management Oracle system and special user interfaces designed for users who are not very familiar with decision support computer systems. The data is collected through Web technologies, with PERL codes. The system provides the user with hydrologic maps which may be used to analyse the current situation and simulate hydrologic flow control scenarios;
- another DSS used in environmental protection, air and soil pollution control has been developed by University of Ljubljana, Slovenia. The proDEX system is developed in Python. It is dedicated to complex environment pollution issues, integrates with relational distributed databases and uses GIS in its architecture;
- in Chinese universities, the departments of informatics teach courses on DSSs, focused on different areas of application. Thus, the Shanghai Jiao Tong University focuses on developing Decision Support Systems for durable development and environmental protection. These Decision Support Systems integrate with artificial intelligence technologies – intelligent agents.
- research in the field has been carried out in Romania as well, as a result of the global effects which influence the environment and which produced major damages between 2004 and 2006 in our country. The "Lucian Blaga" University of Sibiu has developed a system, funded by the state budget, based on cross-platform (UNIX, Windows, etc.) Open Source technologies such as the PHP application server, the MySQL database server, and the Apache Web server. The purpose of this project was to create a flood (disaster) warning system, which will be presented as a case study in subchapter 4.

## 2. Decision support technologies and tools

The complexity of durable development issues require rational decisions, and decision-making is becoming increasingly difficult especially in the field of environmental protection. Due to the advances in decision theory and the study of decision support systems, new decision support methods and instruments have been developed. However, designing and building instruments able to assist the decision-maker in making decisions for complex issues is a highly demanding task (Boboşatu, 2008).

Using certain techniques and methods which are generally accepted in DSSs may contribute to the improvement of risk identification and prevention processes. These involve making strategic decisions with the synergetic contribution of different committees and groups of experts. Their activity is frequently hindered by physical, temporal and cognitive barriers. In addition, these methods and techniques used by DSSs are simply general recipes for approaching specific decisional situations. In practice, they need reinterpretation, refinement, adaptations and additions.

The use of a DSS for risk identification and prevention will enable the decision-makers to turn to the best account the intellectual capital needed for its application. As most decision-makers mainly focus on content and less on procedure, this is not as easy and well documented as it appears to be. Moreover, the use of a DSS contributes to the reduction of co-ordination malfunctions in the case of collective decision processes and facilitates the integration of intermediary reports obtained through the application, co-ordination and aggregation of the methods and techniques employed.

An important role in the development of DSSs is played by the concept of OLAP (On-Line Transaction Processing) with the technologies it is based on: ROLAP (Relational Online Analytical Processing), MOLAP (Multidimensional Online Analytical Processing) and HOLAP (Hybrid OLAP).

In MOLAP, data is stored in multidimensional cubes. The data is not stored in a relational database, but in proprietary formats. This technology has the following advantages:

- excellent performance (the MOLAP cubes are built for quick data interrogation and are optimal for "Slice and Dice" operations);
- ability to perform complex calculations (all calculations are generated the moment the cube is created, and thus results are obtained very fast).

ROLAP is an alternative to MOLAP (Multidimensional OLAP). While both analytical technologies, ROLAP and MOLAP, are designed so as to allow data analysis through a multidimensional data model, ROLAP is significantly different from MOLAP as it requires additional storage space and calculations. ROLAP instruments access data in the relational database and generate SQL interrogations to calculate information adequately, when required by an end-user (Filip, 2004).

ROLAP enables the user to create additional tables in the database (aggregate data tables) which sum up data in any desired size combination. The advantages of this technology are:

- scalability in handling a large volume of data, especially models with millions of members;
- the data is stored in relational databases that can be accessed through any SQL reporting instrument;
- ROLAP instruments are more performant in handling non-aggregate fact tables (for example, text descriptions), while MOLAP instruments are less performant when interrogating those elements.

The HOLAP technology tries to combine the advantages of ROLAP and MOLAP to obtain faster performances. When detailed information is needed, HOLAP allows "drill through" operations which retrieve data directly from the relational database.

The concepts of OLAP and data warehouse are complementary. The data warehouse collects the information needed by decision-makers starting from the data source and its main objective is to centralise decisional information by ensuring the integration of extracted data, their coherence and the preservation of their evolution. That is why, the implementation of data warehouses is based on ROLAP. The data warehouse maintains data integrity and feeds data storehouses.

Data storehouses are the result of extracting a part of the information in the data warehouse required by the decision process and are useful to a class of decision-makers for their specific analysis needs, case in which they are oriented on analysis subjects. The data storehouses efficiently support the OLAP analysis processes, and they are implemented by using the MOLAP technology (Boboşatu, 2008).

Usually, Web-oriented DSSs use a "three-tier" or "four-tier" architecture (Power, 2002) and enable a decision-maker to send a request through a Web browser (Internet Explorer, Netscape, etc.) to the Web server through HTTP (Hipertext Transfer Protocol). The Web server processes the request using a program, or a script and displays the result in the decision-maker's Web browser who placed the request. Web applications are designed to enable any authorised user to interact with them through a Web browser and an Internet (Intranet) connection. Usually, the code of the application is located on the remote server, and the user interface is displayed on the user's browser. The instruments for developing Web-oriented DSSs are still new and rather complex. Many decision-makers have heard of HTML, but this is just a small part of the multitude of instruments used in developing a DSS. In general, decision-makers are bombarded with terms and acronyms such as Web Server API (Application Programming Interface), Java applets and servlets, Java Script in HTML pages, ActiveX and Plugins,.NET components, etc.

## 3. The environment and disaster management

Man lives in an environment which is permanently exposed to a diversity of more or less dangerous situations, generated by numerous factors. Extreme natural phenomena such as: storms, floods, drought, landslides, earthquakes and others, in addition to technological accidents (severe pollution, for example) and conflicting situations, may influence directly the life of every person and that of society as a whole. These phenomena, also termed as catastrophes or disasters (or hazards, to use a geographical term), must be precisely known so that they could be dealt with promptly. The reduction and mitigation of the effects of such disasters require a thorough interdisciplinary study of hazards, of vulnerability and risk, as well as proper dissemination of information. Informatics is called upon to play its own role in this field.

In this context, *hazard* is the probability that a potentially dangerous phenomenon might appear and affect both the environment and human beings. Thus, hazard is a natural or anthropic phenomenon, harmful to the human being, whose consequences appear because of the fact that safety measures have been exceeded. Natural hazards are a form of interaction between man and the environment, in which certain adaptation limits of society are exceeded. The presence of human society is mandatory so that these hazards may be possible. If an avalanche takes place in Antarctica, for example, it is nothing else but a natural phenomenon. If the same phenomenon occurs in Făgăraş Mountains, where a cabin or a road is affected, we are facing a natural hazard.

*Vulnerability* emphasises the degree in which people and their possessions are exposed to hazards, it indicates the level of damages which a certain phenomenon may produce and it is expressed on a scale from 0 to 1, 1 meaning the total destruction of property and loss of human lives in the affected area. The destruction of the environment triggers an increase in vulnerability. For example, deforestation produce greater erosion and trigger landslides, faster and more powerful freshets, and an increased vulnerability for settlements, access ways and communication networks.

*Risk* is defined as the probability that people and their property be exposed to a hazard. Risk is the probable level of deaths, injuries, damages produced by a certain natural phenomenon or group of phenomena, in a certain place and time. The elements of risk are: population, property, access ways and communication networks, economic activities, etc. exposed to risk in a certain area.

Floods are natural phenomena and a component of the Earth's natural hydrologic cycle. Floods are natural phenomena which have always influenced the development of human society; they are the most common natural disasters on Earth and they produce the greatest number of deaths and the greatest damages all over the world. In the same time, floods

determined people to change their approach to such natural disasters, from regarding them as a *caprice* of nature, to man's attempt to *fight* floods, to *defend* himself from floods and then to *prevent* floods.
Under the present-day circumstances, when profound climate changes have occurred and their effects such as floods and other disasters, a disaster/flood warning system such as the one described below in subchapter 4 is extremely useful (and complementary the other systems).

## 4. Decision support systems for disaster management. Case study

This subchapter presents a case study, the results of a research contract, funded by he state budget between 2007-2008, and carried out by the authors and the research team at the "Lucian Blaga" University of Sibiu.
Flood management is made easier by the fact that floods occur in predictable locations and in most cases warning is possible. That is why the project is very useful as it uses mathematical simulation and modelling in case of disaster and because it proposes an effective flood warning method.
The lifecycle of a disaster has three stages:

- the prevention/warning stage;
- the disaster stage;
- the post-disaster stage.

The project described below is included in the first stage, given its main objectives: warning the population through a fast flood warning system, "collecting" data and sending it to the dispatcher to be disseminated to the institutions in charge with such situations and the population in the affected area.

### 4.1 Specific objectives

Starting from a critical analysis of all other similar systems in the world and in Romania, we may infer that the theme dealt with substantially improves human knowledge in this field of study and brings several original elements through the development of a "fast flood warning system", as current warning strategies do not include such a solution, as well as through the data-collection method it presents. The present-day warning systems are the telephone, the fax machine, television, radio, etc. and not the SMS alternative we have developed in this project and which we are describing in this subchapter. This approach might be termed as a "relatively new" and viable alternative, given current circumstances when natural phenomena are becoming increasingly frequent and their consequences increasingly serious.
The research results are applicable to various institutions such as prefectures, disaster prevention county committees, county councils, disaster prevention local councils, civil protection county inspectorates, environmental protection county agencies, etc.

### 4.2 General presentation

Under disaster circumstances (water inrush, floods, etc.), the first systems that are going to "fail" are, in this order: TV cable, the power supply network, and possibly the mobile phone network. As shown below in figure 1, the system designed to inform the citizen on the imminence of a flood "short-circuits" – in general – between points 3 and 4 (5) and respectively 2-5. Thus, we consider our solution feasible and realistic as it provides a practical alternative to existing warning systems. (Cioca, M. et. al., 2008), (Cioca, M. et. al., 2009).

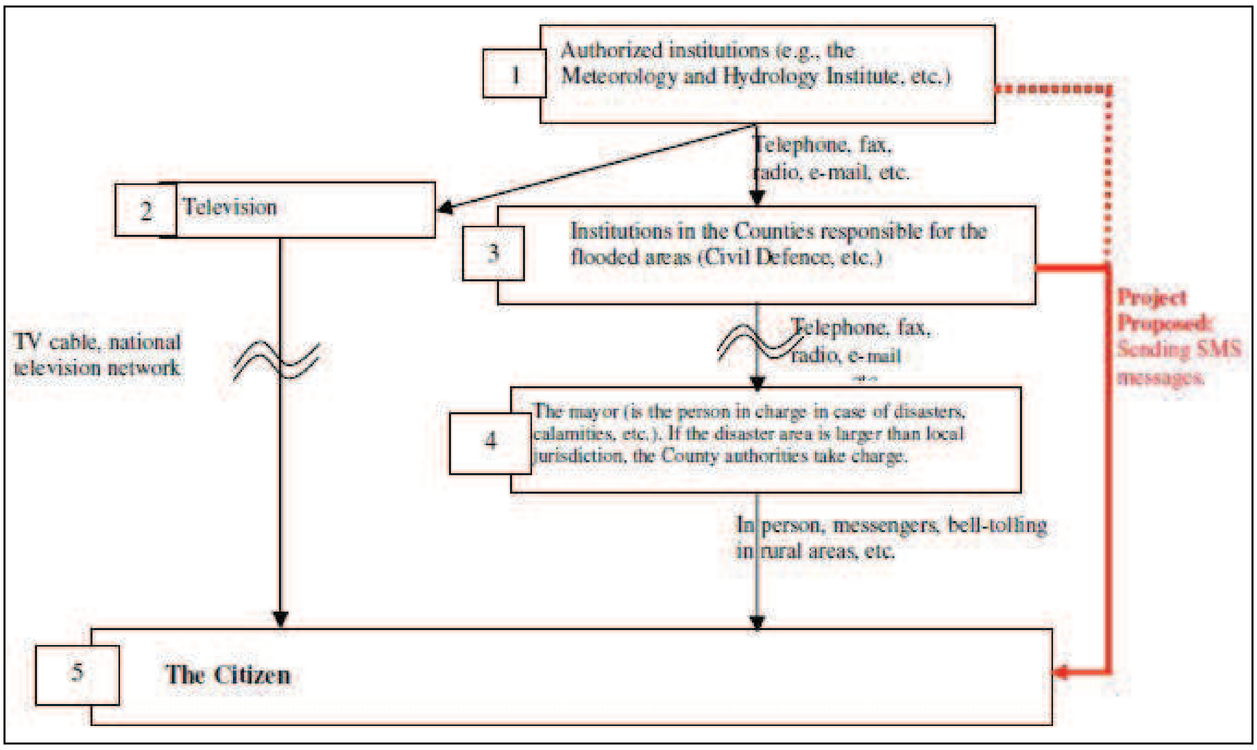


Fig. 1. Disaster Warning System Scheme

The first part of the paper deals with the warning system – described briefly in section 4 – while its second part deals with the data collection and dispatch system (section 5).

The system constructed during the development of the project and presented in this present paper is viable also because mobile telephony has gained more subscribers than fixed telephony; some families own even 2 or 3 mobile phones so there is a huge chance that at least one member of the family receives the warning message.

In figure 1 (Cioca, M. et. al., 2007) (with a continuous line) the system is implemented at a regional (county) scale and may be easily expanded to a national one (with dotted line); if implemented at a national level, the system will radically reduce the number of situations when man is taken "by surprise" by raging waters.

In conclusion, in case of a water inrush, citizens may find themselves in one of the following situations:

- they are not informed on the matter;
- they are informed too late;
- they are informed in time (this has been rather uncommon in rural areas in between 2004 and 2008).

The warning system increases the chances that citizens might find themselves in the last of the three categories mentioned above.

The system:

- enables the users to send disaster-warning text messages;
- to the authorities (or directly to citizens);

- is as feasible and platform independent as possible;
- is easy to use and user-friendly to users with intermediate computer skills.

### 4.3 Technical specifications – dispatcher system
#### 4.3.1 Fundamental architecture
*Client-Server*
The Client - Server architecture is one of the most commonly used in application development and it ensures the division of the application operation logical model into smaller functional units (Daconta et al., 2003), (Fensel et al., 2002), (Shadbolt et al., 2006), (Sheth et al., 2003).
*Http (Https) Web Architecture*
The application is based on a web platform. The advantages of using a web platform are:
- the fact that the communication protocol has already been implemented and tested on an international scale (HTTP/HTTPS);
- at the client level, no specialized software is required; a web browser is the only requirement; thus, the architecture can be implemented on a large number of systems with no particular configuration of these stations;
- system upgrading is a simple operation and requires just a single modification of the segments in the specified system.

Data transmission security is ensured by using the HTTPS, which provides a secure channel between the client station and the system residing on the server.

#### 4.3.2 Technologies
*Client*
The client requires a minimum number of software applications, which,as we shall see below, are rather inexpensive:
- Web browser (Firefox, Internet explorer >5.5, Netscape) – to access the system residing on the server;
- the access to the host server (intranet, internet) – to ensure this interconnectivity for this station. Any communication media may be usually employed, from wire to wireless technologies;
- hardware requirements are those of the abovementioned software application.

*Server*
The server software requirements are the following:
- Operation System: Linux Based – better stability both in terms of security and performance;
- programming language: PHP 5.x;
- SGBD: MySQL 5.x;
- WEB Server: Apache 2.x.

The optimum system hardware will be specified only when the solution has been implemented on the host system. The higher the number of users, the more powerful should the hardware be to ensure optimum performance (Jeffery & Kacsuk, 2004), (Laszewski & Wagstrom, 2004).
*Specialized Hardware*
GSM communication is ensured by a GSM Modem and if the number of SMS messages is too high, the Bulk SMS Message service provided by a local mobile operator could be a good choice.

The Bulk SMS Message service is a service provided by certain mobile operators which p the interconnection between the local system and the mobile operator.
One of the drawbacks of such a system is the fact that the connection may be interrupted on account of implementation reasons (cable faults), but on the other hand this system is able to send a large number of SMS alerts.

### 4.4 System architecture

#### 4.4.1 Basic architecture

The basic system architecture is presented in (Cioca et al., 2009).
The required software is presented in the (Cioca, 2008).

#### 4.4.2 Detailed architecture

a. Risk Levels

Five levels of risk are defined within the system:

- Disaster;
- High risk;
- Medium risk;
- Low risk;
- Minor risk.

These levels are to be used on a regular basis in the entire warning process.

b. Dangerous Events

The following (main) dangerous events are defined within the system:

- Earthquake;
- Floods;
- Fire.

The above are just examples; other events may also be defined.

c. Regionalization

This process involves designating certain areas where dangerous events are likely to occur (villages, cities, etc.). This regionalization process divides a territory in order to make it manageable during the occurrence of external events that require supervision.

d. Scenarios

This process involves assigning one or more areas to a person in charge, depending on the type of dangerous event.

e. Users

There are several types of users:

a. General Administrator

This user is in charge with the entire system, its configuration, user management, etc.
The most important operations:

- User management;
- Operation Parameters Management (number of messages sent per time unit, etc.);
- Monitoring the warning log.

b. Local Operator

This user performs the most important task, i.e. to initiate alert process. This user selects the scenario, the area and this request is sent to the system which informs the persons in charge.

c. Personal Operator

This user updates the contact information (especially phone numbers, contact details, etc).

The basic scheme of the entire SMS warning application is presented in the figure 2.

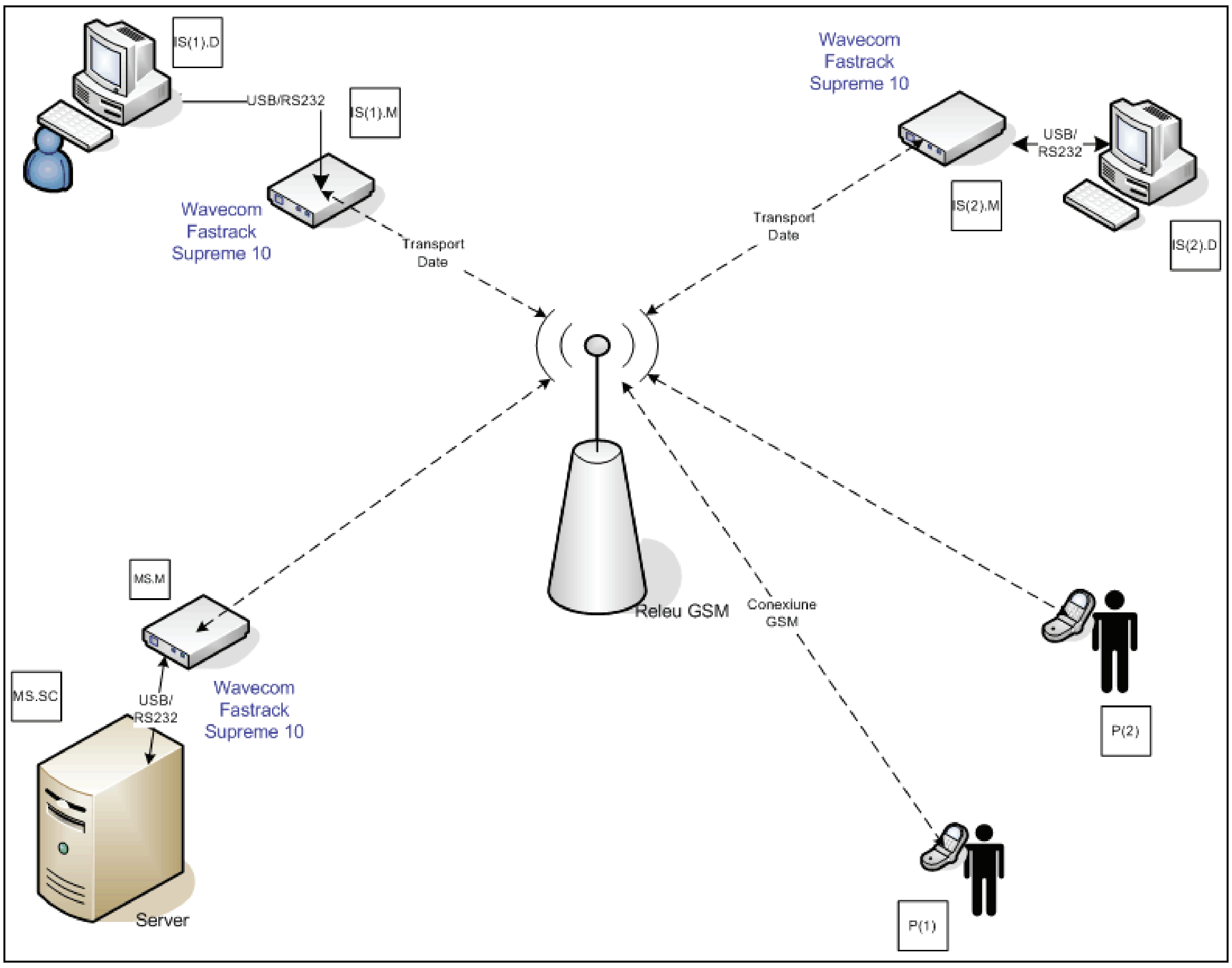


Fig. 2. Basic Scheme of the Disaster Warning Process (the dispatcher sends SMS to people in danger)

### 4.5 Communication between the system and the GSM environment

#### 4.5.1 General details

In this implementation, we have used a Fastrack Modem M1306B:
General product specifications:

- the best GSM/GPRS connectivity characteristics;
- internationally tested solution;
- 900/1800 Mhz dual band;
- AT interface, provides connectivity to a wide range of equipment;
- hardware connection: RS232 cable.

#### 4.5.2 General presentation

The characteristics are presented in detail below:
Standard access to environment:

- 900 Mhz
- E-GSM, ETSI GSM

GPRS compatible:

- Class 10
- PBCCH support
- Coding schemes CS1 to CS4

Interfaces:

- RS232(v.24/V2.8)
- Baud Rate: 300, 600,1200,2400,4800,9600,19200, 38400,57600,115200
- 3 v SIM Interface
- AT Command set V.25 and GSM 07.05 & 07.07
- Open AT interface form embedded application SMS:
- Text & PDU
- Point to Point (MT/MO)

Audio:

- Echo cancelation
- Noise Reduction
- Telephony
- Emergency Calls

#### 4.5.3 Communication protocol implementation; interface instructions

In order to transmit a text message (SMS) by using a modem the following instructions should be used on the serial interface. At this moment, just this modem function is to be used. The modem is able to perform many other tasks, but this is the only one implemented so far.

| | |
|---|---|
| AT | Initiate model connection |
| OK | Result |
| AT+CMGF=1 | Setting mode – SMS Mode |
| OK | Result |
| AT+CMGW="+0740******" | Setting Number |
| >Text Sample | Message ends with ^Z |
| +CMGW: 1 | Message Index |
| OK | Result |
| AT+CMSS=1 | Send message |
| +CMSS: 20 | Send message index |
| OK | Result |

### 4.6 Technical specification – data collection system

#### 4.6.1 Communication between the system and the GSM environment

The system has been conceived as a minimal system, in which active components are preset to known GPS locations (or locations of some other type).

*Operation*

Basically, the system functions as follows: it collects data, it sends it to the central station where the danger is rated. If the danger rate is higher than a default level, the system initiates an alert request for the staff in charge.

The basic scheme of the entire data-collection application is presented in the figure 3.

*Component parts*

The system contains the following entities:

- MS – Main Server or main data collection, processing, and emergency alert server;
- ISS1… n – individual static (known coordinates) data collection stations, i.e. stations operated by specialized personnel who observed and manually enters data into the system;
- P1…n – Personnel in charge

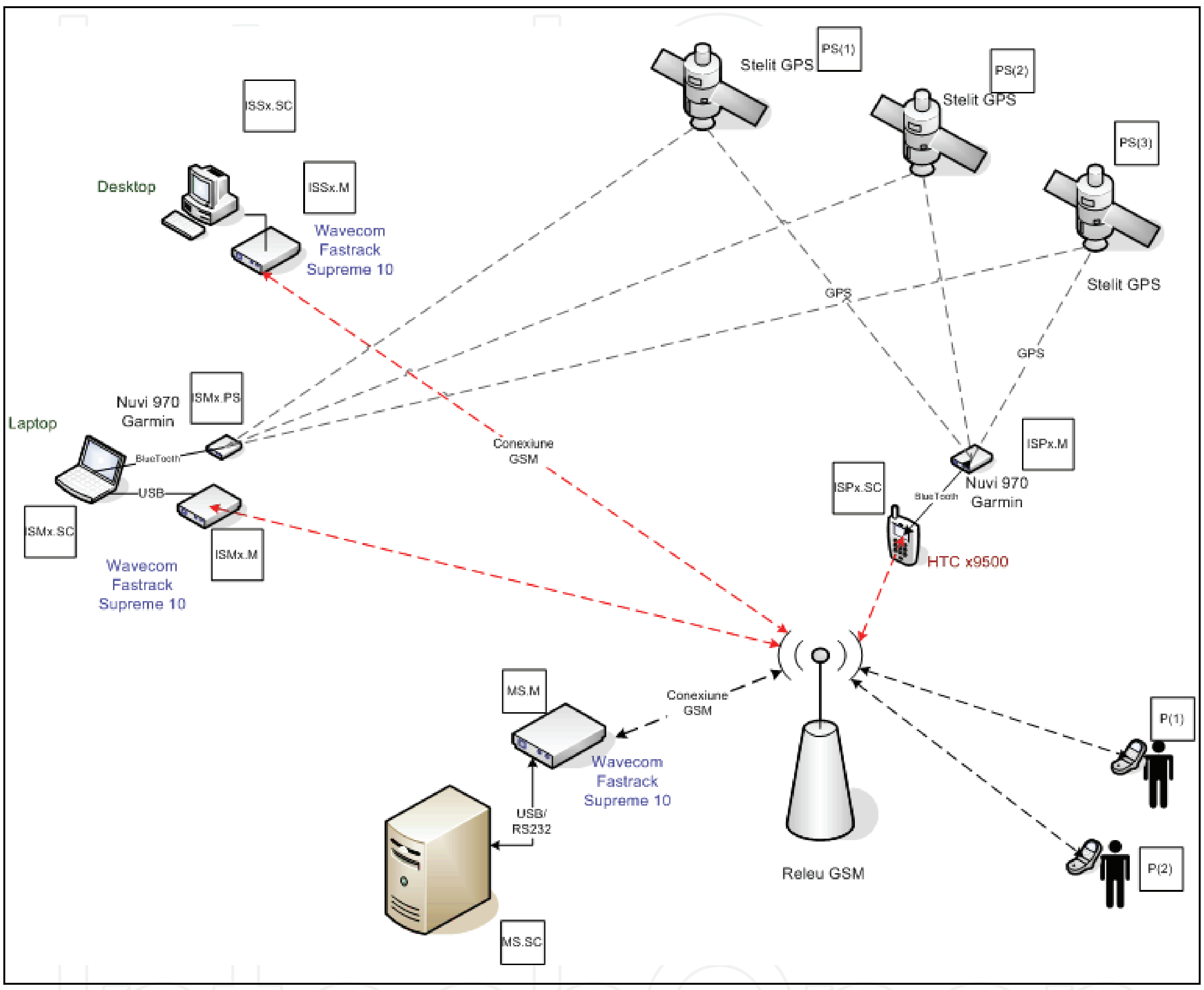


Fig. 3. Basic Scheme of the Data Collection and Dispatch Process

4.6.1.1 Main Server or MS

Consists of the following subcomponents:

- Computing system (MS.SC);
- GSM receiver/transmitter (MS.M).

*(Technical) Operation*

- the computer system (MS.SC) checks on a regular basis if there are any new messages (collected data). This operation is to be performed through OpenAT commands sent on the RS232 interface for the attached modem (MS.M);
- the collected data is processed and if one of the system parameters exceeds the specified limit, the warning process is initiated, the persons in charge are alerted (Px), through OpenAT commands sent through the RS232 interface for the GSM modem.

4.6.1.2 ISS

Individual static data collection system having (GPS coordinates known)
It is composed of:

- a computer system (desktop) (ISS(x).SC);
- GSM transmitter (ISS(x).M).

*(Technical) Operation*

- the user enters data into the system (temperature, water level, etc.)
- the computer system (ISSx.SC) archives data ad through OpenAT commands data is transmitted to the GSM modem (ISSx.M).

The modem sends the data through the GSM network to the Main Server MS.

### 4.6.2 The dynamic system

It is conceived as a dynamic system, in which all active components are mobile, and their location is determined by the GPS equipment.

*Operation:*

Basically, the system collects data, sends it to a central processing system, where the danger rate is analyzed. If the danger rate is higher than a specified limit, then the computer system initiates an alert request for the personnel in charge with crisis management.

*Component parts:*

The system contains the following entities:

- MS – Main Server or main data collection, processing, and emergency alert server;
- ISM1… n – individual data-collection mobile stations, operated by specialized personnel who observe and enter manually data into the system
- PS1...n – Positioning satellites
- P1...n – Personnel in charge

4.6.2.1 MS – Central Processing, Collection, and Alerting System

It includes the following subcomponents:

- computer system (MS.SC)
- GSM receiver/transmitter (MS.M)

*(Technical) Operation*

- the computer system (MS.C) checks new messages on a regular basis (collected data). This operation is performed through OpenAT commands send throughteh RS232 interface for the attached modem (MS.M).
- collected data is processed and if one of the parameters exceed the specific limit, the warning process is initiated, the persons in charge are alerted (Px), through OpenAT commands sent through the RS232 interface for the GSM modem.

4.6.2.2 ISS

Individual static data collection system (known GPS coordinates) It includes the following subcomponents:

- a computer system (desktop) (ISS(x).SC);
- GSM transmitter (ISS(x).M).

*(Technical) Operation*

- the user enters data into the system (temperature, water level, etc.)

- the computer system (ISSx.SC) archives data and through OpenAT commands data is transmitted tothe GSM modem (ISSx.M) through the RS232 interface.
- the modem sends the data through the GSM network to the Main Server MS.

4.6.2.3 ISM

Individual dynamic data collection system (unknown GPS coordinates, may be determined through ISM(x).PS)
It includes the following subcomponents:
- a computer system (laptop) (ISM(x).SC);
- GSM transmitter (ISM(x).M);
- Positioning system (ISM(x).PS).

*(Technical) Operation*
- the user enters data into the system (temperature, water level, etc.);
- ISMx.SC receives data from ISMx.PS through the Bluetooth interface;
- the computer system (ISMx.SC) archives data (GPS coordinates + Collected Data) and through OpenAT commands data is transmitted to the GSM modem (ISM(x).M);
- the modem sends the data through the GSM network to the Main Server MS.

4.6.2.4 ISP

Individual dynamic data collection system (unknown GPS coordinates, may be determined through ISP(x).SC).
It includes the following subcomponents:
- a computer system (PDA, Smartphone) (ISP(x).SC);
- Positioning system (ISP(x).PS).

*(Technical) Operation*
- The user enters data into the system (temperature, water level, etc.);
- ISPx.SC receives data from ISPx.PS through the Bluetooth interface;
- ISPx.SC sends the data through the GSM network to the Main Server MS.

### 4.7 Further developments

Future research will consider the following:
- Extending the mobile data collection platform; a possible scenario is presented in the (Cioca, 2008).
- the possibility that the person in charge might send back a code to the server through which the system would be able to make decisions (create new alerts, distribute the alert to other levels);
- adding sensors to the system that would help sending alerts automatically, or at least in an aided manner; the sensors might be installed in the field, in key locations, which would thus allow human operators to be assign a different task.

### 4.8 Level and impact area of the results. Other similar approaches

The critical analysis conducted through the method described in (Cioca et al., 2007) of the present-day disaster management and warning systems, has led to the conclusion that the SMS warning system is very useful and has not been implemented in Romania. Worldwide, there are several devices that helped us build the system and the software modules able to handle the device presented above. Moreover, besides this SMS warning system, the real-time data collection system is an equally important element.

The subject this project is a new one in our field of study; even though there are a few weak attempts of some international researchers to approach the matter, no Romanian researchers have tackled it so far (Cioca, 2008).
Nevertheless, after a long and painstaking struggle to find similar approaches, we have identified the following:

- in August 2004, the Dutch government funded a project of LogicaCMG involving the development of a natural-disaster and terrorist-attack warning system (http://edition.cnn.com/2005/TECH/11/09/dutch.disaster.warning/);
- JNW, the first company specialized in SMS warning systems in case of tsunamis in Sri Lanka(http://www.groundviews.org/2007/09/13/sms-news-alerts-uringemergencies-the-experience-of-jnw-and-the-tsunami-warning-of-13th-september-2007/).

## 5. Conclusions

In a constantly changing economic and social environment, organisations, managers, specialists in finance and accounting, people in charge with warning the population in case of disasters, etc. must make important decisions caused by the mobility of internal and external factors.
Decisions made in this context must balance advantages and disadvantages, forecast short-term, medium-term and long-term consequences on the activity of an organisation or community which may be affected by disasters, and be assessed before implementation. Decision support systems are meant to meet such requirements. The development of such systems is a time-consuming operation and it can only be carried out by specialised personnel. The modeling, formalisation and implementation efforts of knowledge in the field are substantial. Numerous modelling methods, support systems for creating representations and implementing solutions have been developed (Donciulescu et al., 1986), (Donciulescu et al., 1985), (Filip, 2008), but the mere operation of data collection is extremely difficult. Once the system has been created, it must pass a series of tests, all the defects must be corrected and only then it may be exploited under the direct supervision of those who implemented it.
The motivation to develop a complex system for the management of the environment and public dissemination of environment-related information is twofold:

- to provide the managers who make decisions in environmental issues with a complex environment management system, which enables them to make scientifically verified decisions, based on principles derived from ecology; such principles are: preservation of ecological balance, and biodiversity (genofund and ecofund), reducing water, air and soil pollution, reasonable exploitation of natural resources; the principles for approaching a complex environment management system and for the public dissemination of information related to the environment are as well presented;
- in addition, a system for the public dissemination of information related to the environment and a disaster warning system for the authorities are required to protect the population and their property from natural disasters (floods, drought, landslides, avalanches, severe pollution of air, water and soil and other disasters).

An important contribution to the development of the complex environment management system and public dissemination of information related to the environment is the *integration of subsystems (component modules) with the complex environment management system*. In this context, the architecture of the complex environment management system and public

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dissemination of information related to the environment emphasises the component modules and the interaction among them. DSSs dedicated to the environment require a system of mathematical models, of the simulation and control for the assessment of environmental risk (floods, landslides, drought, etc.) and their consequences, a disaster warning system, an Internet system for the management of environmental data, an environment management expert system, and finally, pilot systems for environment management and public dissemination of information related to the environment.

In other words, in order to develop performant and complex DSSs for disaster management, on the one hand, a multidisciplinary approach is required, an approach which should bring together specialists in various fields, such as: environmental sciences, GIS, geography, mathematics, informatics, organisations in charge with dealing with such situations; on the other hand, a global approach which should unite institutions and people from different countries, as such phenomena are not restricted to certain areas on Earth and they may occur anywhere; a transfer of know-how between partners/researchers worldwide brings mutual benefits to all and might prevent the loss of human lives and material damages.

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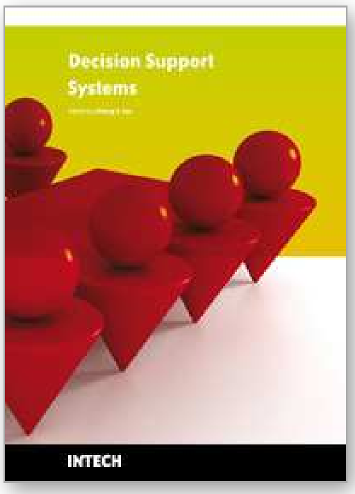

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Decision support systems (DSS) have evolved over the past four decades from theoretical concepts into real world computerized applications. DSS architecture contains three key components: knowledge base, computerized model, and user interface. DSS simulate cognitive decision-making functions of humans based on artificial intelligence methodologies (including expert systems, data mining, machine learning, connectionism, logistical reasoning, etc.) in order to perform decision support functions. The applications of DSS cover many domains, ranging from aviation monitoring, transportation safety, clinical diagnosis, weather forecast, business management to internet search strategy. By combining knowledge bases with inference rules, DSS are able to provide suggestions to end users to improve decisions and outcomes. This book is written as a textbook so that it can be used in formal courses examining decision support systems. It may be used by both undergraduate and graduate students from diverse computer-related fields. It will also be of value to established professionals as a text for self-study or for reference.

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