A qualitative analysis of the early warning process in disaster management

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ABSTRACT

Early warning systems are an important means of improving the efficiency of disaster response and preparedness. However, in its analysis of the technological aspects of the infrastructure, the literature has failed to carry out an investigation of early warning process. This paper has sought to take a step toward understanding this issue by carrying out a qualitative analysis of the early warning process in disaster management. This has involved participatory observations and conducting interviews with practitioners from the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN). The results have shown that this research area is a promising way of increasing efficiency and reducing the response time to warnings. This might be achieved by conducting a process analysis, which could provide evidence and information about bottlenecks or investigate the misuse of information systems or tasks by the players involved.

Keywords

Early warning process, Process modeling, Disaster management, Qualitative analysis, Practitioner Case.

INTRODUCTION

Several natural disasters have affected the communal life of a number of countries and caused serious damage to all of them. These events can be defined as a disruption of the "local capacity"' of a community and have several adverse effects (e.g. loss of life, the spread of disease, financial problems, environmental degradation, etc). In Brazil, floods are the most frequent kind of natural disasters - 54% compared with other types - and those which cause the most serious damage to the country. From 1980 to 2010, the United Nations (UN)[1] recorded 2,887 floods, 195,843 deaths, close to 2 million displaced people, and financial losses of around US$ 397 million. Additionally, the 2013 Report of the Brazilian Institute of Geography and Statistics (IBGE) showed that 27.7% (or 1,543) of Brazilian towns and cities have already been affected by floods with close to 1.4 million people being made homeless (IBGE, 2013). Officially, Brazil encompasses more than 4,700 flood-risk areas

Early warning systems are designed to analyze the risks of vulnerable communities, carry out the task of monitoring environmental variables, issue warnings, and ensure that appropriate response capabilities are in place. A people-centered approach, for emergency management, should thus be employed with the aim of catering for the needs of users, including their social, cultural, psychological and ecological requirements, thereby based on gender, age and local assets (Adger, 2000; Blaikie et al, 1994; Lindell et al, 2007; De León et al., 2009; UN, 2015). These systems can play an important role in preventing loss of life and reducing the serious consequences of a disaster when an imminent event is detected and an early warning is issued throughout the community at risk, with special perspectives and challenges in Brazilian territory (see i.e. Londe et al, 2014). However, while most of the works in the literature analyze the technological infrastructure or recommend new systems (Alfieri et al., 2012; Horita et al., 2015), only a few of them investigate the early warning process. This understanding is particularly important because the interconnection among data collection, decision support system, and early warning process, could provide more valuable insights from the available information rather than thousand of useless data, completely disconnected from decision-making.

This paper addresses this problem by conducting a qualitative analysis of the early warning process in disaster management. It employs participatory observations and includes interviews with practitioners from the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN). Once the early warning process is defined, we intend to adopt the guidelines of Horita et al. (2016) for structuring the whole decision-making process (from decision-makers' tasks to data sources), which in turn will support the interconnection between decision-making and information systems (e.g. decision support systems and mobile data collection). The potential benefits of this are as follows: (1) supporting of the targeted data collection, (2) the analysis of the effect of emerging (or lack) of information, and (3) the interconnections between decision support systems and decision-making processes, i.e. the way they define how information systems can better feed the decision-making, and thus give it support.

This paper is structured as follows. Section 2 outlines the theoretical background of this work. Section 3 introduces the case study and research method. On the basis of this, Section 4 describes the preliminary results, while Section 5 summarizes the research findings and makes recommendations for future work.

[1]http://www.preventionweb.net/english/hazards/statistics/?hid=62.

BACKGROUND: EARLY WARNING IN DISASTER MANAGEMENT

Early warning has been defined as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response" (UNISDR, 2004). Early warning systems define the technological infrastructure that can assist in carrying out these tasks. A technological infrastructure has been installed as a means of supporting data processing and forecasting natural disasters; it is based on expert models in early warning systems. However, these systems need to go beyond this infrastructure, by taking account of how risks are understood and providing information for an early warning system. This is because these factors might be required for triggering actions that can prevent or mitigate a disaster. Early warning systems are widespread within the field of disaster management and act as an important alternative to supporting disaster preparedness and response. Picozzi et al. (2015) devised an early warning system for earthquakes which provides alert messages within about 5 to 10 s for seismic hazard areas, while Alfieri et al. (2012) analyzed a European operational warning system for water-related disasters. Another line of inquiry has been to use information from crowdsourcing platforms - e.g. Twitter,, and OpenStreetMap - to provide updated information for early warning systems. In their work, Chatfield and Brajawidagda (2013) have demonstrated that social media messages could act as a supplementary source of information in disaster detection. The use of crowdsourcing was also explored in the work of Meissen and Fuchs-Kittowski (2014). This work employs crowdsourcing either as input data for further model processing or as input data for checking the plausibility of prediction model outputs or to augment the overall picture of the hazardous situation. There has also been some work on disaster management that is aimed at modeling the tasks of the decision-makers. Within this group, McEntire and Myers (2004) have outlined the tasks and procedures that should be carried out to prepare communities for disasters. Blecken (2010) introduced a reference task model, which supports humanitarian organizations in modeling and optimizing their supply chain management.

The works cited above make clear that there are a considerable number of studies on the use of early warning systems for disaster management but most of these only lay emphasis on the technological infrastructure of the systems. Similarly, although there are a very few works that examine the question of decision-making in disaster management, none of them discusses the early warning process. It is important to analyze this because it might provide evidence of the information bottleneck or the misuse of information systems by the players, In this way, improvements could be made with the aim of increasing efficiency, reducing the number of false alarms, and shortening the response time required for warnings.

CASE STUDY AND THE RESEARCH METHOD

Research Context: The National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN)[2]

The National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN), which is a branch of the Brazilian Ministry of Science, Technology and Innovation (MCTI), was created in 2011, after the disaster of the Serrana Mountain Region of Rio de Janeiro State. Among CEMADEN's activities, the following tasks play a crucial role in supporting disaster management in Brazil: (1) the development of warning for impending disasters that can support prevention and response measures; (2) the development and implementation of monitoring systems for natural disasters; (3) the operation of these monitoring systems; and (4) the issuing of warnings of imminent natural disasters to the National Center of Disaster Risk Management (CENAD, in Portuguese).

Although CEMADEN has its own monitoring equipment (including hydrology stations, meteorological stations,

[2] http://www.cemaden.gov.br.

and automated rainfall gauges), the center works in collaboration with several institutions such as the National Water Agency (ANA), the Brazilian Geological Research Company (CPRM), and the National Institute of Meteorology (INMET). These provide further data about weather conditions, risk maps, and environmental variables, which thus supplement the existing data of the center. All these data can thus be made available to support the monitoring activities and warning services carried out inside a Monitoring Room (Figure 1).

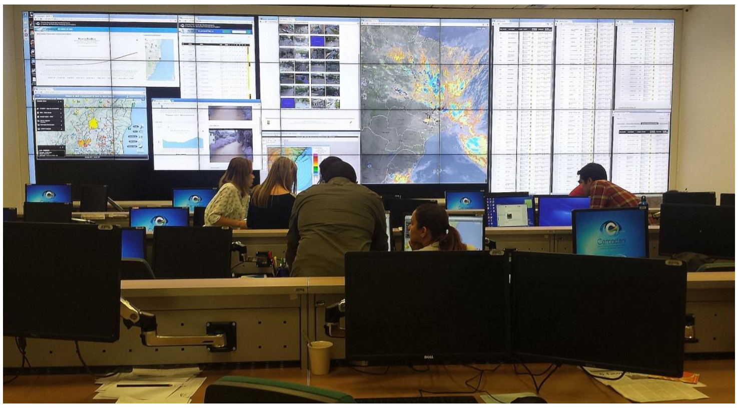

Figure 1. The Monitoring Room

The room is equipped with a video wall, which can display different kinds of information, e.g. the number of open warnings and data from the hydrology stations, or flooded areas. This is used by a monitoring team that works in s six-hour shifts, starting at midnight. The size of these teams ranges from five to seven members, and includes at least one specialist in each area (hydrology, meteorology, geology, and disaster management). The monitoring team has three channels of communication: (1) between the members, (2) with the CENAD, and (3) for urgent notifications. Since all of the members are inside the monitoring room, the communication can take place on an individual basis, or a meeting of the team might be held in the middle of the room. In turn, the communication with CENAD, which is a branch of National Secretariat of Civil Defense, is conducted through e-mail by the disaster management specialist. If it is an emergency - e.g. either a serious disaster is imminent or a disaster is already occurring - the warning can be issued to CENAD by phone or through video conferencing so that the contingency plans of the National System of Civil Defense can be activated.

Finally, the early warning levels are defined by a matrix (Table 1), which intersects two variables - the potential impact and the possibility of an occurrence of a natural disaster - and this can divided into three levels - moderate, high, and very high.

		Potential Impact		
		Moderate	High	Very High
Possibility of Occurrence	Very High	Moderate	High	Very High
	High	Moderate	High	Very High
	Moderate	Moderate	Moderate	Moderate

Table 1. A matrix of warnings showing different levels of disaster

Here, there is an assessment of the potential impacts of a disaster and the estimated damage in terms of the people in the communities and buildings affected; while the risk factor is represented by the analysis of variables such as the vulnerability of communities, weather conditions, land use, and inhabitants exposed to risk.

Method of Analysis

Since the objective of this paper is to analyze the decision-making process of early warning in disaster management, the following research question has been raised : *How is the early warning process operated by an emergency agency?*. This research question led us to conduct a qualitative analysis that was underpinned by a case study methodology (Yin, 2009; Runeson and Höst, 2009). The methodology followed three phases: (1) the preparation of the case study protocol (Runeson and Höst, 2009); (2) the data collection through interviews and participatory observations; and (3) the data analysis.

We first began this research by assuming that an early warning process can be modeled by means of the Business Process Modeling and Notation (BPMN) (OMG, 2013). We are not suggesting that an early warning follows a sequential pattern, mainly because it includes several variables of uncertainty, e.g. the changes in the thresholds caused by geological factors or the lack of data from the vulnerable areas. Despite this, the structural elements of BPMN are employed as analytical features in this paper. These features are then used to determine key factors such as activities, sequence flows, and the players involved, which are essential for analyzing the early warning process.

Elements	Description	Sources
Activity	This variable relates to a generic term for the work which an institution performs.	OMG (2013)
Actor	The stakeholders related to an activity or a decision by interacting directly (e.g. making a decision) or indirectly (e.g. processing data). They can be a single actor (e.g. hydrologist or disaster manager) or an institution (e.g. National Water Agency).	
Sequence Flow	This variable defines the order, which activities will be performed.	

Table 2. Analytical features

Once the analytical features were defined, we were able to embark on Stage 2. With the aid of the case study protocol, we conducted six interviews with members of two different monitoring teams from CEMADEN. The first team comprised two geologists, two meteorologists, one disaster management specialist, and one hydrologist. The second team is composed by one geologist, one meteorologist, one disaster management specialist, and one hydrologist. All the interviews were accompanied by a questionnaire with six semi-structured questions and lasted around 30-50 minutes. A semi-structured interview was chosen because it is open-ended, more dynamic, and allows improvisation on the part of the interviewer and scope for a fuller exploration of the studied objects (Runeson and Host, 2009).

All the phases of the methodology were carried out by a PhD student with a background in business process modeling, disaster management, and information systems, and a research assistant with background in the monitoring room and doing fieldwork in disaster management. Their work was supervised by a professor with a background in information systems and disaster management, and another with experience in hydrological analysis and disaster management.

PRELIMINARY RESULT: THE DECISION-MAKING PROCESS OF EARLY WARNING

The decision-making process of early warning comprises a set of tasks, which can be carried out either by an individual specialist - meteorologist, hydrologist, geologist, or disaster management professional - or by the team, i.e. all the members of the team (Figure 2) [3]. The main reason why we chose the BPMN to model this system, was that it is a recognized language and notation, that is widely used in the literature and in practical work.

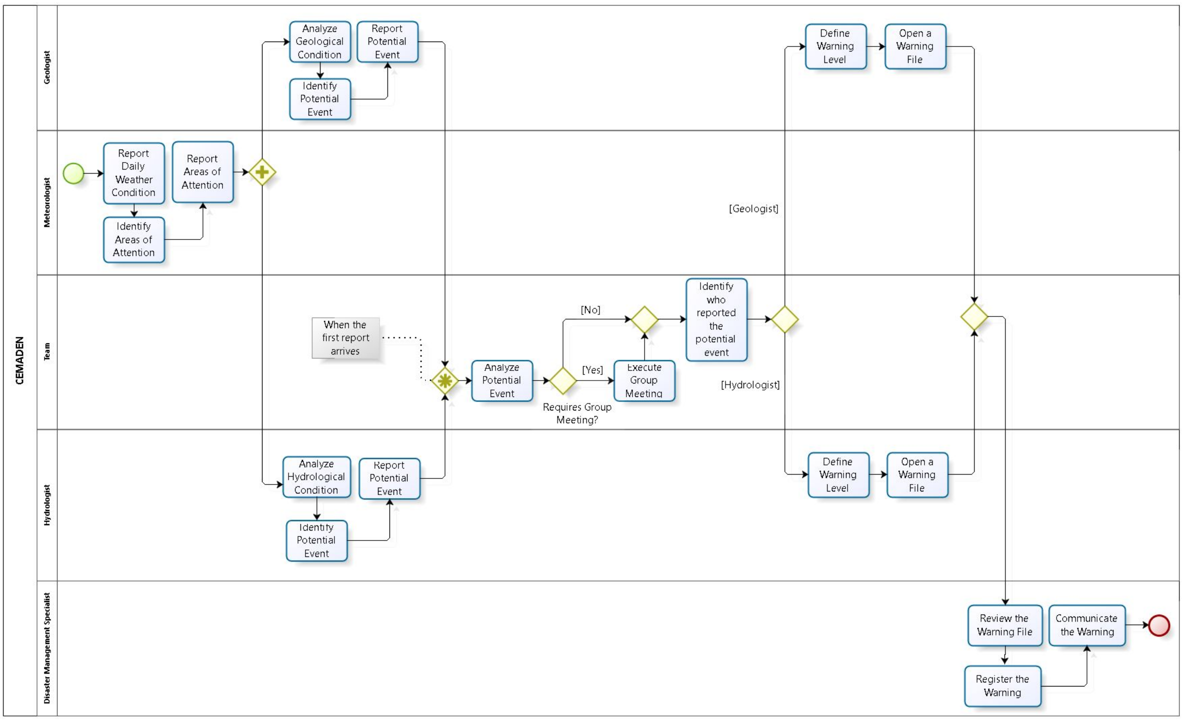

Figure 2. Decision-making process of early warning

The process starts with the meteorologist giving a daily weather report, which covers the areas likely to experience a high volume of rainfall (or: the areas requiring attention); for instance, the northern area of the State of Minas Gerais. This information is gathered by satellites or meteorological stations. Once these areas have been identified, the meteorologist informs the hydrologist and geologist. Following this, they analyze the historical data and the current data for the respective conditions in the areas at risk; for example, the hydrologist analyzes the volume of accumulated rainfall and the current amount of rainfall. This information is given by the hydrology stations or rainfall gauges. Both the hydrologist and geologist, work in parallel, and once one of them has detected a potential disaster, he communicates this to the team. The team thus analyzes all the available information about the potential risk, and decides whether there is a need for a group meeting or not. As soon as the group meeting has been held, the member, who reported the potential risk, defines the warning level. The threshold is important information for supporting this task; however, not all the municipalities have a fixed threshold, and in these cases, the member makes a subjective assessment on the basis of the available information or requests another member with more expertise for assistance. The next task is to collate all the information about the potential risk (e.g. the defined warning level, the description of the area, and the weather conditions according to the meteorological and

[3] We used Bizagi Modeler as process modeling tool. http://goo.gl/N27qyi

hydrology data, volume of rainfall and satellite images) and this is stored in what is called the "Warning File". When this file has been completed , it is sent to the disaster management specialist, who revises it, registers the warning in the monitoring and early warning system, and communicates the warning to CENAD (by email or phone). Every warning takes into account the features of a particular municipality, and attempts to assess what risk areas need special attention based on the accumulated rainfall data given by the measurements of the rain gauges located there. The warnings are then sent to CENAD which forwards them to the municipal civil defense network.

RESEARCH FINDINGS AND SUGGESTIONS FOR FUTURE WORK

This paper has conducted a qualitative analysis of the early warning process in disaster management. It involved gathering local knowledge and information from the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN) through an approach that relies on narrative and participatory observations within the monitoring room, and carrying out interviews with members of the monitoring teams.

Although the disaster management specialist has a clear set of fieldwork activities like undertaking the response tasks, the analysis revealed that it is still not clear what activities are required in the decision-making process of early warning. The interviews highlighted the fact that the members of the monitoring teams think these specialists tasks should include areas like risk analysis and assessing the potential damage caused by a disaster. However, they lack an approach which can enable them to estimate the extent of the possible damage or serve as an appropriate tool for risk analysis.

The interviews showed that the monitoring teams have a wide range of data available with both static and dynamic features. Static data includes the risk mapping carried out by the Mineral Resources Research Company (CPRM), the estimated population living in risk areas, and the thresholds that are defined, whereas dynamic data covers everything provided by satellites, radar, and meteorological stations. However, the use of these data for supporting decision-making process is hampered by the fact that they are not integrated in a way that allows a correlation or "what-if" analysis to be conducted. More research in this area is needed, to find a useful way of reducing the time of the analysis.

There is also a need for a fuller discussion of the factors which determine the warning level, as well as the definitions of what these levels represent. Table 1 displays a matrix of the factors involved; however, it fails to take account of other important factors like the response capability of the communities. The use of Volunteered Geographic Information (VGI) raises new perspectives for supporting in this task, although several works could be find in the literature (Horita et al., 2013; Haworth and Bruce, 2015). Since the challenge now is to obtain valuable insights from the amount of available data, a step forward in this line of work could be the structuring of these data by means of ontologies or information category system (Link et al., 2015).

Finally, further interviews should be carried out as a means of improving the way the decision-making process of early warning can be generalized, as well as to find out any unreported or hidden activities, players, or sequence flows. An improvement could also be made in the analytical features (Table 2), such as code categories for applying the coding technique (Runeson and Höst, 2009). In addition, there is an emerging trend for employing reference task models to assist in disaster management (Blecken, 2010).

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