Integrated risk response techniques in emergency situations: "the Mozambique floods case simulations"

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Abstract

Mozambique is one of the countries which is most vulnerable to natural catastrophes in the world with the second highest annual per capita death rate from disasters, 328 deaths per million, ranking only below the P.D.R of Korea; flood disasters are responsible for half of the fatalities and a third of the economic losses from natural disasters worldwide. Its geographical location, along the Indian Ocean with an area of more than 1,700 km^2, gives a degree of higher exposure to tropical depressions of different magnitudes, severe floods and droughts. Within the country, disasters are under the management of the National Institute for Disaster Management (INGC) a governmental entity composed of a multisector commission to deal with emergencies and natural catastrophes. Natural disaster risk management is also a wide field that attracts the attention of many stakeholders in the country, namely NGO, governmental institutions, academics and researchers, international agencies and others at international level.

This particular research paper aims to investigate and propose different techniques of responses in emergency situations such as floods and tropical depressions. The study will explore different approaches which are applied in emergency situations, combining theories and practices in order to formulate an integrated model. Stakeholder participatory approaches, earlier warning and probabilistic and mathematical simulation are among the main components of the Integrated Risk Response Techniques.

The main objective in developing such Integrated Risk Response Techniques is to provide the natural disaster risk managers with a holistic tool that can be applied, in case of emergencies, and reinforce the sustainability of the emergency planning processes. The use of such techniques might create added value for the national and regional response mechanisms in case of emergency.
Keywords: floods, emergency, disasters, modeling, simulation.

1 Introduction

The geographical location together with climate conditions of Mozambique contributes to a higher level of vulnerability and exposure to natural hazards. For the last 45 years, Mozambique was hit by about 53 natural disasters mainly floods, tropical depressions and droughts. Also, this is a result of the existence of different river basins, with different particularities and characteristic that cross the country.

These particularities and differences between the basins also influence the analysis over the magnitude and impact the floods on each single river and their water flow. In Mozambique, usually different rivers have different time scale of floods, what most of the times cause a paradoxical constraint on disaster risk management through the country. It is quite normal to have floods in a certain region while others are facing droughts.

The 2000 floods created a motivation among many people in order to classify this event statistically. Governors, academics and other stakes from the civil society were surprised by the magnitude of the floods and a comparative reference was investigated. (Christie and Hanlon [8]) are among the few sources that the author found regarding this matter. They refer to a series of different primary sources of information, comparing the 2000 flood to others that their memories might still have in mind "Eduardo Cuna a local chief in Chokwé – one of the cities that was washed away - mentions 1915 flood as the worst that his father used to talk about". Another source that they refer to is a report by Abélio José Estives a former colonial administrator in Chibuto – a town on a hill overlooking the Limpopo 60 km downstream from Chokwé – who also mentions the 1915 flood as being the worst by then. Further, they refer to a South African engineer and flood historian Dirk van Blanderen, whose records go back to 1893 and 1894 heavy rains that caused serious floods in northeast South Africa. The Limpopo River appears to have reliable historical records on water levels, especially at Xai-Xai city where in February 2000 the water in the worst case went up to 4.7 meters above the flood level. Figure 1 below illustrates a chart of the water level of Limpopo basin at Xai-Xai, whose measurements have been taken since 1915.

The above chart illustrates how often floods of a certain magnitude use to happen at the Mozambique Limpopo Basin. From this chart we can see that the magnitude floods assume different king of scale. And in order to reinforce the assumptions given by different sources who classify the year 2000 floods as a kind of a 100 to 150 years flood case and comparing the 1977 floods to the ones from 1915, which are ranked as kind of 50 years flood and finally the others assumed as regular for 10 years to 20 years ranking floods, figure 1 gives such overview. Taking this into consideration means that the 2000 floods might occur once every 100 or 150 years, while others might occur once every 50 and or every 10 to 20 years respectively. This kind of analysis facilitates to create environmental stochasticity models of catastrophes, what should be part of the proposed integrated techniques.

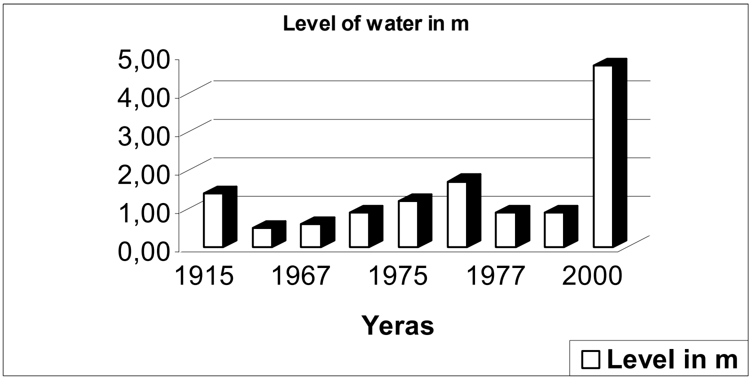

Figure 1: Level of floodwater at Xai-Xai City (Limpopo River) (source: adapted from Christie and Hanlon [8]).

The idea behind this approach is based on the author's mental model that aggregates different critical thinking in regard to natural disasters as part of sustainable development of the country. Sustainable development is a development strategy that manages all assets, natural resources, and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being. Sustainable develop, as a goal rejects policies and practices that support current living standards by depleting the productive base, including natural resources, and that leaves future generations with poorer prospects and greater risk than our own. (Repetto [4]). This is achievable through the development of a sustainable planning as part of holistic approach such as integrated technique model.

2 Current legislation and vulnerability

2.1 The INGC

The National Institute for Disasters Management (INGC) is the Mozambique's legal entity responsible for planning, implementation, coordination and control of all issues and policies regarding disaster management. The INGC is an autonomous entity under the Council of Ministers representing the Coordinative Council for Natural Disasters a multisectoral unit. The main objectives of the INGC are:

- To integrate the disasters prevention process in the process of national development.
- To promote national and international solidarity in case of disasters.
- To guarantee efficient coordination and active societal participation in the process of disasters management.
- To contribute for maintenance of safe environment.
- To promote a regional and international coordination of disaster management especially those from neighborhoods.

- Take preventive measures in order to avoid human and property losses from both manmade and natural disasters.
- To conceive a legal frame, plans and norms for the development of efficient standards in the process of disasters management.
- To guarantee the implementation of disasters management policy through the national plan of disaster management, contingency plans and others intersectoral mechanisms.

At the present moment, the INGC developed a national disaster policy, which frames the management process national wide; this appears to be the main tool for disaster risk management, integrating actions from the main national institutions dealing with environmental issues. Nevertheless, comparing the national policy and those from other vulnerable countries such as the Philippines and Bangladesh it appears to be weak in both size and contents, therefore the need to propose a more integrative approach in the process of developing response techniques in case of emergencies.

2.2 Vulnerability and disasters

"*Natural disasters are generally considered as a coincidence between natural hazards (such as flood, cyclone, earthquake and drought) and conditions of vulnerability. There is a high risk of disaster when one or more natural hazards occur in a vulnerable situation*" (Maskrey, A.).

The terms "vulnerable" and "vulnerability" have been turning up more frequently beginning in the 1980s in the context of disaster literature. Liverman (Ferranti and Perry [9]) have identified dozens of authors using the term and related ones such as resilience, marginality, susceptibility, adaptability, fragility, and risk. According to (Wisner [10]) the development of the these concepts are welcomed and show that increasing number of people recognizing the importance of distinguishing physical hazards from the importance the disasters that someone follow.

Vulnerability is also partly the manifestation of human tendency to defy hazard – by necessity (lack of alternatives), by default (ignorance) or by willfulness (desire to take risks). It is essentially a deterministic property, whereas risk can be viewed more in terms of probabilities, although actuaries would tell us that these are sufficiently estimable to be far from purely random. The vulnerability of those who take the risk can be represented by a mathematical model by which choices among actions are made. This model is based on the notion that a "rational" man can express his preference between two payoffs in a method that is consistent with certain axioms. We show that the value to himself of a payoff may be expressed as a numerical function of the payoffs, called a utility, and that preference between actions giving him a probability distribution over payoffs is based on the expected value of the utility of the action.

Let M denote the set of payoffs of the choice and let M* denote the set of all probability distributions over M that give all their mass to only a finite number of points of M. we use P, P_1, P_2 and so on, to denote payoffs (that is, elements of M) and p, q, p_1, p_2 , and so on to denote elements of M*.

The only properties used here are

(a) M* is closed under convex linear combinations,

$$(that \quad is\, p_1, \in M^* and \quad p_2 \in M^* imply \quad \pi p_1 + (1-\pi) p_2 \in M^* 0 \le \pi \le 1),$$

(b) all degenerate probability distributions belong to M*. we can enlarge M* to contain continuous distributions, for example, provided that these two conditions are still satisfied (Ferguson [7]).

Definition 1: A preference pattern or a preference relation on M* is a linear ordering, $\le$, for M*; that is (a) (linearity) if p_1 *and* $p_2 \in M^*$ then their $p_1 \le p_2$ *or* $p_2 \le p_1$ (or both), (b) (transitivity) if p_1, p_2 *and* $p_3 \in M^*$, and if $p_1 \le p_2$ and $p_2 \le p_3$ then $p_1 \le p_3$.

Definition 2: if A utility on M* is a real valued function, u, defined on M*, which is linear on M*; that is, if p_1 *and* $p_2 \in M^*$ *and* $0 \le \lambda \le 1$, then

$$u(\lambda p_1 + (1-\lambda) p_2) = \lambda u(p_1) + (1-\lambda) u(p_2) \tag{1}$$

If a function u satisfies (1), it follows by induction that $p_i \in M^*$ and $\lambda_i \ge 0$ for $i = 1,...,n$, with $\sum_1^n \lambda_i = 1$, then

$$u(\sum_{i=1}^{n} \lambda_i p_i) = \sum_{i=1}^{n} \lambda_i u(p_i) \tag{2}$$

Definition 3: A preference pattern, $\le$, and a utility, u, on M* are said to agree if for all p_i *and* $p_2 \in M^*$. $p_1 \le p_2$ if, and only if, $u(p_1) \le u(p_2)$.

If $P_1, P_2, ..., P_k$ are elements of M, and $f_1, f_2, ..., f_k$ are nonnegative numbers whose sum is one, we shall use the notation $(f_1 P_1, f_2 P_2, ..., f_k P_k)$ to denote that element of M* which chooses payoff P_1 with probability f_1 payoff P_2 with probability f_2, …, and payoff P_k with probability f_k. If we define for each $P \in M, h(p) = u(1P)$ for a given utility u, then

$$u((f_1 P_1, f_2 P_2, ..., f_k P_k)) = \sum_{i=1}^{k} f_i h(P_i) \tag{3}$$

Which is simply the expected value of the function *h* using the distribution $(f_1 P_1, f_2 P_2, ..., f_k P_k)$. Thus, if exists a utility, *u*, which agrees with a person's preference pattern, $\le$, that person will act as if he wished to minimize the expected value of the function *h*. Hence we can see from the above eqns. (1), (2) and (3) that vulnerability, to some extent, is a function of preference if we consider the situation where a person might lack opportunities or desire to take risk.

3 Risk management

Like any other management process, risk management comprises the main steps recommended for the managers such as planning, organizing, controlling and evaluating processes; i.e., it represents a set of structured actions to perceive and deal with natural hazards risk before disaster occur. Based on (Melcher [11]) and the IIASA modeling concepts the application of risk management used in the study comprises: prevention, mitigation, preparedness, response, rehabilitation, and reconstruction. Within this approach, it considers as essential the analysis of risks as the basis to identify and define appropriate measures for reducing risks. The understanding of these elements, as well as the concept of strengthening of capacities in this area is based on the definitions contained in the wide literature both about natural disasters and risk management. According to Melcher [11] Risk management in general can be characterized by the following:
"Risk management is the systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, assessing and monitoring risk. For any organization, whether a large corporation, a government agency, or a family farm, risk management is, or should be, an integral part of good management. It is a continuous, adaptive process that needs to be integrated into all relevant aspects of the decision-making procedures of the organization".

Another definition by (Smith [12]): "*Risk Management means reducing the threats to life and property (and environment) posed by known hazards, whist simultaneously accepting unmanageable risks and maximizing any associated benefits*". Disaster management encompasses a variety of measures taken into account before, during and after an event has strike, this represents both concepts of risk management ex-ante and post-event as normally is referred on the contextual literature; this denotes the process of dealing with issue of dealing with both causes and effects of disaster risks (Melcher [11]).

3.1 Pre-disasters phase

The pre-disaster phase is composed by four main steps namely, the risk identification, risk mitigation, risk transfer and risk preparedness. Different institutions and other written sources have established their own framework according to a type of disasters and the surrounding environmental hazards. According to the INGC objectives, this is the decisive phase for all disasters risk management.

Risk identification composes the process of assessment, vulnerability and risk analysis, aiming to facilitate the process of location likely vulnerable zones and the time of possible occurrence of risk in advance.

Mitigation is one of the most popular words in the context of risk management and means to take actions in advance toward the process of eliminate, or avoid risk and its consequences. This process is composed by reinforcing structural engineering measures or usage of hazard-resistant design in one hand. On another hand this process can be carried out by creating a new mindset to people toward living with disaster, devising land-use measures that increase environmental degradation (Kreimer and Munasinghe [13]). One important aspect on risk awareness is risk communication. Preventive risk communication can into play in the period between public awareness of existence of risk and the actual occurrence of any hazardous incident as a result of that risk. The flow of messages that might create the awareness say at certain communication center, with intensity λ might be given by the following formula:

$$P_t(k) = (\lambda t)^k e^{-\lambda t} / k! \qquad (4)$$

The flow defined by the above formula is based on Poisson Formula and the reader can verify that it is stationery, i.e. the probability to run k events in a certain time interval t will depend only on both k and t. assuming k=0 and k-1 we can calculate the probabilities of none event and exactly one event respectively: $P_t(0) = e^{-\lambda t}, P_t(1) = \lambda t e^{-\lambda t}$ Consequently, the probability of an event to run more than once will be given by:

$$P_t(k > 1) = 1 - [P_t(0) + P_t(1)] = 1 - [e^{-\lambda t} + \lambda t e^{-\lambda t}] \qquad (5)$$

Using $e^{-\lambda t} = 1 - \lambda t + (\lambda t)^2 / 2! - \dots$ this leads to the following situation, $P_t(k > 1) = (\lambda t)^2 / 2 + \dots$. By comparing $P_t(1)\, and \quad P_t(k > 1)$ we deduct that, for small values of t, the probability to run more than one event to is minimum compared to that of running one event, therefore the flow also is ordinary. This means in a minimum time interval can run not more than one event. From that we can conclude that Poisson eqn. (1) gives a mathematical model for an elementary flow of events, such as calls for emergency responses.

Risk transfer (insurance and reinsurance) is one of the most effective tools in the context of risk management. This consist on ones who can not handle the risk under a certain set of conditions" options and rights" agrees with another agent who can assume the responsibility to assume the all consequences or part of them, in case a disaster strike. This is the scenario recommended for the natural disasters risk management in developing countries where there is lack of quick mechanism of recovering and as a result the programmed investments are diverted to recovering programs. Unfortunately, this concept is not applied for natural disaster in Mozambique given the level of exposure to extreme events. Managers of the five insurance companies existing in the country decline to assume the risk, as the probability of asset damages from natural disasters is almost certain. i.e. it is equal to one.

Preparedness means to create the appropriate conditions and mechanism to deal with an unlikely event in case it strikes. In the context of natural disaster management preparedness involves the whole process of creating facilities for an emergency response before a disaster strike. Building barriers along rivers, people training through development of emergency plans, evacuation simulations, early warming and shelters are part of the risk preparedness components.

3.2 Post-disaster phase

Actions that are taken after an unlikely event occurred characterize the pos-disaster phase. Normally, this is the phase where the affected areas cannot cope with local initiatives, therefore there is an unusual demand of resources, human, financial and material needed to support the emergency situations.

Post-disaster phase aggregates main phases, namely the emergency response and the reconstruction and rehabilitation process. Rehabilitation and reconstruction starts early with the recovering program, just after a disaster have occurred. Quite number of examples can be listed just to illustrate this fact. The Xai-Xai city at Gaza Province in Mozambique was washed away by the 2000 floods, but rehabilitations effort that took place just after the water was clean enabled to get life back on track. The Asia Tsunami are among many natural disasters, whose international response were to reallocate the affected people by the re establishment of basic infrastructure for such purpose. Those are just representative actions that show how important is this part of pos-disaster phase, characterized by rehabilitation and reconstruction.

4 Findings and conclusions

From the analysis of the above discussions we can conclude that given the exposure of the country to natural hazards there is a need to develop a more integrative model: Models can be defined to be purposeful representation o reality. Mozambique needs a combined planning effort at the regional level in order to cope with natural hazards.

From the sustainable planning point of view we propose that the INGC should combine more effort integrating as much as possible stakeholders in the process of both manmade and natural disaster risk management, combining the normal process of risk management and additional tools such a scientific research, stakeholder participatory and promote insurance policies. Also there is a need of capacity building development process to the exposed people in order to build a new mindset on how to deal and live with disasters.

Finally, the academic institutions should be empowered and oriented to a oriented more research process in the field of disaster management together with other institutions that deal with disaster risk management. A recommended risk management system should de one that combines all approaches that fit in the process, hence an integrated risk response to emergency situations.

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