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Natural disasters: acts of God, nature or society? On the social relation to natural hazards

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Abstract

Natural disasters are characterised by complex relationships and interactions between physical hazards and society. These, as well as local context, cultural aspects, social and political activities, and economic concerns, present difficulties in practical application of mitigation concepts and models.
This paper outlines general approaches in natural risk assessment and gives an insight into the contextual dynamics surrounding a hazard event. Since precise measurement of uncertainties and exact prediction of damages is hardly feasible, the incorporation of a hazard of place concept in vulnerability assessment is proposed. Qualities that determine potential damage are identified and characteristics described. It is suggested that, even without assessing risk exactly, vulnerability reduction decreases damages and losses. The chosen perspective illustrates that natural disasters are a result of social decision processes rather than acts of God or nature.

Introduction

We begin our discussion with the words of David Okrent – professor of engineering and applied science at the University of California – to introduce central conceptions in risk assessment. His comment on societal risk is based on testimony he presented on 25 July 1979 to the Subcommittee on Science, Research, and Technology, U.S. House of Representatives, thus four months after Three Mile Island accident:

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"The terms 'hazard' and 'risk' can be used in various ways. Their usage in this article is defined by the following simple example: Three people crossing the Atlantic in a rowboat face a hazard of drowning. The maximum societal hazard in this case is three deaths. Three hundred people crossing the Atlantic in an ocean liner face the same hazard of drowning, but the maximum societal hazard is 300 deaths. The risk to each individual per crossing is given by the probability of the occurrence of an accident in which he or she drowns. The risk to society is given by the size of the societal hazard multiplied by the probability of the hazard. Clearly the hazard is the same for each individual, but the risk is greater for the individuals in the rowboat than in the ocean liner" (Okrent [1]). We will not elaborate on Okrent's lecture about a national approach to risk management. However, we will use his example to illustrate our usage of terms and our approach.

Since Okrent's statement, the field of risk studies has moved significantly away from the 'engineering-physical' paradigm towards incorporating perspectives from a range of disciplines. With some delay, European physical science literature and, as a consequence, civil protection practice have begun to place emphasis on social variables, such as preparedness, non-structural mitigation measures, regional planning, and vulnerability. However, a major problem is the complex and multifaceted character of the hazard and disaster management 'community'. Within the European Union the organisers of the International Conference on Natural Risks and Civil Protection [2] consciously attempted to encourage informed dialogue across countries, disciplines and professional boundaries. But this praiseworthy type of initiative is often accompanied by frustration and disappointment among participants: "For the latter (physical scientists) the risk is the probability of damage or loss of life and property. It was surprising to discover that the probability of occurrence of a dangerous event is not considered in the definition of hazard presented at the conference by the social scientists. This implies a big difference in the overall approach to risk mitigation, especially in people's education and risk communication" (Barberi [3]). This may be due to differences in use of language, in underlying approaches and conceptualisation, and in attitudes towards scientific, social, and political questions between stakeholders, civil protection practitioners, social and physical scientists.

Studies have demonstrated that the question "row boat or ocean liner" is insufficient for reducing loss and damage. The 'probability concept' based on factors such as hazard and exposure is more hazard analysis than risk assessment. General intra-disciplinary approaches are not capable of seizing all characteristics of natural disasters, involving many social, economic, political, technological, organisational, and physical factors. The complex nature and structure of natural disasters, therefore, transcend the 'exact' methods associated with traditional 'hard' sciences. In order to take into account all

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these factors, high levels of complexity and uncertainty, 'softer' and more flexible methods and tools are required.

Obviously, there is a need for better understanding, building trust, and co-operation in this multidisciplinary enterprise. Consequently, it would seem logical to begin clarifying and distinguishing some central terms and concepts. Approaches presented make evident that the problems in disaster management are multilayered, disordered, and characterised by uncertainty. Thus, as a preliminary attempt, an easily intelligible and – more important – applicable conceptual approach is described which should help to increase resilience, reduce vulnerability, and minimise the effects of natural disasters for communities. The approach is also relevant for less obvious undertakings, such as environmental impact studies, in which the effect of human actions on hazard and risk is an important issue. The approach should provide a better basis for the incorporation of the multitude of relevant factors in such studies.

Theoretical framework

Central terms and definitions

The authors' intention is not to make a terminological proposal; but before discussing these issues, we need a common set of definitions for the terms used in this paper. For that purpose we return to Okrant's example illustrating both central idioms and theoretical framework. Since we focus on natural hazards we assume that a physical process, such as the wind, is responsible for drowning. We can distinguish a physical process from a natural event by defining the latter as an uncertain but somewhat predictable natural process within a specific period of time in a given area. The event is regarded as a resource or as a hazard. The line of distinction is a flexible threshold that depends on factors such as experience and socio-economic conditions. Consequently, by natural hazard we mean a natural event in a given area, settled by people, which is regarded as potentially damaging to human life and property. The factor 'exposure' describes all individuals, social structure, and material elements being exposed to a specific natural hazard.

A first step towards natural hazard assessment lies in listing and qualitatively mapping natural hazards. Thereafter we can try to assess quantitatively both physical processes and exposure. A possible hazard assessment applied to Okrant's example would be: this type of boat occupied by three people will overturn at wind force 8 and wave height 5m.

As we know, the way in which physical processes impact on society is the result of a great variety of factors: socio-economic, psychological, and cultural. Thus, we consider some other factors without assessing the risk of drowning, in the first place preparedness. By preparedness we mean all precautionary activities and measures in a given area, which enable society to respond rapidly and effectively to disaster situations. Coming back to Okrant,

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we must consider if there are lifeboats and life-vests on board, or the existence of educational activities and measures (boarding only under the condition that the passenger can swim or the requirement of specific navigation licences for the captain to navigate certain waterways).

Closely connected to this is prevention. Hereby we understand all activities and measures in advance of a disaster designed to prevent natural hazards and their effects, and to provide permanent protection from their impacts. A distinction could be made between structural and non-structural prevention measures that can refer to both physical processes and their consequences. Examples of the former would be special hull constructions, installation of stabilisers, and lighthouses. Examples of non-structural measures are the preventive striking of sails or insurance – which incidentally has its origin in merchant navigation (e.g. the term 'free alongside ship').

All activities and measures taken in advance of a natural hazard event aimed at decreasing or eliminating its impact on society and environment can be named *mitigation*. This is the result of hazard analysis, preparedness, and prevention. An additional factor necessary for assessing risks is response. Hereby we mean all activities and measures taken immediately prior to and following disaster to reduce impacts and to recover and reconstruct an area affected by a disaster. The main components of response – also important for Okrant's shipwrecked people – are rescue and relief, humanitarian assistance, and recovery and reconstruction.

Probably the most important factor in risk assessment is vulnerability to hazard. However, there is confusion regarding its meaning, its measurement, and the causes of spatial outcomes associated with vulnerability studies [4]. Before outlining our concept we need to define this central expression. By vulnerability we mean the condition of a given area with respect to hazard, exposure, preparedness, prevention, and response characteristics to cope with specific natural hazards. It is a measure of the capability of this set of elements to withstand events of a certain physical character. Consequently, returning to Okrant's example, we need to analyse and assess these parameters in order to value the vulnerability of our boat or its crew to specific wind forces and wave heights.

General approaches

The original impetus in risk assessment came from the pioneering effort of Starr [5] to answer today's well known question, "How safe is safe enough?" His 'revealed preference' approach assumed that, by trial and error, society has arrived at an 'essentially optimum' balance between the risks and benefits associated with any activity. One may therefore use historical or current risk and benefit data to reveal patterns of 'acceptable' risk-benefit trade-offs. The subsequent 'formal-normative' efforts towards an 'objective' assessment of a 'subjective' risk, risk comparisons, and conventional definition of risk turned

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out to be ineffective and less satisfying. Following previous examples: a specific type of boat may have better qualities of stability; however, one cannot determine a reliable risk of drowning.

Psychological-cognitive approaches (studies in risk perception resulting in 'expressed preferences' [6]) have shown that individuals do have preferences for or aversions to specific types of boats; and these are not necessarily in accordance with qualities of stability or safety. However, perception and assessment of shipwreck disasters convey underlying preparedness and prevention, but, to a large extent, discard the risk of drowning. Cultural-social approaches have illustrated spatial and temporal differences in risk assessment [7]: depending on society and culture, navigation can be an indispensable basis of subsistence or rejected due to religious reasons. Risk communication may help us to convince passengers to choose a specific type of boat or induce them to take up mitigation measures. However, it will not avoid the capsizing of a boat. Overall social perspectives, for instance chosen by Luhmann [8], have made clear: there is a danger of a ship overturning; whoever goes aboard takes the risk of drowning. Furthermore, we know that the use of storm warning systems create new risks; Geenen [9] thoroughly demonstrated that, although the forecasting of a hazard event partly transforms danger into risk, it can imply a gain in social security.

For over 50 years, geography has focused on various questions and dimensions of hazards [10]; more recent studies [11] and models [12] have especially underlined the social context that surrounds hazards. Regarding our example, the overall context and social embedding of the Titanic was crucial in the extent of magnitude of the disaster. The crew, considered as experienced and skilled, made mistakes that were not foreseen. The ocean liner, supposed to be unsinkable, had shortcomings, which turned out to be fatal. Survival chances for shipwrecked people were severely limited by the water temperature in the North Atlantic, and not by, for example, the presence of sharks, as could have been the case in another area. Passengers' chances of survival were also affected by their social status, since the price of a ticket indirectly determined the distance to a lifeboat. Is the decrease of preparedness measures compensated by the newest ship control and navigation techniques? Do these techniques fail during the rise of a storm? These remarks and questions illustrate the way in which the manifestation of a disaster may vary according to its context.

Throughout time, people have dealt with the most of the phenomena that we now call risk by explaining them as acts of God, luck, fortune, or fate. However, the physical processes were the same but natural-mystical way of thinking determined awareness; natural disasters interpreted as 'acts of God' paralysed scientific arguments, prevention and technical measures. As God was losing ground the long predominant theological approach to explain natural phenomena was replaced by scientific descriptions. Today, many sociologists refer to natural disasters as social rather than natural phenomena.

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Following the system theory, we could even define disaster as *information that triggers code-specific operations and cause output losses in a given area* (in the case of natural disasters, nature triggered and caused these effects).

However, the overall damage due to natural hazards is the result both of natural events that act as 'triggers', and a series of societal factors. In practice, there is only a fine line between resources and hazards, between water out of control (flood hazard) and water under control (reservoir resource). The Chinese word for risk *weijji* combines both characters meaning 'opportunity' and 'danger' to imply that uncertainty always involves some balance between profit and loss. These uncertainties involved in the assessment of both natural and human factors makes a precise determination of risk (in the sense of Okrent) practically impossible.

Moreover, as the aim of risk assessment is to provide the basis for damage reduction, the precise measure of risks (prediction of damages) might not be necessary, or even important. The crucial point, in our opinion, is to identify which areas are subject to different levels of potential damages and which factors determine such damages. This, in turn, can be used to identify the actions that must be taken to reduce future damages, even if we cannot quantify them exactly. Disaster mitigation is a social rather than a biophysical process. This is underlined by some hard facts which should complement the theoretical approaches: according to the World Bank, the per capita cost of natural disasters in relation to GDP is at least 20 times higher in developing than in developed countries; up to 95 per cent of recent disaster casualties have occurred in poor countries; and, world-wide, only one dollar is spent on prevention for every $100 spent on rescue efforts [13].

It has been argued that an exact determination and assessment of the risk of drowning for individual ship's passengers is not feasible. We are not able to determine exactly how many people out of the three hundred on the ocean liner and how many out of the three on the rowboat will drown. But this is not crucial, since our intention is the derivation of specific measures to avoid the capsizing of a ship or at least reduce its consequences; the appropriate measures can be identified by determining indicators, assessing valid parameters, and considering different scenarios. Indeed, the question "rowboat or ocean liner" remains for the analysis of exposure, but in addition to this we want to know: How many non-swimmers are on board and how many have had shipwreck experience? What is the temperature of the water? How long will it take for assistance to arrive after the event? Is the ship equipped with warning systems? It is assumed that if we try to determine and assess the mentioned factors (i.e. vulnerability assessment), then use these findings to modify hazard, exposure, preparedness, prevention, and response in a way that reduces vulnerability, we certainly can reduce the risk of shipwreck and corresponding negative consequences.

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Vulnerability as hazard of place

Vulnerability studies mostly examine the source of biophysical or technological hazards (vulnerability as pre-existing condition) or focus on coping responses, societal resistance and resilience to hazards (vulnerability as tempered response) [4]. The proposed concept combines elements of the two, thus both geographic and social space are seized. Modifying Starr's question by asking 'How vulnerable is safe enough?' we conceive vulnerability as both a biophysical hazard as well as a social response within a specific geographic domain. Since hazards affect spaces, we try to find indicators, which allow assessing the degree of vulnerability of a given area: biophysical, technical, and social vulnerability.

The approach presented below is an attempt to identify 'qualities' or 'factors' which determine potential damage and characteristics that are relevant for defining the 'values' of individual 'factors'. Each characteristic is assessed by means of 'mapable' indicators which, obviously, vary according to the scale of the analysis.

Conceptual approach and preliminary investigation

The approach proposed is structured as a sequence of steps that consider each one of the factors that constitute vulnerability (Fig. 1). Each of these steps results in a map representing the factor considered.

Vulnerability is determined through the overlay of the former maps. The resulting vulnerability map can be described as a natural hazard map, which shows the degree of ability to cope with and respond to specific natural hazard events. 'Average class values' obtained are based on the assumption that all factors are equally important. Since this map is based on the previous maps, indicators are the same as the ones used for the hazard, socio-economic, exposure, preparedness, prevention, and response maps.

The vulnerability map (Fig. 2) shows a number of areas that are uniform with respect to the 'value' of the considered factors. Inside each uniform area a synthesis of values from the previous maps is given, which gives an impression of the overall vulnerability of the unit. The values that contribute to this synthesis are shown as a sub-index for each area. Thus, each uniform area in

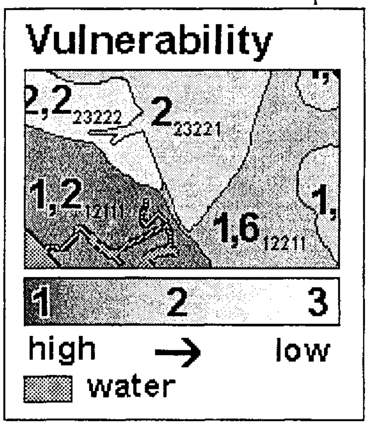

Figure 2: Example of the Vulnerability map

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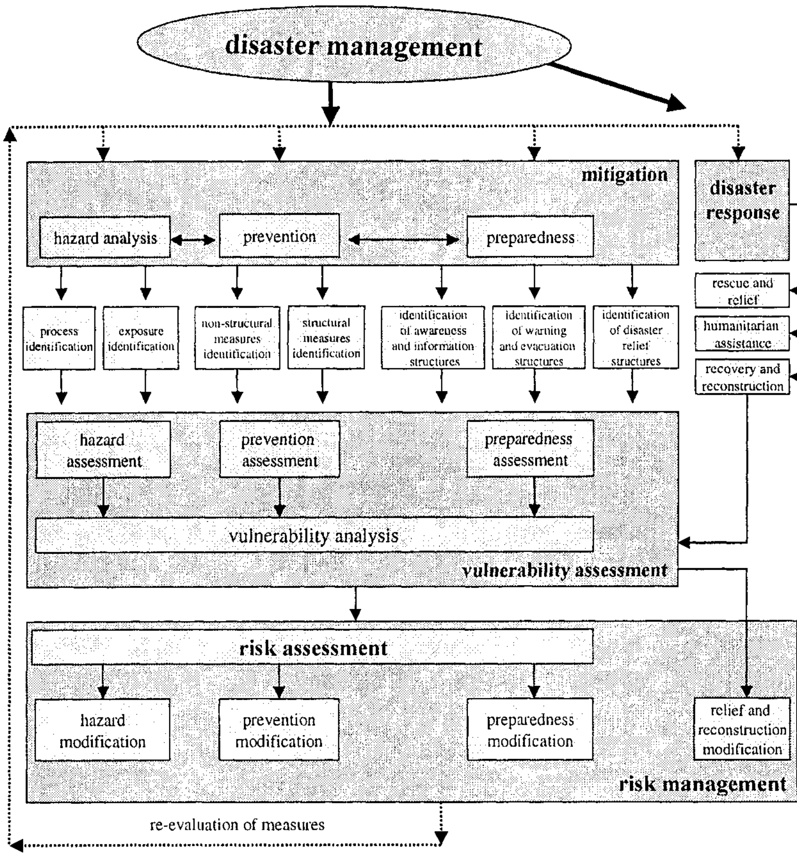

Figure 1: Natural disaster management process

the vulnerability map has a 'vulnerability class' and (as sub-indices) the corresponding values for hazard, exposure, preparedness, prevention, and response. Since each index corresponds to a specific factor, the vulnerability map shows not only the vulnerability of an area, but also refers to the reasons for that vulnerability. Consequently, if one desires to reduce the vulnerability of a particular area, the vulnerability map shows where changes could be introduced. E.g. if high vulnerability is caused mainly by low preparedness and high exposure, one can focus on these two factors in order to reduce vulnerability.

Although the approach shares a number of shortcomings with other approaches, mainly the impossibility to arrive at exact results, it has a number of important advantages.

In the first place, the approach is applicable; it is based on the assessment of a series of easy-to-determine factors or indicators, combined in a simple way through a series of clearly defined steps. The result of this

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combination is a 'measure' of vulnerability. A second advantage is that the approach is intelligible; no expert knowledge is needed for its comprehension. In this way a theoretical scientific framework can be linked more easily to concrete policy actions than is generally the case. Many theoretical approaches fail to link successfully to practice, which is vital in light of the ultimate goal of disaster management: reduction of damage to human life and property. A further advantage lies in the fact that the indicators for the larger part of the maps (with the exception of the hazard map) are expressed in binary form, which greatly facilitates the collection of necessary data. Furthermore, in the vulnerability map not only the degree of vulnerability is given, but also the cause of vulnerability. By means of a sub-index, the map interpreter is directed to a specific factor (hazard, exposure, preparedness, prevention, and response).

Although theoretically a combination of vulnerability maps for different hazards is possible, the interpretation of such a map would be much more difficult. Therefore, it is advisable to prepare a separate vulnerability map for each hazard considered.

Various conceptual and theoretical issues outlined in this paper can be incorporated. For instance, adequate prevention measures can be found more easily after vulnerable areas have been identified. Afterwards, cost-benefit-analysis can support more accurate the search for measures and the decision finding process. Furthermore, the hazard of place approach can facilitate a single or multihazards approach with differing hazard characteristics, contrasting contexts, and diverse methodological approaches [4]. The approach is also relevant for other studies such as EIA. In these studies hazard and risk are generally approached from a physical point of view, while social factors are largely ignored

Concluding remarks

The proposed approach places emphasis on vulnerability rather than risk in an attempt to synthesise physical and social factors into the implementation of natural risk assessment. Social scientific results are made spatially explicit (*pixelising the social*); physical hazard characteristics have been pushed beyond its biophysical dimensions (*socialising the pixel*).

The chosen perspective underlines the need for changes in public attitudes, behaviour, policy and practice. Communities must develop comprehensive on-going planning strategies that encompass all aspects of the natural hazard problem. Therefore, new approaches to hazard reduction which broaden the analytic focus to take account of the full range of interacting issues and problems that occur in modern societies have to be developed and applied. In conclusion, the approach suggests adapting the people to the hazard rather than adapting the hazard to the people.

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References

[1] Okrent, D. Comment on societal risk. *Science,* **208**, pp. 372-375, 1980.

[2] Horlick-Jones, T., Amendola, A. & Casale, R. (eds). *Natural Risk and Civil Protection*, E & FN Spon: London, 1995.

[3] Barberi, F. A perspective from the natural sciences. *Natural Risk and Civil Protection*, ed. T. Horlick-Jones, A. Amendola & R. Casale, E & FN Spon: London, pp. 533-534, 1995.

[4] Cutter, S.L. Vulnerability to environmental hazards. *Progress in Human Geography,* **20 (4)**, pp. 529-539, 1996.

[5] Starr, C. Social benefit versus technological risk. *Science,* **165**, pp. 1232-1238, 1969.

[6] Slovic, P., Fischhoff, B. & Lichtenstein, S. Facts and fears: understanding perceived risk. *Societal Risk Assessment. How safe is safe enough?*, ed. R.C. Schwing & W.A. Albers jr., Plenum: New York, pp. 181-216, 1980.

[7] Douglas, M. & Wildavsky, A. *Risk and culture: an essay on the selection of technological and environmental dangers*, University of California Press: Berkeley, 1982.

[8] Luhmann, N. (ed). *Soziologie des Risikos*, De Gruyter: Berlin and New York, 1991.

[9] Geenen, E.M. *Soziologie der Prognose von Erdbeben: Katastrophensoziologisches Technology Assessment am Beispiel der Türkei*, Duncker und Humblot: Berlin, 1995.

[10] Burton, I., Kates, R.W. & White, G.F. *The environment as hazard,* Oxford University Press: New York, 1978.

[11] Weichselgartner, J. Hochwasser als soziales Ereignis: Gesellschaftliche Faktoren einer Naturgefahr. *Hydrologie und Wasserbewirtschaftung*, **3**, pp. 122-131, 2000.

[12] Mitchell, J.K., Devine, N. & Jaeger, K. A contextual model of natural hazard. *Geographical Review,* **79 (4)**, pp. 391-409, 1989.

[13] Linnerooth-Bayer, J. & Amendola, A. Global change, natural disasters and loss sharing: issues of efficiency and equity. *Geneva Papers on Risk and Insurance*, **25 (2)**, pp. 203-219, 2000.