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Short Communication

Unifying and Broadening Views on Disaster Risk and Disaster Risk Management

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Abstract

In literature, disaster risk is usually depicted as a combination of a hazard, usually from nature, combined with vulnerability and exposure. A famous illustration of this is the fleur-de-lis, which can be found in almost all IPCC assessment reports. While such representations are easy to interpret, they fail when combined with a supposedly mathematical representation. This note shows that the usual representation, whether in the form of a figure or an equation, can be treated rigorously when two probabilities are present: the probability of a natural hazard occurring at a location where an anthropogenic hazard is present. In other words, the disaster risk is simply the product of the natural risk times the anthropogenic risk. Furthermore, the mathematical representation of a disaster risk proposed here is a guide for the implementation of disaster risk management measures.

Introduction

According to the disaster terminology established by the United Nations, [1] and centralized in the Sendai Framework measures, disaster risk is described as "*The potential loss of life, injury or destroyed or damaged assets that threatens a system, society or community in a given period, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity*", while the disaster is defined in the same terminology as follows: "*A serious disruption of the functioning of a community or society at any level due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, resulting in one or more of the following: human, material, economic and environmental losses and impacts*".

Another key point for this work is the semantic difference between Concept and Definition, which is generally not perceptible to risk managers. These terms are generally considered synonyms, although in reality there is a gap between them. A concept can be attributed to a local and temporal view, perhaps related to a specific culture and expressing a position that can be personal or of a group of people. This case fits perfectly with the concept of disaster. A disaster that claims thousands of lives in one part of the planet (severe disruption) may have little impact on those who live far away from that location. A definition is something that is not subject to spatial or temporal variation and can therefore be used to measure something objectively. Unlike the concept of catastrophe, Newton's definition of the "mass quantity" of a body is invariant. Any object that measures 1 kg at the location of the catastrophe presented above will have the same 1 kg at the location where the catastrophe was undersized. It is in this sense that the risk of disaster presented at the beginning of this session should be understood. Although it is written as "probability" (probabilistically determined), it does not cease to belong to the set of definitions that form the framework of mathematics. The theory of probabilities, developed in the 17th century by Pascal and Fermat [2], is essential to understanding catastrophic risk. In other words, although science has provided us with elements to understand risk for over 4 centuries, still resort to numbers or expressions without logical meaning to express risk. Of course, a mathematically rigorous formulation of risk does not guarantee that such an equation has an analytical solution. Nature, with its immense possibilities of modeled representations, is described by equations that are

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not and may never be solved analytically. I would like to focus on two simple examples: the complex, non-linear, coupled second-order Navier-Stokes equations and the simplicity of Heisenberg's uncertainty principle. Such expressions show us the limit of what can objectively be claimed about what these equations or principles describe.

In the following sessions, the mathematical rigor at the disposal, a vision that simplifies what disaster risk is presented. Although such a proposition may seem meaningless to those fixated on the usual standards of risk description, it expresses in a simple way that risk management is essentially the management of vulnerabilities or, as it is called here, anthropogenic hazards.

The classic view of disaster risk

The modern concept of risk only emerged with the transition from traditional to modern society [3]. The modern understanding of risk presupposes subjects or institutions that are responsible for their actions and that make decisions under conditions of apparent uncertainty. Some of these uncertainties can be measured or quantified probabilistically and are therefore more accurately referred to as "risks". Risk situations in human society can therefore be "managed" and risk has become a theoretical focus to reinforce a scientific and probability-based approach. The issue of risk raises concrete problems that require empirical investigations. However, these empirical investigations need to be structured by a theoretical framework, so it is not surprising that risk is studied in fields as diverse as mathematics and the natural sciences, but also psychology, economics, sociology, cultural studies, and philosophy. To illustrate how the academic fields view disaster risk, cited below are two of the most commonly used terms: the climate change view and the disaster risk reduction view.

IPCC view

The definition of 'risk' in the context of climate change impacts, in the IPCC Sixth Assessment Report has retained the notion of 'hazard' to describe the climatic driver of a risk [4]. This is consistent with the definition of 'hazard' and also focuses on the potential for negative consequences. For this reason, IPCC Working Group I has developed the more general concept of 'climatic impact driver' to provide information on "natural or human-induced climate events or trends that may have an impact (harmful or beneficial) on an element of society or ecosystems". However, according to the VI IPCC report, the disaster risk is described as follows [5]: "*The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species*".

DRR view

The UNDRR Global Assessment Report 2022 [6] emphasizes that risk creation exceeds risk reduction. Disasters, economic losses, and the underlying vulnerabilities that drive risk, such as poverty and inequality, are increasing, while ecosystems and biospheres are at risk of collapse. In addition, the Sendai Framework on Disaster Risk Reduction 2015–2030 focuses on strengthening measures that address all dimensions of disaster risk such as hazard, exposure, vulnerability, and coping capacity. In other words, it is these measures that will prevent the emergence of new risks and reduce existing risks. The Sendai Framework calls for the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political, and institutional measures as a pathway to resilience, as they improve response and recovery preparedness [7,8]. In this broader context, the UNDRR has adopted the terminology of disaster risk mentioned in the introduction to this article.

Describing the risk of disaster in mathematical terms

As mentioned above the possibility of expressing disaster risk in a mathematical relationship is explicitly mentioned in the current UNDRR terminology. Several authors express the above terminology, i.e. "probabilistically determined as a function of hazard, exposure, vulnerability, and capacity", to emphasize which elements are included in the definition.

The literature on catastrophes is full of expressions or supposed mathematical representations that conceptualize what can be defined. In a detailed overview, Vilagrán de Leon [9] presents a menu of available terms and shows different risk equations that highlight similarities and differences of the respective risk: Risk = hazard x vulnerability; Risk = (hazard x vulnerability) / (coping capacity); Risk = hazard x vulnerability x deficiencies in preparedness; Risk = hazard x vulnerability x exposure; Risk = hazard + vulnerability + exposure – coping capacities. These and similar formulas are often found in the literature. In the strict mathematical sense, however, they are meaningless, because in all these equations the only thing that can be expressed probabilistically under all circumstances is the occurrence of a hazard event.

Considering that probability is the measure of the likelihood of an event occurring in a chance experiment and is expressed as a number between zero and one, where zero stands for impossibility and one for certainty, now proposed is a new way of looking at each of the pretentious expressions examined by Vilagrán de Leon [9].

Firstly, let's understand that the definition of Disaster Risk adopted by UNDRR includes independent events. From a probabilistic perspective, two events are said to be independent of each other if the probability of one event occurring does not affect the probability of the other event occurring. In other words, the observations about one event, this does not affect the probability of the other. In this case, the probability of an event occurring that depends on two other independent events is equal to the product of the probability of the events separately. Thus, if a random event Ω is dependent on a random event α and another random event β, then the probability of Ω is written as:

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$$P(\Omega)=P(\alpha)\times P(\beta) \tag{1}$$

With this elementary representation, the risk of catastrophe should be written as follows:

$$P(D)=P(H)\times P(V)\times P(E)\times P(C) \tag{2}$$

H, V, E, and *C* stand for Hazard, Vulnerability, Exposure, and Capacity respectively, and are independent events. However, V, E, and C have something in common. They are anthropic constructs, while H is a contribution of nature. Therefore, it is proposed to combine these three terms into a single term in equation (2) and denote them with the letter *A*, which stands for anthropic.

$$P(D)=P(H)\times P(A) \tag{3}$$

The adoption of equation (3) emphasizes that the risk of a disaster is a combination of natural and human forcing factors.

Here, consider that the possible values of *P(H)* e *P(A)* are limited between [0;1] where 0 (zero) means that there is no risk and 1 (one) means that the event is certain. Thus, a disaster will occur if, and only if, *P(H)* = 1 and *P(A)* = 1 because for any other combination of these two terms *P(D)* < 1.

Finally, the question remains: What does this mean? Why is it necessary to write or emphasize these seemingly obvious things? From a conceptual point of view, there is no difference between this account and the one summarized by Vilagran de Leon. However, it is clear here that disaster risk is more than a concept. It is a definition and a combination of a natural and a man-made threat.

The above equation is also directly related to another term from the terminology of the Sendai Framework: disaster risk management. According to [1], disaster risk management is "*the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses*". However, simply looking at equation 4 allows us to take a different look at the "policies and strategies" for disaster risk reduction, i.e. the management of anthropogenic hazards.

For example, concerning the disasters that most affect countries [10] and are classified as hydrometeorological [11], risk management is understood as monitoring and warning of the occurrence of a potentially hazardous natural event. This includes the initiatives promoted by international organizations such as WMO and UNDRR, known as EW4ALL [12]. Such initiatives are necessary but not sufficient as they only address part of the equation. Natural hazards, such as a severe storm, can be detected and warned, but this is far from sufficient for risk management, especially as humans have no way of intervening in these events. In other words, disaster risk management means more than monitoring and alerting to natural events; it means managing anthropogenic threats. And here it is demonstrated, similar to a theorem, that "disasters are not natural".

Comment and conclusion

The formulation of disaster risk in the form of equation (3) is more than a mathematical formalism, because it expresses clearly and transparently what is implied in the title of Ilan Kelman's great book "Disaster by Choice" [13]. Disasters are the result of human action or inaction and can be summarized by the word vulnerability. Reducing risk, i.e. making the probability as low as possible or even zero, is achieved by reducing vulnerabilities, be they technological, as in Chernobyl, cultural, such as gender differences, political, such as governments denying climate change, infrastructural, such as poorly planned highways and cities, social, such as poverty, and many others that can be cited as examples.

Equation (3) also shows another essential component of Disaster Science, namely its multidisciplinary character. There has never been any doubt that monitoring an extreme precipitation event and the floods and flash floods it can cause is part of risk management and is linked to the natural sciences. However, this is only the first term on the left-hand side of the equation. The second term has to do with all other areas of knowledge. In other words, the simplicity of expressing disaster risk through a rigorous mathematical equation allows us to demonstrate implicit things explicitly.

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