Disaster Risk and Vulnerability: Concepts and Measurement of Human and Environmental Insecurity

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3.1 Introduction

Disaster risk management is a development strategy that is notably attracting the increasing concern of policymakers and the general public due to the current emphasis on various components of human and environmental security. From the scientific perspective, comprehension of disaster risk is often manifested by compartmentalization of knowledge; in contrast, from the political and social point of view, this situation leads to a fragmented concept of management. The result is decreased effectiveness in terms of disaster risk reduction and, thus, an integrative framework seems essential.

This chapter provides conceptual and methodological contributions as a general guide to a comprehensive risk management base regarding a holistic approach of disaster risk, given a special relevance to the concept and the different dimensions or components of vulnerability. They can be better understood within the notion of human and environmental security. The integration of an appropriate measurement of these individual and collective vulnerability dimensions enables a grasp of the risk complexity while demanding an interdisciplinary approach for the effectiveness of risk management.

The issues are treated below in four parts. First, a state-of-the-art discussion of risk and its theories from different disciplines is summarized to indicate certain difficulties encountered in the conceptualization of the notion of risk (3.2). Second, a conceptual framework of disaster risk is developed from an integrated approach (3.3). The third part focuses the discussion on the vulnerability concept and on its relevance on risk measurement to favour the awareness and the effectiveness of decision-making (3.4). The fourth session presents the territorial safety as the objective of disaster risk management; i.e. security for the society and for the ecosystem in the space of configurations based on their compatibility and the balance of their interactions (3.5).

3.2 Theories of Risk

Theoretical contributions on risk from different disciplinary perspectives may be classified in various categories including: a) process, analogue or systemic models; b) structural and cognitive explanations; c) interpretative representations; d) quantitative methods; and e) taxonomic frameworks.

The process model proposed by Rowe (1977) is widely used in the field of technological risk and toxicology. This approach suggests the existence of four stages: hazard identification, risk estimation, risk evaluation, and risk management. An example of an analogue model is provided by Covello, von Winterfeldt, and Slovic (1987) in an attempt to explain risk communication using signal theory. Palmlund (1992) proposed an analogue model with the classic structure of a Greek tragedy (with actors, scenario, drama, and roles) in order to explain the environmental tragedy from a political and social perspective. An example of a systemic model is provided by Kates (1971) from the human ecology school of thought. He describes the notion of adjustment to natural hazards considering the interactions between nature, humans, and technology. This model attempts to explain the dynamics of the interaction between the components, but does not necessarily provide information on the underlying causes of the process.

A classic contextual or structural explanation, where risk is seen as an attribute of social structures, is that proposed by Douglas and Wildavsky (1982). A cultural theory of risk is proposed by Rayner (1992). In this category, we may also include those approaches proposed by the political economy school, which may be considered constructivist. This is the case in the work of Westgate and O’Keefe (1976), Wi-
Systematic classifications (taxonomies) have also been used to provide order and structure for a range of phenomena and circumstances. Examples may be found in the classification of natural hazards proposed by Burton and Kates (1964), the classification of dangerous materials proposed by Slovic, Fischhoff and Lichtenstein (1985) and the vulnerability classifications developed by Wilches-Chaux (1989) and Aysan (1993). Many of these conceptual proposals have been published in the Journal of the Society of Risk Analysis, founded in 1980. This journal was inspired by concerns for technological risk in particular. However, many of the ideas put forward may be extrapolated to the field of risk associated with natural and socio-natural phenomena.

Finally, mention must be made of the postmodernist ideas put forward towards the end of the 20th century by social scientists such as Ulrich Beck, Niklas Luhmann, and Anthony Giddens. For these authors, risk is intimately linked to societal development and is influenced by the decision-making and communication processes that occur under the influence of current power relations (Muñoz-Carmona 1997). A theoretical proposal that attempts to integrate all of these categories can be found, for example, in the theory of the social amplification of risk proposed by Kasperson, Renn, Slovic, Brown, Emel, Goble, Kasperson and Ratick (1988). This attempts to lay out a causal process integrating the technical, social, cultural, and psychological dimensions of risk.

On a historical note, the first specialized research centre to be established on the topic of disaster was the Disaster Research Centre at Ohio State University, which built on the pioneering geographical research of Gilbert White and his collaborators at the University of Chicago. This centre was founded by sociologists, Enrico Quaranelli and Russell Dynes in 1963, and was later moved to the University of Delaware in 1985. Research here was concentrated on the social response to disaster and on post disaster recovery, following, in the first instance, analogies with response in case of nuclear attacks. However, the first centre to really study risk was the Centre for Technology, Environment, and Development (CENTED) at Clarke University. This centre was established by geographers Robert Kates and Roger Kasperson, and physicist, Christopher Hohenemser, in 1972. The centre concentrates on both natural and nuclear risks. Since then, at least six research centres were established in the USA in the 1970’s, and at least seven more during the 1980’s (Golding 1992). During the 1990’s, stimulated by the International Decade for Natural Disaster Reduction (IDNDR), innumerable centres and programmes dealing with risks and disasters were founded around the world. The topic gained popularity since then and it was increasingly recognized that the terms hazard, vulnerability, and risk have different meanings and implications from both the methodological and practical angles.

For many years the term risk was used to refer to what is today called hazard, and still currently many references are made to the word vulnerability as if it were the same thing as risk. Notwithstanding, on the whole, the enunciation of a risk notably implies a potential for loss; and when a hazard event occurs and the loss is substantial – as a result of the vulnerability degree of the exposed elements – the term normally used is disaster. In the vocabulary of the United Nations, a disaster is “a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope using only its own resources” (UNDHA 1992). Nowadays, the risk of a major disaster is also termed a major risk, (Harding/Romerio/Rossat/Wagner/Bertrand/Frischknecht/Laporte 2001).
3.2.1 Conceptual Approaches

The different approaches to risk concepts and evaluation are based, in general, on different disciplinary foundations. One can distinguish between two major approaches, namely the socio-technical approach which may be considered as having been derived from the applied sciences and economics, and the socio-cultural approaches derived from sociology, psychology, anthropology, and culture studies.

The socio-technical approach includes contributions by the natural and engineering sciences and is based on probabilistic estimation of risk. This approach is adopted in toxicology and epidemiology, the actuarial sciences and economics where cost-benefit comparisons are made. All these approaches are based on statistical prediction and on probability analysis. With reference to the socio-cultural vision, diverse social theories of risk may be identified and, as Ortwin Renn (1992) points out, there may be as many perspectives in sociology as there are sociologists. Renn classifies the theories in two categories, namely objectivist and constructivist. Moreover, the socio-cultural vision also covers psychological approaches which include psychometric analysis and the cultural school that bases its work on the analysis of groups and organizations. Unlike the socio-technical methods, socio-cultural approaches do not offer a common denominator for measuring the social and cultural acceptability of risk (Douglas 1985).

3.2.2 Objectivism and Constructivism

Probabilistic estimates of risk attempt to predict failures in the security of complicated technology systems, even where insufficient data are available on the system being analysed. Failure and event trees are used for the analysis, and the probability of failure of each component of the system is evaluated in a systematic fashion linking these to the structure of the system. This approach is useful for detecting deficiencies and for improving security levels in complex systems. The actuarial approach represents a classic example of objectivist approaches to the analysis of risk, where the base unit is an expected value that corresponds to the relative frequency of an average event in time.

Undesirable events are understood in terms of physical damage to persons and ecosystems. This may be observed and objectively measured with appropriate scientific methods. An application of this approach can be found in the case of predictions of road accidents for some future year. Results may be extrapolated from data on fatal accidents in previous years. The estimation of risk is reduced to a single dimension and is represented by an average in time, space, and context. Estimations of health and environmental risks basically use the same types of method.

The approach taken by economics transforms physical damage or other undesirable effects into subjective benefits. The base unit of these benefits describes the level of satisfaction associated with a possible action or transaction. An attempt is made to compare risks with benefits (Camerer/Kunreuther 1989). Since risks represent possible and not real costs it is necessary to relate them to the probability of occurrence of an event. Ultimately, what is sought is the use of resources in order to maximize benefits for society. Economic risk comprises a logical and coherent framework for situations where decisions have to be made by individuals and where decisions on loss are confined to the decision-maker’s immediate environment. Although the economic perspective permits a unidimensional measure of risk that supposes that the benefits and risks are commensurable, there are many factors that impede its use in risk management policies. These include: the problem of aggregating individual gains, the existence of variations between individual preferences, the problem of taking appropriate action to reduce future negative consequences, the impacts on third parties, and the notions of rationality and ethical considerations that the model is based on.

In general, such technical analysis provides society with a limited and narrow definition of desirable effects, reducing the possibilities to numeric probabilities based on relative frequencies. Unfortunately, the objectivity that is associated with such calculations, which may be seen as a virtue, can also lead to the serious problem of oversimplifying a complex phenomenon.

On the other hand, the psychological approach suggests that individuals respond according to their perception of risk and not according to objective risk levels and scientific evaluations of this. Such estimations are only taken into account by individuals to the extent that they are considered in the light of individual perceptions. This approach assigns importance to the beliefs people have regarding the possibility of the

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1 Field of mathematics that is directly related to risk evaluation using probabilistic (analytic) and statistical (data) models. The insurance industry has been based on actuarial studies since many years ago.
occurrence of an undesirable event. In this regard, the question arises as to whether perceptions are based on adequate information or rather, on biases and ignorance, which would make them very inadequate if they are to be used as criteria for decisions on risk reduction. From the point of view of many anthropologists and cultural sociologists, social responses to risk are determined by prototypes and cultural mores i.e. clusters of convictions related to different perceptions of reality. Seen from this perspective, environmental risks are considered to be purely social constructions.

3.2.3 Individualism and Structuralism

Individual and contextual models have been proposed by social scientists to explain social responses to risk. The individual model is largely based on psychology, whereas the contextual one is sociologically oriented. In the case of the individualist paradigm an attempt to understand group behaviour is made by studying individuals. An example of such models can be found in the “theory of knowledge and personality” (Wildavsky/Dake 1990). This offers an explanation of the cognitive response to risk, which is based on the knowledge, information, aversion or tolerance of risk that is characteristic of different personality types. Psychometric and risk perception theories are based on this type of paradigm, as are some economic models of risk based on the theory of expected gains to which Camerer and Kunreuther make reference (1989).

Theoretical development of risk perception commenced with the research of Tversky and Kahneman (1973, 1974). These authors were interested in the identification of factors that influence the probability estimations of persons. They concluded that when people face complex problems that involve probability and event frequency, they apply certain rules of judgment and heuristics in order to simplify the problem. These often lead to biases and value judgments. Later contributions by Slovic, Fischhoff, and Lichtenstein (1981) led to the psychometric and cognitive theory of risk perception, based on prediction of individual responses to certain activities, particularly those of a technological nature.

Through the contributions of cultural theory and structuralism an attempt has been made to advance the understanding of the ontological aspects of risk and of the connection between sociological variables and individual attitudes to risk. The ontology of risk refers to its metaphysical status as a property and quality of the physical world. This is a common supposition amongst those who promote the technical evaluation of risk. In the case of contextual approaches, the context is taken as a starting point. These models take into account the social structure, institutional forms, and culture. This approach has many variations, including those proposed by Rayner, Renn, Palmlund, Wynne, and Kasprowski, although the latter author avoids providing social factors with an ontological character (Krimsky/Golding 1992).

Structuralists and contextualists defend the position that risk is subjective and varies according to the context, criticizing attempts to give it an objective and measurable character. Cultural theorists have even gone as far as to criticize the psychometric paradigm indicating that risk is inevitably the result of a social process, even though it has some roots in nature. That is to say, they defend the position that the most appropriate approach to risk analysis is sociological and not psychological, given that risk is a social product (Thompson/Wildavsky 1982). The debate between individualism and contextualism can only be resolved if we find a reply to the difficult question as to whether personality precedes context or vice versa.

All concepts of risk have a common element: a distinction between reality and possibility. If the future were predetermined or independent of present human activities, the term risk would have no significance. If the distinction between reality and possibility is accepted, then the term risk could be defined as “the possibility that an undesirable state of reality (adverse effects) will occur as a result of natural events or human activities” (Luhmann 1990a). This definition means that humans can and do make causal connections between actions (or events) and effects, and that undesirable effects can be avoided or reduced if the causal events or actions are avoided or modified. According to this definition, risk is a descriptive concept (a representation) and, at the same time, takes a normative dimension. The definition of risk involves three elements: undesirable results, the possibility of occurrence, and a state of reality. All approaches to risk provide different conceptualizations of these three elements. These may be paraphrased in the following three questions: How may we specify and measure uncertainty? What are the undesirable results? What is the concept of reality we hold to? This helps us to distinguish between the different perspectives (Renn 1992).

The distinction between risk evaluation and risk reduction is of interest in this regard, since it has implications regarding the distinctions between science and political decision-making. If risk is seen as being
Conceptual Framework for Decision-making Effectiveness

Risk management is a crucial issue at both the scientific and political contexts, but the concept of risk is a polysemous notion. Psychologists, sociologists, and historians generally consider risk as a social phenomenon. This approach may be termed as constructivist.

From this perspective, understanding of risk requires knowledge of individual perceptions and social representations, and of the interactions between the different social actors. On the other hand, engineers, geologists, geographers, economists, and epidemiologists generally adopt an approach that may be described as realist or objective, based on the hypothesis that risk can be quantified or objectively assessed. The same dichotomy of subjective vs. objective features has been inherent to the security concept.

In addition, the enunciation of risk, like security and insecurity, is performative; a situation is described as safe, or on the contrary risky, to attribute a positive or negative value to it and to begin to act. It is precisely in this respect that risk, security, and insecurity can be considered performative – or normative – notions. Furthermore, with regard to the notion of environmental and human security, to speak of insecurity is also to suggest a threat to security – always potentially menaced by crisis or disaster – and the risk one takes in according or refusing trust to the systems that organize the social context. The relationship between environmental and human security and risk involves the idea of threat. A hazard is only considered a risk when there is a threat to exposed elements. Thus the components of security provide a framework for analysis of the vulnerability – and of the resilience – of each element at risk in a hazard prone territory, (Harding/Romerio/Rossiaux/Wagner/Bertrand/Frischknecht/Laporte 2001).

Therefore, the antagonism between the objectivist and constructivist paradigms must be transcended, and more confidence must be placed in both qualitative and quantitative methods. Action and decision, implicit in the definition of risk, require a compromise between subjective risk perception and the scientific need for objective measurement. While the objective approach lacks the social dimension, which is an important consideration when assessing disasters, subjective definitions are equally unsatisfactory, since they imply that risk is a matter of personal interpretation only. This position is totally inoperable when intervention in risk becomes a must from the public policy angle. That is the reason why there is a need for a common language and a holistic theory of risk from an interdisciplinary perspective and based on the approach of the complex dynamic systems (Cardona 2004).
3.3.1 Differences between Risk and Disaster

Risk is not synonymous of catastrophe (Beck 2007, 2008); risk means the possibility of future disaster. The term disaster risk suggests that there is a possibility that a dangerous phenomenon or event will occur and that there are exposed elements predisposed or susceptible to being affected. The reduction of risk, therefore, means the reduction of the possibility of future disaster. Hence, disaster is a social context or process, triggered by a natural, technological or anthropogenic phenomenon, which in interaction with a susceptible medium causes intense alterations in the normal functioning of the community. These alterations may be expressed, amongst other things, as loss of life, serious health problems, damage or destruction of individual and collective goods, or severe damage to the environment. For this reason, rapid response is required in order to restore the well-being of affected persons or ecosystems and to re-establish adequate levels of normality. Disaster implies loss and damage, and consequential impacts that the affected community is unable to absorb or to cushion the effects and recover using its own resources and reserves. This suggests that there are levels and types of loss and damage that do not signify disaster for society. Disaster is a given situation, a product that is tangible and measurable.

Disaster supposes the prior existence of determined risk conditions. That is to say, disaster is the materialization of pre-existing risk. On the other hand, when defined as the probability of future loss, a disaster can be explained by the prior existence of a latent threat and certain intrinsic or constructed characteristics of society that predispose it to suffer determined levels of damage. Disaster risk may be considered a collective or public risk. It is the type of risk which signifies a threat to all members of the prone community. Once this risk is recognized as such by the community something must be done about it. Commitment by public and private institutions and the community itself becomes a must. But, collective risk supposes a series of interdependent, dynamic, and uncertain problems that require collective action in order to solve them. Unfortunately, it is not uncommon for communities that are exposed to and aware of dangerous phenomena to do nothing about it due to resource restrictions, or because perception of the danger is insufficient to stimulate collective action. On occasions, some community members are conscious of the danger and carry out individual actions to reduce it, but the community as a whole still remains vulnerable. The risk level of a society is related to its development level and the ability to modify the risk factors that affect it. In this sense, disasters may be considered unmanaged risks. Risk is constructed socially, even where the physical phenomenon is natural.

Definitions and concepts may hide many different aspects and vary notoriously with scientific discipline, ideology, and ontological viewpoint. As with almost all conceptual processes, the epistemological foundations and context are crucial for understanding the way a topic is dealt with. For example, ‘the reduction [or mitigation] of natural disasters’ has been a useful slogan for mobilizing support in general, but from a conceptual viewpoint this terminology is imprecise and confusing. What is it precisely we search to reduce or mitigate? Although it may seem to be a subtlety, it is a very different thing to talk of ‘disaster risk reduction’ as opposed to ‘natural disaster reduction or mitigation’. From a decision-making viewpoint or from the point of view of the public in general, different ways of defining the same term will elicit different responses. Moreover, the risk of disaster used to refer to a probability is different to risk from disaster, which refers to feasible consequences. Concentrating on risk clearly allows us to discriminate between activities ex ante and ex post, and between the needs and activities relevant to one or another of these situations. Here, it is clear that the management approach has been long dominated by consequences (interest in humanitarian response) and not by an interest in the probability that these will occur (interest in prevention-mitigation). Although these approaches have common objectives, they signify different things in terms of funding, methods, functions, interests and expertise. In other words, it is not the same to visualize the problem from a social and economic development perspective, for example, as it is to look at it from the perspective of preparedness for humanitarian emergencies.

3.3.2 Disaster Risk as Potential of Crisis

The formulations of the problem owe a lot to the original ideas of the so-called human ecology school of thought first proposed by geographers at the University of Chicago during the second decade of the 20th century and further developed by White (1942, 1964, 1973), Kates (1971, 1978) and Burton (1962), by Burton and Kates (1964), as well as by Burton, Kates and White (1968, 1978) in their studies on hazards and disasters. On the other hand, the convolution of the
frequency of hazard events with the severity of its feasible consequences has been the traditional approach for risk assessment from the techno-hazards point of view.

Prompted by these ideas, the Office of the United Nations Disaster Relief Coordinator (UNDRO) and UNESCO organized an expert meeting in July 1979 with the objective of proposing a unification of disaster-related definitions. The report from that meeting, *Natural Disasters and Vulnerability Analysis* (UNDO 1980), included the definitions of natural hazard (H), vulnerability (V), elements at risk (E), specific risk (S), and risk (R). From this perspective, risk may be defined as

\[ R = E \cdot S = E \cdot H \cdot V \] (given that \( S = H \cdot V \)) (1)

Whilst essentially maintaining this conceptual framework, during the Institute for Earthquake Engineering and Engineering Seismology meeting, held in 1985 in Skopje (Former Yugoslav Republic of Macedonia), this author proposed the suppression of the variable related to the exposure, because it is implicit in the notion of vulnerability. In other words, one cannot be ‘vulnerable’ unless one is ‘exposed’. Originally, this formulation was presented by Fournier d’Albe (1985), Petrovsky and Milutinovic (1986) and later by Coburn and Spence (1992). The expression of risk as a function of hazard and vulnerability that is now widely accepted in the technical and scientific fields, and increasingly in the social and environmental sciences, was formulated as follows:

\[ R_{ie} \bigg|_t = f(H_i, V_e) \bigg|_t \] (2)

This signifies that once the hazard or threat (Hₙ), is known (expressed as the probability that an event with an intensity greater or equal to i will appear during a period of exposition t), and the vulnerability (Vₑ), is also known (understood as the intrinsic predisposition of an element e, to be affected or to be susceptible to damage with the occurrence of an event with an intensity i), the risk (Rₑ), is expressed as the probability of loss to the element as a result of the occurrence of an event with an intensity greater or equal to i. That is to say, risk in general may be understood as the probability of loss during a given period of time t (Cardona 1985, 1986).

Now, if \( C_p \) expresses a crisis potential, \( T_a \) represents the possibility of occurrence of a trigger agent, and \( I_c \) are the instability conditions of a system, from the perspective of the complex systems, it is possible to posit the following meta concept:

\[ C_p \bigg|_t = f(T_a, I_c) \bigg|_t \] (3)

This expression is more general and contains the abovementioned equation of risk, which is a particular case of behaviour of a specific non-linear dynamic system, at the border of chaos, in which it is important to consider the triggering agent or perturbation – i.e. the hazard – but also the dynamic conditions of instability – i.e. the vulnerability – (Cardona 1995, 1999, 1999a). The possibility that a crisis can appear must always be considered in a lapse or a ‘window’ of time, which would mean to express each factor in probability terms.

The evolution of the complex systems cannot be represented in an adequate way by linear functions or soft and continuous curves, except in the case of approximations over short segments of time. Equation (3) is appropriate to describe the potential bifurcations or inherent unpredictable development of the system. In the case of risk, the instability conditions are the weaknesses or the deficiencies that may be of environmental or ecological character; demographic, social or cultural; economic, institutional or political, among others. The concepts of vulnerability, or predisposition to be affected, and resilience, or capacity of recovery and adaptive behaviour, play an important role due to their important relation with the possible occurrence of discontinuities. One system may pass from an almost constant state to another one if it is altered by a sufficiently impacting perturbation, which does not only depend on the intensity of the event but also on possible instabilities that are not easily perceptible of the system. Lastly, a few words about the potentiality of the trigger event or agent are needed. This potentiality undoubtedly contributes to knowledge of one main component of risk: the hazard; the latent danger or probability of occurrence of a damaging event. It is necessary to have in mind that without hazard, without a trigger phenomenon, there would be no risk and no possible future disaster.
3.4 Vulnerability as a Key Concept

Vulnerability of human settlements and ecosystems is intrinsically tied to different socio-cultural and environmental processes, but it is also related to the fragility, the susceptibility, or the lack of resilience of the exposed elements, both from society and environment. It is also closely tied to natural and built environmental degradation at the urban and rural levels. Thus, degradation, poverty, and disasters are all expressions of environmental problems and their materialization is a result of the social construction of risk, brought about through the construction of vulnerability or hazard, or both simultaneously. Therefore, when seen from a social viewpoint, vulnerability signifies a lack or deficit of development. In this regard, risk is constructed socially, even though it has a relationship to physical and natural space. In many places, increases in vulnerability are likely to be related to factors such as rapid and uncontrollable urban growth and environmental deterioration. These lead to losses in the quality of life, the destruction of natural resources and landscape, and loss of genetic and cultural diversity. In order to analyse vulnerability as part of wider societal patterns it is necessary to identify the deep rooted and underlying causes of disaster vulnerability and the mechanisms and dynamic processes that transform these into insecure conditions. All this leads to the conclusion that the underlying causes of vulnerability are economic, environmental, demographic, and political processes that affect the distribution of resources among different groups, which in turn reflect the distribution of power in society. Some global processes require more attention than others. These include population growth, rapid urban development, international financial pressures, degradation of the earth, global warming, and environmental change and war. To take but a limited number of examples, urbanization processes have been an important factor in damage caused by earthquakes in urban areas; population increase helps to explain increases in the numbers of persons affected by floods and prolonged droughts; and deforestation increases the chances of flooding and landslides (Blaikie/Cannon/Davis/Wisner 1994). Adhering to the hypothesis that the lack of development and vulnerability are correlated and considering that the lack of capacity to cope, recover, and adapt is also a factor of vulnerability, particularly taking into account the climate variability and change, this author has suggested that vulnerability originates in:

a.) Physical fragility or exposure (D): the susceptibility of human settlements and environment to be affected by a dangerous phenomenon due to its location in the area of influence of the phenomenon and to a lack of physical resistance.

b.) Social, economic, and ecological fragility (F): predisposition of society and ecosystems to suffer harm resulting from the levels of marginality and social segregation of human settlements and disadvantageous conditions and relative weaknesses related to social, economic, and environmental factors.

c.) Lack of resilience or ability to cope and recover (-R): limitations in access to and mobilization of the resources of the human settlement, and incapacity to adapt and respond in absorbing the socio-ecological and economic impact.

According to this model (figure 3.1), vulnerability conditions in disaster prone areas depend on exposure and susceptibility of physical elements (human settlements, infrastructure, and environment), the socio-economic and ecological fragility and the lack of resilience or ability to cope with the context. These factors provide a measure of direct as well as indirect and intangible impacts of hazard events. Vulnerability, and therefore, risk are the result of inadequate economic growth, on the one hand, and of deficiencies that may be corrected by means of adequate development processes, on the other hand.

Indicators or indices could be proposed to measure vulnerability from a comprehensive and multidisciplinary perspective (Birkmann 2006). Their use intend to capture favourable conditions for direct physical impacts (exposure and susceptibility), as well as indirect and, at times, intangible impacts (socio-ecological fragility and lack of resilience) of hazard events. Therefore, according to this approach, exposure and susceptibility are necessarily hard conditions for the existence of physical risk, or first order effects, and these are hazard dependent. The propensity to suffer negative impacts as a result of the socio-ecological fragilities and not being able to adequately face disasters, are circumstances of the context that can be considered soft conditions, related to second order effects that aggravate the impact and usually are non-hazard dependent.

Using the meta concepts of the theory of control and complex system dynamics, to reduce risk it is necessary to intervene in a corrective and prospective way...
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Figure 3.1: Theoretical Framework and Model for a Holistic Approach to Disaster Risk Assessment and Management. 

![Theoretical Framework and Model for a Holistic Approach to Disaster Risk Assessment and Management](image-url)

This kind of thinking attempts to integrate in a holistic way the contributions of the physical and social sciences with the idea of obtaining a more complete vision of the factors that create or exacerbate vulnerability (Cardona/Hurtado 2000a, 2000b, 2000c; Cardona/Barbat 2000; Cardona 2001). The conceptual framework and model for a holistic approach to evaluate disaster risk consider several dimensions or aspects of vulnerability proposed by Wilches-Chaux (1989), which are characterized by the above mentioned three categories or vulnerability factors. These dimensions are correlated to human security components and briefly described as follows:

a.) **Physical (habitat) dimension**: This depicts locations in susceptible areas and deficiencies in the resistance of the exposed elements. The latter affects the capacity to absorb the shocks associated with dangerous phenomena. Examples of the physical dimensions of vulnerability from a habitat perspective can be found in the inadequate levels of seismic resistance of buildings located in earthquake prone areas, the location of a community in a landslide or flood prone area, etc.

b.) **Environmental dimension**: There is an increase in vulnerability when the development model is not based on an adequate relationship with the environment and promotes or fosters the exploitation and destruction of natural resources. These circumstances inevitably lead to deterioration in ecosystems and an increase in vulnerability. Self-adjustment in order to compensate the direct and indirect impacts of human activity or of natural events may become very difficult.

c.) **Economic dimension**: More economically depressed sectors are more vulnerable in general. Poverty can increase vulnerability. At the local and individual levels this is expressed in unemployment, lack of income, and difficulties in gaining access to services. At the national level, this is expressed in terms of excessive economic dependency and lack of control over external factors, lack

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of diversification of the economic base, restrictions on international commerce, and the imposition of retrograde monetary policies.

d.) Social dimension: The higher the levels of social integration of the community, the easier it will be for the community to absorb the consequences of a disaster and react more rapidly. Societies may be less vulnerable when they react as an organized group or according to group interests, and more vulnerable where individual or circumstantial interests prevail.

e.) Political dimension: This may be expressed in terms of the level of autonomy of a community in the use of resources and decision-making. The community is more vulnerable under centralist schemes of decision-making and government. Lower levels of regional and local autonomy impede actions that respond to the felt needs of the population at these levels. Participation in decision-making that affects the community will help reduce vulnerability.

f.) Institutional dimension: This relates to the difficulties faced in undertaking risk management. The lack of preparedness or of efficient and effective mitigation actions when collective risk is known to exist are sources of vulnerability. Institutional vulnerability is also expressed in the lack of flexibility and in excessive bureaucracy, and in the fact that political decisions and the desire for protagonism prevail over more rational ways of dealing with problems.

g.) Educational dimension: The lack of knowledge of causal factors and effects of disasters, the lack of a sense of the community history and the lack of preparation and understanding of individual and group responses to disaster are all aspects that make a community more vulnerable. Deficient education or lack of educational coverage in a susceptible community and the lack of socialization of information also increase vulnerability.

h.) Cultural dimension: This relates to the way individuals see or perceive themselves and the groups or collective units they belong to. This may at times negatively influence the behaviour given the existence of pernicious stereotypes that are neither questioned nor changed. The communication media play a crucial role in this, given that they contribute to the slighted use of images and the transmission of imprecise or inconsequent information related to the environment, society, and disaster.

i.) Ideological dimension: This relates to the ideas and beliefs that exist as regards the world, its existence and future. It is at times expressed in passive and fatalistic attitudes and religious beliefs that limit action under certain circumstances. Dogmatic perceptions may generate confusion as regards purpose and a lack of reaction or loss of motivation that limits the undertaking of transforming actions.

This deconstructive approach helps us visualize vulnerability from different angles and perspectives that involve also technological, anthropological, and psychological aspects. The proposal facilitates an understanding of vulnerability as a dynamic and changing circumstance or condition. Moreover, we can also see it as an accumulative process of permanent fragilities, deficiencies, and limitations that play a role in the existence of higher or lower levels of vulnerability.

The Holistic Approach is compatible to the 'Pressure and Release' model and to the 'Access' model; both related to the progression of vulnerability - chain of explanation - and to the analysis of the principal factors of human vulnerability (Wisner/Blaikie/Cannon/Davis 1994, 2004). From the perspective of these models vulnerability is related to the situation or the characteristics of a person or group that influence the impact of hazard event or process on them. This situation or characteristics of people depend on their unsafe conditions that are product of a set of dynamic pressures whose explanation is due to another set of root causes. The main subtle conceptual differences between these models and the Holistic Approach are that in the latter human and environmental insecurities are the result of a set of vulnerability dimensions and factors in each level of the chain or hierarchy of the explanation. Vulnerability is not only referring to the people but also to the contexts and to the complex interactions of society and environment; particularly, interactions not only from the global to the local but also from the local to the global. This is important for the exacerbation of socio-natural hazards and disaster risk understanding in the framework of climate change and environmental degradation, and to improve the resilience-building processes where a top-down political decision approach has to be combined with a bottom-up of awareness and social practices of environmental protection and disaster risk reduction.

3.4.1 Quantifying and Applying the Model

The Holistic Approach was used to evaluate disaster risk in countries of Latin America and the Caribbean
in the framework of the Disaster Risk Management Indicators Program for the Americas, led by the Institute of Environmental Studies (IDEA), of the National University of Colombia for the Inter-American Development Bank (IDB) (Cardona 2006, IDEA 2005a, 2009b, ERN 2009). In addition, it has been applied in Italy at the regional level in Lombardy (Prevenzione Lombardia 2007).

The methodology applied for the calculation of Urban Seismic Risk index, USRi, proposed by Carreño, Cardona, and Barbat (2007a) is useful to illustrate the quantifying and application of the holistic approach described above. The model was developed to guide the risk management decision-making, helping to identify the critical zones of a city and their vulnerability from an interdisciplinary perspective. This approach contributes to the effectiveness of risk management, inviting to the action or intervention by identifying the hard and soft weaknesses, reflected by distinct type of indicators of the different units of analysis (districts or areas, for example) of an urban centre. The total urban disaster risk is measured not only in terms of the direct impact of expected physical damage but also considers indirect impact factors that account for the socio-economic fragility and coping capabilities of the city’s population and its institutions. In this application, the USRi is the total risk $R_T$ obtained from the potential direct impact of earthquakes denoted as physical risk $R_P$ and on the indirect effects given by and impact factor $(1+F)$ based on the aggravating coefficient, $F$. Thus, it is expressed as follows:

$$USRi = R_T = R_P (1 + F)$$  \hspace{1cm} (4)

where

$$R_P = \sum_{i=1}^{p} F_{FRi} \cdot W_{FRi}$$  \hspace{1cm} (5)

and

$$F = \sum_{i=1}^{m} F_{SFi} \cdot W_{SFi} + \sum_{j=1}^{m} F_{L Bj} \cdot W_{LBj}$$  \hspace{1cm} (6)

The factors of the physical risk are based on the gross values of the physical risk descriptors such as the number of potential deaths, injured, or the destroyed area, among others. The factors of the aggravating coefficient are based on socio-economic conditions (social fragilities) and coping capacity descriptors (lack of resilience) such as area of slums, social disparity, population density, awareness level, public space available, hospital beds, physicians, firemen, etc. They are calculated using transformation functions that standardize the gross values of the descriptors, transforming them in commensurable factors which take values between 0 and 1; $w$ are the weights or influences of each factor of physical risk, social fragility and lack of resilience, respectively. They represent the relative importance of each factor and are calculated by means of the Analytic Hierarchy Process (Saaty 1980). Figure 3.2 presents the summary of the USRi results for all cities of Metro Manila.

Once the results have been obtained for each locality or district, it is easy to identify the most relevant aspects of the total risk index. The results can be verified and the mitigation priorities can be established as regards the prevention and planning actions to modify those conditions (sub-indicators) having a greater influence on risk. In addition, this technique allows comparing risk among different megacities, therefore this methodology allows using a common rule of measurement to compare and benchmark the results. It is a comprehensive technique where the concept underlying is one of controlling risk rather than obtaining a precise evaluation of it. This methodology has been applied at the urban level to Bogotá, Metro Manila, Barcelona, Manizales, and currently to Istanbul (Cardona 2001; Cardona/Hurtado 2000a/b; Carreño/Cardona/Barbat 2007a, Fernandez/Mattingly/Bendimerad/Cardona 2006, Suarez 2007, Khasai 2007; Marulanda/Cardona/Barbat 2009; Carreño/Cardona/Marulanda/Barbat 2009).

### 3.5 Territorial Safety as an Object of Risk Management

One of the objectives of risk management and of sustainable human development is to guarantee to human communities the territorial safety\(^5\) that they require in order to develop their lives with quality and dignity. This is, in fact, an attribute that is beneficial for communities and for nature. Territorial safety is the result of the interaction between a set of factors that allow a territory, as space of policymaking and management (Agudelo 2005), to offer stability to

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\(^{5}\) Territory as space of mutual interactions between society and nature is understood as a space of management not only as an area or surface.
those who inhabit it; that is to say, they provide permanence of the conditions that make life in space and time possible. These conditions or factors – some are natural and others anthropogenic – on which the capacity of the territory depends to offer stability and security for their inhabitants, are mainly food security, ecological security, social security, economic security, and institutional and legal security (Cardona/Wilches-Chaux 2006). In general, the responsibility of the state is to generate the conditions that permit territorial safety in its different dimensions, as much for the people as for the ecosystems that comprise the territory. For that reason the security is an attribute both for the society (human) and for the ecosystems (environment) on which sustainable development depends; understanding sustainable development as that form of development which allows that the dynamics of nature neither become a threat to human communities and their processes of production, nor that the dynamics of human communities become a threat to ecosystems.

Risk management may be understood as a set of elements, measures, and tools directed towards intervention in hazards and vulnerabilities with the objective of reducing existing – by corrective interventions – or controlling future possible risks – by prospective interventions (Lavell 2000). This concept of prevention and mitigation can be differentiated from another group of tools whose objective has been the improvement of intervention in disasters once these occur: preparedness activities, response, and reconstruction. Risk management aims to articulate different types of actions, assigning a central role for prevention and mitigation, but without abandoning disaster response, in an attempt to develop preventive policies that significantly reduce the need for intervening in disasters once these occur.

This type of management should not be seen as a purely government-led process, but a participatory exercise, involving governmental and non-governmental actors with the idea of dealing with risk and disaster. In this sense, risk management policy must be based on the involvement of the diverse social, institutional, public, and private forces and groups that exist, on a broad and inclusive territorial basis; i.e. a national, regional or local system for disaster risk management. A part of the improvement in human living conditions consists in the achievement of greater levels of security and survival in relation to the actions and reactions of the environment. This calls for a better understanding of the forms of interaction between our immediate social environment and the natural environment (Duque 1990). It follows, therefore, that risk management is a fundamental strategy for sustainable human development given that it attempts to establish an equilibrium between natural ecosystems and the societies which oc-

Figure 3.2: USRI results for the holistic seismic risk evaluation of Metro Manila. Source: (Fernandez/Mattingly/Bendimerad/Cardona (2006) and Marulanda/Cardona/Barbat (2009).
cupy and utilize them, guiding human actions and activities that affect the environment and vice versa.

It should be realized that disasters are to a great extent an expression of an inadequate relationship between the development model and the environment within which the model is supposed to operate. Conflicts between economic, social, political, and cultural objectives and mores may lead to inconsistencies in this regard, possibly ending up in a disaster. Because of this, risk management should be an explicit objective and component of development planning where where development is understood not only as an improvement in living conditions but also in the quality of life and well-being. Independently of ideological discussions, development should guarantee the needs of humans and their environment, and promote quality growth. Territorial security is in general a fundamental component of sustainable development and, for this reason risk reduction is also a fundamental strategy in the search for equilibrium between human settlements and nature.

3.5.1 Risk as a Measure of Human and Environmental Insecurity

It is necessary to make risk manifest for decision-making. Risk must be recognized and it thus becomes a preoccupation for somebody. However, risk is a complex and at the same time, curious concept; its existence is consubstantial for human beings. It is an abstraction of a transformation process that denotes simultaneously a possibility and a reality. It represents something unreal, related to uncertainty. It reflects an undesirable state of reality which has not yet materialized. It is imaginary, difficult to grasp, and does not exist in the present but only in the future. According to Ulrich Beck (2000: 215) “risks, then ‘are’ a type of virtual reality, real virtuality.” Beck cites Van Loon (2000: 176) who writes: “Only by thinking of risk in terms of reality, or better, a becoming-real (a virtuality) its social materialization can be understood. Only by thinking risk in terms of a construction can we understand its indefinitely deferred essence.” Risks are necessarily constructed but they are not constructed on the basis of imagination; that is, we are not free to construct risk as we please (Adam/Van Loon 2000).

In risk analysis, the context – management capacity and related actors – determines the limits, reasons, purpose, and interactions to be considered, which reveals its normative character. Analysis has to be congruent with context and this must be taken into account when analysing the sum of the contributing factors. If not, analysis would be totally irrelevant or useless.

Vulnerability is the state of reality that underlies the concept of risk. It is the causal reality that determines the selective character of the severity of damage when a hazard event appears (Cardona 2001). Vulnerability reflects susceptibility, the intrinsic predisposition to being affected; the conditions that favour or facilitate damage. The measurement of vulnerability is a challenge; many believe it is not feasible. However, it is fundamentally important to understand how vulnerability is generated, how it increases, and how it builds up. The evaluation and follow-up of vulnerability and risk is needed to make sure that all those who might be affected, as well as those responsible for risk management, are made aware of it and can identify its causes. To this end, evaluation and follow-up must be undertaken using methods that facilitate an understanding of the problem and that can help guide the decision-making process.

It is important to mention that research in and the development of the concept of risk in the applied and physical sciences commenced with the modern development of probability theory. In this context, the concept of probability had quasi-deterministic overtones, where probability scores were influenced by an epistemic lack of knowledge or, in other words, uncertainty. This can, in principle, be overcome by more experimentation and learning exercise. But the need to formulate statistical physics in order to study certain complex phenomenon has introduced a component of irreducible uncertainty, which has been called randomness. These two types of uncertainty reflect the duality that underlies the concept of probability, and therefore of risk. At present some other analytical theories are related to the uncertainty: the theory of fuzzy sets, the theory of possibility, and the theory of evidence (Kikuchi/Pursula 1998). According to Max Weber (1991) the sociology of risk is a science of potentialities and of Möglichkeitsurteile; i.e. of judgments about possibilities.

There are a wide range of approaches for integrating data and modelling risk and vulnerability. Inductive approaches model risk through weighting and combining different hazard, vulnerability, and risk reduction variables. Deductive approaches are based on the modelling of historical patterns of materialized risk (i.e. disasters, or damage and loss that have already occurred). Other approaches combine the re-

6 Such as it is defined in a platform for disaster risk modelling like CAPRA (ERN 2009a). See <www.ecapra.org>. 
results of inductive and deductive modelling. An obstacle to inductive modelling is the lack of accepted procedures for assigning values and weights to the different vulnerability and hazard factors that contribute to risk. Deductive modelling will not accurately reflect risk in contexts where disasters occur infrequently or where historical data are not available. In spite of this weakness, deductive modelling offers a short cut to risk indexing in many contexts and can be used to validate the results from inductive models. There are no standard procedures for measuring or weighting the effectiveness of risk reduction, given the large number of stakeholders and the wide variety of activities involved.

Risk indicators or indices are feasible techniques for risk monitoring and may take into account both the harder aspects of risk as well as its softer aspects (Cardona/Hurtado/Duque/Moreno/Chardon/Velásquez/Prieto 2003; Cardona 2006; IDEA 2005a, 2005b). The usefulness of indicators depends on how they are employed. The way in which indicators are used to produce a diagnosis has various implications. The first relates to the structuring of the theoretical model. The second refers to the way risk management objectives and goals are decided on. This aspect is important given that it is preferable to promote an understanding of reality not in strict terms of the ends to be pursued, but, rather, in terms of the identification of a range of possibilities, information on which is critical to organize and orientate the praxis of effective intervention (Zemelman 1989). An appropriate technique based on indicators can be a rational benchmark or a common metric to rule the risk variables from a control point of view (Carreño/Cardona/Barbat 2007b). The goal is not to reveal the truth, but rather to provide information and analyses that can improve decisions.

It is important to recognize that complex systems involve multiple facets (physical, social, cultural, economic, and environmental) that are not likely to be measured in the same manner. Physical or material reality have a harder topology that allows the use of quantitative measurement, whilst collective and historical reality have a softer topology where the majority of the qualities are described in qualitative terms (Munda 2000). These aspects indicate that a weighing or measurement of risk involves the integration of diverse disciplinary perspectives and this may usher in problems of comparability. In other words, in order to measure risk and its management we need a holistic focus (Cardona 2001, 2004, 2006). This type of integral and interdisciplinary focus can more consistently take into account the non-linear relations of the parameters, the context, complexity, and dynamics of social and environmental systems, and contribute to more effective risk management by the different stakeholders involved in risk reduction decision-making. It permits the follow-up of the risk situation and the effectiveness of the prevention and mitigation measures can be easily achieved. Results can be verified and the mitigation priorities can be established with regard to the prevention and planning actions to modify those conditions having a greater influence on risk (Carreño/Cardona/Barbat 2007a).

3.5.2 Politics and the Decision-making Process

It is important to stress that the concept of risk is linked to decision-making and, therefore, it has a time dimension relating to the feasibility and convenience of taking action. Risk is directly related to its mediation; be it scientific, political, economic or popular. Once one knows that there is a possible consequence, one faces a responsibility. This responsibility takes the form of a decision, although not to decide is by itself a decision. From a risk management perspective, actions that reduce the vulnerabilities and stimulate the strengths and capabilities of exposed communities must be the main objective of risk management planning and actions; i.e. the decision science from the perspective of disasters.

Political decisions on risk are taken under conditions of uncertainty and are based on data of variables and, at times, of undetermined quality. This may be complicated by the political manipulation of uncertainty in order to speed up or slow down a decision and action. Quality, understood as the ability of a product to satisfy determined requisites, is the concept that underlies the determination of its attributes and criteria that allows an analysis of the decision-making process (Funтовicz/Ravetz 1990, 1992). Hence, the key question is: what is the role of the information in decision-making? Once the problem of
designing criteria has been resolved, the following question arises: who will determine the criteria to be used? (Corral 2000) Uncertainty with regard to risk and the fact that the scientific community can not possibly resolve and characterize these problems totally (‘given that no expert can provide certainty for political decisions’) has led to a request for the inclusion of more actors, including the community, into the decision-making process. This permits a plurality of perspectives which, whilst not denying the competence of experts, permits the inclusion of a wide range of stakeholders in decision-making. It provides a combination of skills that permit all those involved in the problem to enrich the collective vision. Thus, the determination of criteria must be arrived at by dialogue and cooperation between experts, decision-makers, and other relevant actors, using the notion of **quality** as a baseline.

The models that are applied in the design of public policies such as risk management may influence the quality of the decision process. Opting for one type of modelling over another (for instance, mono-as opposed to multi-criteria models) may lead to different results which then push public policy objectives in a determined direction. Therefore, despite what many believe, the design of a public policy like risk management is very much related to the evaluation technique used to orient that policy. The quality of the evaluation technique, called by some as its scientific pedigree, has unsuspected influence on policy formulation. If the diagnosis invites action it is much more effective than where the results are limited to identifying the simple existence of weaknesses or failures.

The quality attributes of a model are represented by its **applicability**, **transparency**, **presentation**, and **legitimacy**. Respect for these attributes determines the scientific pedigree of a particular technique. Applicability refers to the way a model is adjusted to the evaluation problem at hand, to its reach and comprehensiveness, and the accessibility, aptitude, and level of confidence of the information required. Transparency is related to the way the problem is structured, facility of use, flexibility and adaptability, and to the level of intelligibility and comprehensiveness of the algorithm or model. Presentation relates to the transformation of the information, visualization, and understanding of the results. Finally, legitimacy is linked to the role of the analyst, control, comparison, the possibility of verification, and acceptance and consensus on the part of the evaluators and decision-makers.

In conclusion, the development of techniques that permit a permanent monitoring of territorial and social accumulation of vulnerability or the evolution of physical trigger processes is conducive to the application of realistic and dynamic planning techniques. This should be flexible enough to adjust to continuous or abrupt changes in the natural, economic, and social environment. This type of corrective and prospective approach is more appropriate than the uni-dimensional approaches, given the levels of uncertainty and instability that characterize existing processes of change and which render long term plans almost impossible to realize. In many places economic, social, and cultural factors are becoming increasingly relevant for the dynamics of growth and progress. In view of this, we need to develop less rigid planning models that allow us to more adequately incorporate uncertainty, instability and surprise, using diagnostic and follow-up techniques that permit the monitoring of the social and environmental context and possible perturbing agents.

The holistic approach to disaster risk and management herein described, based on a consistent conceptual framework, has been used to develop evaluation methods to measure vulnerability and risk with the purpose to favour decision-making, implementation, and action. They have been developed taking into account the attributes of the scientific pedigree of modelling. Nowadays, there are examples worldwide of how this model has been used by distinct kind of stakeholders in different territorial levels. The methods based on composite indicators and indices developed and adapted using this model have proven useful in identifying relevant issues of vulnerability, in guiding risk reduction from an interdisciplinary perspective, and taking in mind as objective of these metrics a preventive vision of development.