Methods for the Improvement of Vulnerability Assessment in Europe

D 5. Generic conceptual framework for vulnerability measurement

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1 Introduction and summary description

This deliverable aims at the development of a generic framework that addresses vulnerability and disaster risk to natural hazards from a holistic and multidimensional point of view. The framework takes into account the results of the literature reviews carried out in WP 1 which allowed identifying gaps in existing frameworks. For instance it was highlighted that the assessment of vulnerability requires measurement of both the social and the ecological systems and their interactions (coupling processes), which is an aspect not well represented in the literature so far. Following the objectives of the MOVE project, the framework is independent from scales and hazard type and encompasses different aspects of vulnerability. It provides a general structure for the comparative assessment of the different vulnerability aspects and dimensions addressed within the case studies of MOVE (WP 3). This first section of the chapter introduces and describes the main components of the MOVE-vulnerability-framework which are further discussed thereafter. Additionally, aspects of the applicability and major differences between a risk and vulnerability assessment are outlined.

The diagram of the conceptual framework of Figure 1 does not try to represent a systematised reality. It aims to make an initial identification of elements of coupled social-ecological systems that shape vulnerability outcomes. As a heuristic, the framework is a thinking tool to guide logical and comparative development of indicators. It should not be seen as proposing a set of fixed relationships between the elements described.

The framework recognizes *hazards*, which can be natural or socio-natural, and the society, represented at international, national, sub-national or local scale, as being part of the environment; both elements, hazards and society, coexist and have constant interactions among them.

In general, the concept of hazard is used when referring to the potential occurrence of natural and socio-natural events that may have physical, social, cultural, institutional, economic and environmental impacts in a given area and over a period of time. Therefore, a natural hazard means the potentiality of internal or external geodynamics or hydro-meteorological events that may cause effects to exposed elements*.* Hazards can be single, sequential or multiple in their origins and effects and are characterised by its location, magnitude, frequency and probability. When the intensity or recurrence of hazard events is related to processes of environmental degradation and human intervention in natural ecosystems, the origin of hazard can be considered as socio-natural. They are created where human activity intersects with natural ecosystems. If the hazard is a single event (or combination of events impacting a place) the unit of assessment can be defined in spatial terms and may be a single actor, e.g. a city authority. If the event is a generic concern it will require multiple stakeholders.

The social-ecological system is exposed in the time and space to different hazards, and it can be vulnerable to them. Within the MOVE project we define vulnerability as a degree of susceptibility or fragility of elements, systems or communities including their capacity to cope under a hazardous condition (see Ch 3-4-5). The vulnerability of a system can be manifested in various dimensions such as:

- *Social*: *refers e.g. to human welfare including mental and physical health, both at an individual and collective level.*
- *Economic*: related to potential financial damage and/or disruption of productive capacity.
- *Physical*: refers to the condition of physical assets including built-up areas, infrastructure and open spaces that can be affected by natural hazards. This dimension depicts locations in susceptible areas and deficiencies in the resistance of the exposed elements.
- *Cultural*: related to the meanings placed on artifacts, customs, habitual practices and natural or urban landscapes.
- *Environmental*: *refers to all ecological and bio-physical systems and their different functions*.
- *Institutional*: refers to both organizational form and function as well as guiding legal and cultural rules

The measurement of vulnerability is a challenge; it is related to the degree of exposure, susceptibility, fragility and lack of resilience or lack of response capacities of a socio-ecological system that favours adverse effects. These causal factors of vulnerability are defined as follows:

- *Exposure* is 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*.*
- *Susceptibility and/or fragility* is the predisposition of society and ecosystems to suffer harm resulting from the levels of susceptibilities or fragilities of human settlements and disadvantageous conditions and relative weaknesses related to physical, ecological, social, economic, cultural, and institutional issues.
- *Lack of resilience or (societal) response capacities* is the limitations in access to and mobilization of the resources of the social-ecological system, and the incapacity to respond in absorbing the impact. This factor of vulnerability includes the capacity to anticipate, cope and recover in the short term.

As illustrated in Figure 1, the 6 thematic dimensions of vulnerability describe different features of the susceptibility/fragility component as well as those of the lack of resilience or the lack of (societal) response capacities, as represented through the arrows linking the two boxes. Measurement of vulnerability should then take into account and integrate these different dimensions.

In contrast to vulnerability - *risk* is defined as the expected probability of harmful consequences or losses resulting from interactions between natural or anthropogenic hazards and vulnerable conditions. It is the potential occurrence of physical, social, economic, and environmental consequences or losses, in a given area and over a period of time, resulting from the vulnerability conditions of a social-ecological system exposed to hazards. In order to face the recognized risk, it is necessary to involve the *risk governance* which includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken. These *risk management* decisions include tasks on *risk reduction, prevention, mitigation and transfer* and also *preparedness and disaster management*, which allow implementing measures for *hazard intervention* or *vulnerability intervention* that lead to *exposure and susceptibility reduction* and *resilience improvement*.

Furthermore, *adaptation and adaptive capacities* in particular encompass from our perspective techniques and strategies to be devised that enable society to absorb and deflect the impact of hazards and focuses on interactions and changes which take place in the long term. The adaptation box includes components on exposure reduction, susceptibility reduction and resilience improvements that correspond to the three factors of vulnerability. The framework makes a distinction between those acts that are aimed at the best ways of living with an identified hazard (coping) and those aimed at efforts to adjust practices, goals and values to a new reality of uncertainty and a dynamic hazard landscape (adaptation).

Coupling acknowledges that any defined hazard is given form and meaning by interaction with social systems, and similarly that social systems are influenced by their actual and perceived hazard context. The term takes into account the dynamics and interactions between social and ecological systems. Social-ecological systems are complex systems which co-evolve and build resilience through non-linear processes of change and learning which ultimately determine conditions of vulnerability to hazards. The interaction of environment and society leads often to the development of a specific disaster event. The term coupling within the MOVE-framework acknowledges the longer-term interaction and uncertainties that can shape vulnerability perception and risk management, especially with unexpected and threshold breaching moments as exemplified by climate change and rapid urbanisation.

The challenge of *scales* is considered in the framework. In general, the central choice of the appropriate scale for a vulnerability assessment is driven by the policy needs and in this regard is determined by the specific scale of underlying processes and the availability of data to support the reporting at the policy level. However, the choice of the scale significantly influences the results of the assessment. It may happen that what reduces vulnerability at an aggregate, higher scale may well produce localised increases in vulnerability. Arrows between different spatial scales remind to consider potential cross-scale interaction and issues related to up- and downscaling.

The *arrows* on the figure encourage to examine interactions and the processes by which one element in the production of vulnerability and risk is connected to or interrelates with others. All elements of the framework are linked to each other and the surrounding wider social and hazard environments. Many linkages can be explored, for instance between hazard and risk governance or between different components of vulnerability.

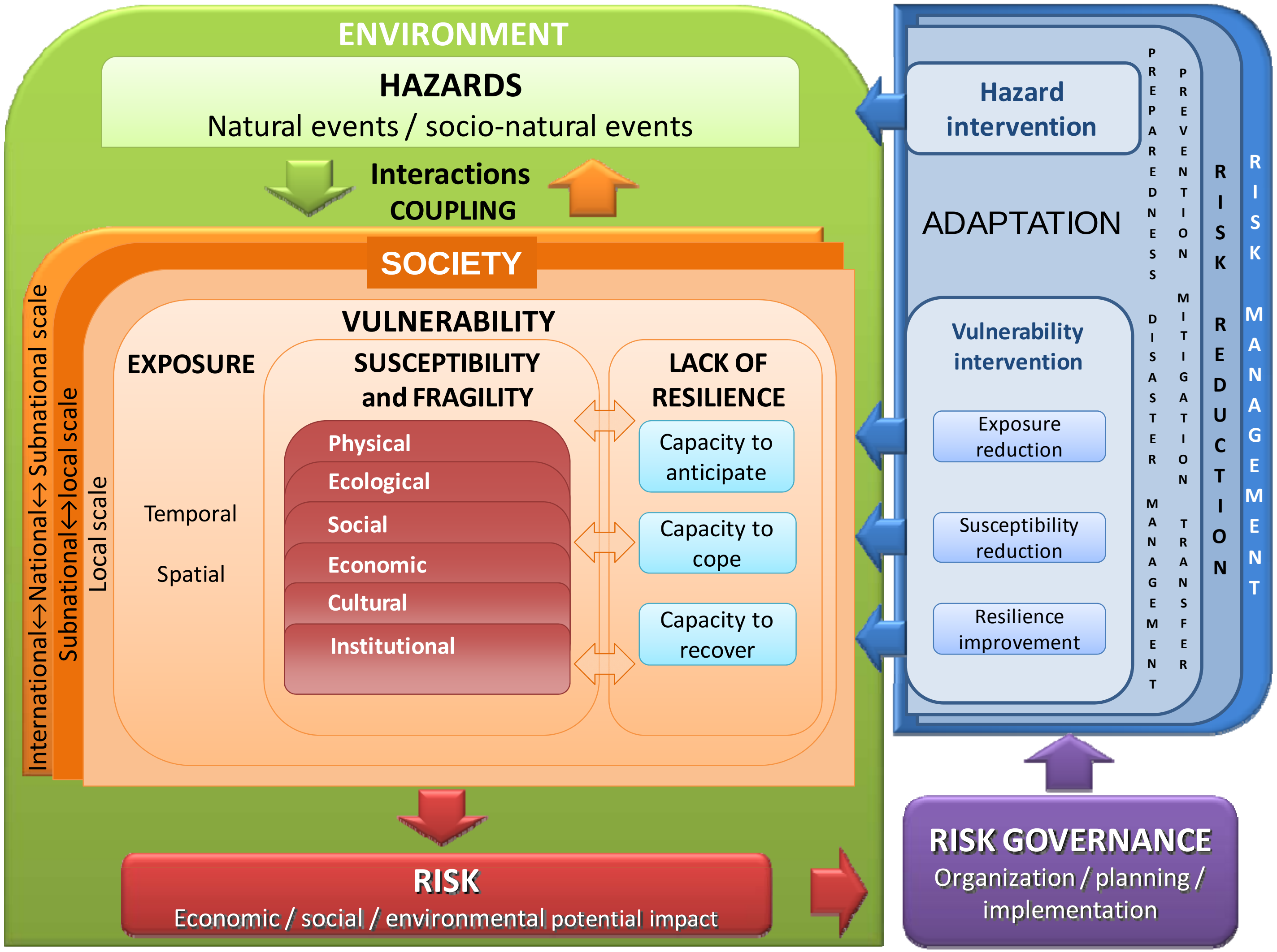

Figure 1: Theoretical framework for a holistic approach to disaster risk assessment and management.

2 Natural and socio-natural hazards

2.1 Natural hazards

The term "natural disaster" has been very frequently used in the past to refer to the occurrence of severe natural phenomenon. Events such as earthquakes, tsunamis, volcanic eruptions, hurricanes, floods, landslides, among others, have been directly considered synonyms of disaster. This interpretation has favored the belief that there is little that can be done when faced with disasters. As natural phenomena these are considered unavoidable. On the other hand, this interpretation has also led to disasters being considered events of bad luck or even the result of supernatural causes. This could help explain why certain communities consider these events unalterable and resign themselves to their occurrence (Cardona 2003).

In general, the concept of hazard is used to refer to a latent threat or proneness that can be expressed as the potential occurrence of natural, socio-natural or anthropogenic events that may have physical, social, economic and environmental impact in a given area and over a period of time (White 1973; UNDRO 1980; Cardona 1990; Birkmann 2006b). Each hazard is characterized by its location, intensity and frequency. Therefore, a natural hazard means the potentiality of an extreme event from the internal or external geodynamics or a hydro-meteorological event that may cause severe effects to exposed and vulnerable elements. In other words, hazard and vulnerability are mutually conditioning situations and neither can exist on their own. They are defined independently for methodological reasons and in order to achieve a better comprehension of disaster risk. Thus, when one or another of the drivers of risk is altered we are intervening risk itself. The study of hazards certainly is a task of natural, earth and applied sciences. At present the altered frequencies and intensities of environmental hazard events as result of climate change is one of the main fields of research (ICSU-LAC, 2009). In this context hazards can be the result of the physical impacts on natural environment of climate extremes – such as warming, scarcity or heavy precipitation, heat waves – or hazards are the extreme events themselves –such as intense tropical storms. These hazards subsequently may have impacts or adverse effects on natural (ecosystems) and human systems (socio-economic).

2.2 Socio-natural events and coupling

When the intensity or recurrence of hazard events is related to processes of environmental degradation and human intervention in natural ecosystems the origin of hazard can be considered as socio-natural. In these cases, the magnitude and the impacts of natural hazards may change and increase. For example where deforestation leads to greater landslide and flood potential; where emission of greenhouse gases leads to changes in climate and an increase in climate related hazards; where destruction of mangroves leads to greater exposure to wave action and coastal erosion, environmental degradation and the coupling process of society and nature has a direct impact on the increasing risk societies are facing.

Research must elucidate as regards the rationale for the type of human intervention undertaken, the limits and opportunities the ecological system presents when faced with such interventions and as to the management strategies that may exist for achieving the same social or economic goals but without the generation of such adverse environmental impacts and results (Lavell 1996, 1999). The Millennium Ecosystem Assessment (2005) gathered knowledge on the state of world ecosystems and analysed impacts of human activities on the environment also with respect to hazards. A field of research is growing regarding disaster risk reduction and the environment through the adoption of a so called ecosystem approach.

Coupling acknowledges that any defined hazard is given form and meaning by interaction with social systems, and similarly that social systems are influenced by their actual and perceived hazard context. The term takes into account the dynamics and interactions between social and ecological systems. Social-ecological systems are complex systems which co-evolve and build resilience through non-linear processes of change and learning which ultimately determine conditions of vulnerability to hazards. Coupling is made explicit through those management practices which, within particular governance systems, allow for the efficient use and enhancement of ecosystem services, biodiversity and cultural values of ecosystems. These features can be described through variables that measure and assess the potential use and functions of ecosystem services in hazardous conditions. On the other hand, the capacity of an ecosystem to provide desired services in the face of abrupt changes is, at present, widely compromised by human action and for most ecosystems. An important component of vulnerability assessment is the identification of drivers and factors that cause the degradation of ecosystem services, diminishing the number and diversity of resources and strategies which can eventually lead to increased impact of hazards on the social-ecological system and finally cause disasters. Coupling acknowledges the longer-term interaction and uncertainties that can shape vulnerability perception and risk management, especially with unexpected and threshold breaching moments as exemplified by climate change and rapid urbanisation.

From the research angle, natural sciences provide a basic platform and understanding of intrinsically delicate and "quasi-stable" physical processes (in terms of geomorphology, ecology, etc.), whereas social science provides an understanding of the social, economic, cultural and political rationale for the types of intervention experienced (Cutter 1994; Kasperson *et al.* 1988), and a basis for alternative forms of intervention that maximize social and economic welfare but without leading to a loss in the productivity and stability of the supporting environment.

From the information and management angle, the challenge for the natural sciences is to make relevant and politically expedient information available to individual and collective decision makers such that the consequences and needed alternatives are transparent. This undoubtedly requires the active and coordinated participation of the social sciences in aspects related to social communication and the design of politically convincing strategies with regard to the dissemination of information and knowledge. As may be easily appreciated, the types of relationship and needed coordination between social and basic, natural or applied sciences vary when dealing with basis research or information management.

In the first case, although the two types of research problem are clearly aimed in the same direction—understanding the factors that contribute to risk and the generation of risk factors - the object of research can be seen as essentially "autonomous" and information generated through the development of the natural-basic and social science "themes" may be seen as an input into the other, but not requiring any direct participation beyond that. However, this conclusion should be reconsidered if we widen our perspective to also deal with research methods and not just goals. Thus, where interdisciplinary and participatory research methods and stakeholder involvement are considered as options with regard to the study of environmental change processes, the need for closer relations and understanding between social and natural, basic and applied science practitioners becomes obvious (ICSU-LAC 2009).

In the case of information and knowledge dissemination amongst decision makers, the stakeholder principle established above, with regard to basis research, holds firm as a principle, but must be complimented with the collaboration of social sciences in the development of information and communication strategies that make hard scientific information available to decision makers in accessible, easily understandable and politically expeditious ways.

3 Vulnerability as a key concept

The term vulnerability has been employed by a large number of authors to refer directly to risk as well as to disadvantaged conditions. Thus, for instance, people refer to vulnerable groups when they talk about the elderly, children or women, without specifying what these groups are vulnerable to. However, it is important to ask: "Vulnerable to what?" In other words, hazard and vulnerability are mutually concomitant and lead to risk. If there is no hazard it is not feasible to be vulnerable when seen from the perspective of the potential damage or loss the occurrence of an event might signify. In the same way, no hazard can exist for an element or system if such an element is not 'exposed' and vulnerable to the potential event. Even though this might seem to be an unnecessary subtlety, it is important to make this distinction. A population might be vulnerable to hurricanes, for example, but not to earthquakes or floods. In physical terms, the resistance or physical susceptibility of the exposed elements is related to their capacity to absorb the shocks associated with dangerous phenomenon.

In other words, 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 occurs. Vulnerability refers to the propensity of exposed elements such as human beings and their livelihoods to suffer damage and loss when impacted by single or diverse hazard events (UNDRO 1980; Timmerman 1981; Maskrey 1984; Cardona 1986, 1990; Liverman 1990; Cannon 1994, 2006; Blaikie *et al.* 1996; UNISDR 2004, 2009b; Birkmann 2006b; Thywissen 2006). Vulnerability reflects *susceptibility*, the intrinsic predisposition to being affected; the conditions that favour or facilitate damage. The measurement of vulnerability is a challenge; it is related to the degree of *exposure*, *susceptibility, fragility and lack of resilience or lack of (societal) response capacities* of a socio-ecological system that favors adverse effects. Many believe that it is not possible to assess vulnerability however it is fundamentally important to understand how vulnerability is generated, how it increases, and how it builds up (Maskrey 1984, 1989; Lavell 1996, 1999; O'Brien *et al.,* 2004; Cardona, 1996, 2004, 2010; Birkmann 2006; Renaud et al. 2009). 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 (Maskrey 1993a/b, 1994, 1998; Mansilla 1996). 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.

Vulnerability of human settlements and ecosystems is intrinsically tied to different socio-cultural and environmental processes (Cutter 1994; Kasperson *et al.* 1988; Cutter *et al.* 2008a/b). Dynamic interactions between social and ecological systems contribute in establishing particular conditions of vulnerability with respect to specific hazards. Coupled socio-ecological systems co-evolve and thus it is important to acknowledge that the environment is not solely the hazard sphere, but rather needs to be seen as an entity which is closely coupled with societies at risk.

Vulnerability refers to *susceptibilities or fragilities* of the exposed elements; i.e. to the likelihood to be affected, but also it is related to the *lack of resilience or lack of response capacities* of the society and environment. Vulnerability is also closely tied to natural and built environmental degradation at the urban and rural levels and the gradual climate change. Therefore, when seen from a social viewpoint, vulnerability signifies a lack or deficit of sustainability. 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 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 social, economic, environmental, and political processes that affect the distribution of resources among different groups, which in turn reflect the distribution of power in society. 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 et al 1994,1996). Adhering to the hypothesis that the lack of sustainability and vulnerability are correlated and considering that the lack of capacity to anticipate, cope, and recover is also a factor of vulnerability, particularly taking into account the climate variability and change, Cardona (1999a/b, 2001, 2010), Cardona and Barbat (2000); McCarthy *et al.* (2001); Birkmann (2006); Carreño *et al*. (2007a); IPCC (2007) and in part Turner et al. (2003) have suggested that vulnerability originates in the following factors (see Figure 1):

- *Exposure* is the likelihood 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*.*
- *Susceptibility and/or fragility* is the predisposition of society and ecosystems to suffer harm resulting from the levels of susceptibilities or fragilities of human settlements and disadvantageous conditions and relative weaknesses related to physical, ecological, social, economic, cultural, and institutional issues.
- *Lack of resilience* (*or ability to anticipate, cope and recover) or lack of societal response capacities* is/are the limitations in access to and mobilization of the resources of the social-ecological system, and the incapacity to respond in absorbing the impact. The resilience includes the capacity to anticipate, cope and recover in the short term.

Although human society is the main focus of the concepts of vulnerability, a fundamental question has to be clarified as to whether human vulnerability can be adequately characterised without considering simultaneously the vulnerability of the "surrounding" eco-sphere. Vogel and O'Brien (2004) stress the fact that vulnerability is *multi-dimensional and differential* – i.e. varies across physical space and among and within social groups; *scale-dependent* with regard to time, space and units of analysis such as individual, household, region, system; and *dynamic* – characteristics and driving forces of vulnerability change over time. This means vulnerability is much more than, for example, the likelihood of buildings collapsing and infrastructure being damaged. Especially the social dimension of vulnerability includes various themes such as social inequalities regarding income, age or gender, as well as characteristics of communities and the built environment, such as the level of urbanisation, growth rates, economic vitality, etc. (Cutter et al 2003). In this context, Birkmann (2006) provides an overview of the different key spheres of the concept of vulnerability (see Figure 2), without intending to be comprehensive.

Risk understanding depends on the understanding of how vulnerability can be captured in its different dimensions and spheres, and taking into account that vulnerability correlates with *physical susceptibility* (including the built environment), ecological fragility, social-cultural issues and socio-economic contexts. In addition, vulnerability is heavily influenced by the *resilience*; i.e. the adaptive ability of a socio-ecological system to absorb negative impacts as result of its *capacity to anticipate, cope and recover* quickly from damaging events. The lack of resilience means an important factor of vulnerability. In the framework of climate sensitivity resilience also means capacity of the system to learn about and adapt to a changing hazard situation.

The figure 2, of Birkmann, underlines that most definitions agree that vulnerability can be understood as the internal side of risk, the discourse further developed the concept of vulnerability and today aspects of *exposure, susceptibility and lack of resilience* enhance the general concepts used to capture vulnerability. Besides these causal factors also different dimensions have been added and further developed.

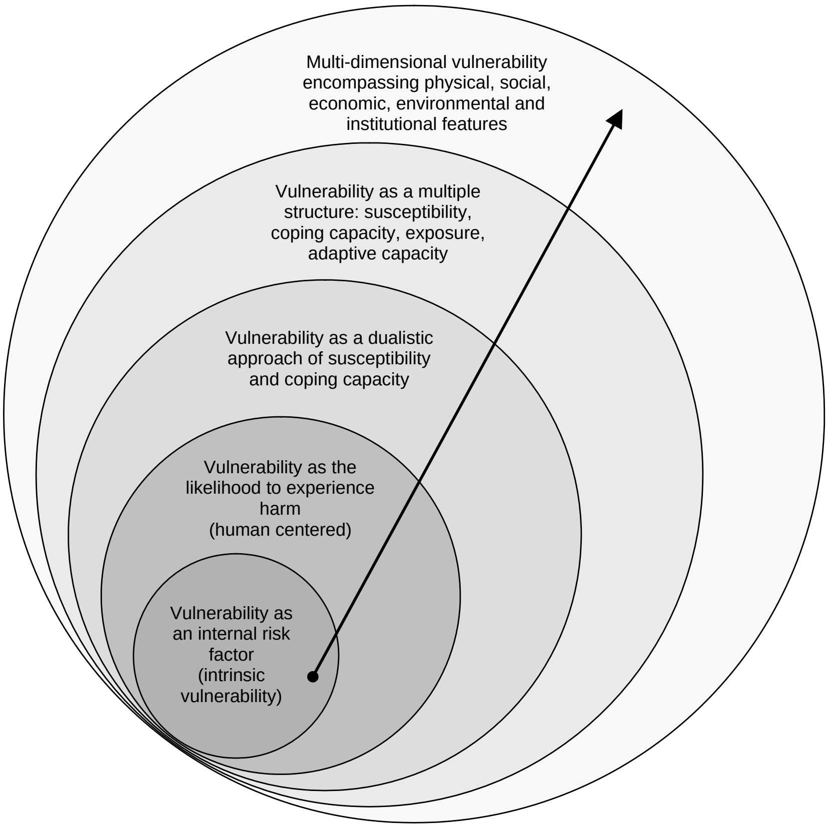

Figure 2: Key spheres of the concept of vulnerability Source: Birkmann (2006).

There are different approaches to vulnerability, which are reviewed and analysed within Deliverable 1 and 2 of the MOVE project. Some of them are 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 et al 1994, 2004). The BBC (Bogardi and Birkmann 2004; Cardona 1999; Cardona 2001) *framework* incorporates the perspective of sustainable development into the assessment of vulnerability (Birkmann 2006b). It distinguishes between the response before a disaster occurs (preparedness/risk reduction) and the response after (disaster emergency management). The BBC framework analysis vulnerability in a dynamic context and stresses the integration of the environmental dimension of vulnerability. It considers the links between communities and specific services and the vulnerability of ecosystem components to hazards (Renaud

2006). 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 a holistic approach, such as it is proposed herein, are that in the latter human and environmental insecurities are the result of a set of *vulnerability factors and dimensions* in each scale 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 and non-lineal 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 frame-work 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.

3.1 Understanding vulnerability

“Vulnerability”, seen from a social or anthropocentric viewpoint, essentially refers to the propensity of human beings and their livelihoods (these may be analysed from an individual, family, group, area, regional, national or international perspective) to suffer damage and loss when impacted by single or diverse physical events, and to confront problems in reconstruction and recovery. Understanding vulnerability requires an analysis of the contexts (physical, institutional, social, economic, etc.), fragilities/susceptibilities and structure of human beings and their livelihoods which predispose them to such damage, loss and difficulties in anticipation, coping and recovery**.** Explanation of vulnerability constitutes a fundamental part of the definition of the notion and in this explanation varied aspects of a physical, technical, social and economic nature intervene, which require the presence and interaction of diverse sciences.

Although one can accept that there are intrinsic or innate levels of vulnerability associated with life in general, as far as risk and disaster studies are concerned, vulnerability, its facets, factors and levels should be seen as a result of defined social processes. That is to say, vulnerability is the most palpable manifestation of the social construction of risk factors (Aysan 1993; Blaikie *et al.* 1996; Wisner *et al.,* 2004). Only by dealing with the socially constructed elements of vulnerability may we broach aspects that are subject to social intervention and change. Intrinsic or innate vulnerability is by definition inherent and in most cases unchangeable and therefore not subject to risk management mechanisms beyond those associated with increases in consciousness, education and knowledge as to the limits of security determined by our “weakness” when faced with certain physical conditions (a paroxysmal volcanic eruption or an upper scale earthquake would be examples of exceptional events to which all life would be highly “vulnerable” irrelevant of what risk reduction practice is in place or could be imagined).

Vulnerability is the result of different social and environmental processes and the characteristics and conditions they give rise to. It is a condition that exists with reference to a concrete hazard context and is, therefore “determined”, delimited or contextualised with reference to defined and delimited physical events (Chambers 1989; Cannon 1994; Wisner 2006; Carreño *et al.* 2007a). That is to say, one is not vulnerable in general (although there are what could be called “general vulnerability factors”), but rather, vulnerable when faced with determined hazard conditions. Thus, vulnerability in relation to earthquakes is not necessarily the same as in relation to floods, drought, or forest fires. Or, vulnerability used in reference to multi hazard contexts is not the same as in mono hazard exposure. This simple affirmation signifies that all vulnerability analyses or studies and all interventions to reduce or control vulnerability must be informed by a thorough understanding of the nature of the different potentially damaging physical factors that threaten different zones and populations. However, it is important to note that within MOVE at least three generic key-factors of vulnerability were identified – independent of a specific hazard: a) exposure, b) susceptibility/fragility and c) lack of resilience/lack of societal response capacity (or ability to anticipate, cope and recover), described in the previous chapter.

One of the outstanding questions relates to the types, levels of sophistication, forms of expression and delimitation of the physical factors required for different types of vulnerability analysis and the methods used to get to this information, ranging from community based hazard and vulnerability analysis through to formal scientific research. Once again this signifies that the methods of generating and disseminating information amongst interest groups and stakeholders are as relevant a question and practice as is the generation of scientific information in itself. Information without communication is of little use where the final objective of research is social improvement and change.

Whilst accepting this general principle as to the hazard specific nature of vulnerability, it is also clear that certain factors, such as poverty, the lack of social networks and social support mechanisms, will affect vulnerability levels irrespective of the type of hazard context— i.e. they are non hazard dependent. Clearly this type of generic factor is different to the hazard specific factors and assumes a different position in the intervention equation and the nature of risk management processes (ICSU-LAC 2009).

3.2 Vulnerability factors and dimensions

The vulnerability conditions in disaster prone areas depend on *exposure* and susceptibility of physical elements (human settlements, infrastructure, and environment), the *socio-economic and ecological fragilities* and the *lack of resilience* or ability to anticipate, cope and recovery. 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. 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 fragilities* and *lack of resilience*) of hazard events.

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 the vulnerability factors and, when it is possible, the hazards directly. Then disaster risk management requires a system of control (institutional structure) and an actuation system (public policies and actions) to implement the changes needed on the exposed elements or complex system where risk is a socio-environmental process. Effectiveness of disaster risk management (*ex ante*: risk prevention, reduction and transfer, and *ex post*: preparedness/disaster management) is related to "risk governance" in the different scales: local, sub-national, national, international.

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 and Hurtado 2000a, 2000b, 2000c; Cardona and Barbat 2000; Cardona 2001[1]). The conceptual framework and model for a holistic approach to evaluate disaster risk consider several dimensions or aspects of vulnerability, which are characterized by the above mentioned three categories or vulnerability factors. Furthermore, different thematic dimensions can be derived when dealing with vulnerability assessment in Europe:

- *Social*: *refers e.g. to human welfare including mental and physical health, both at an individual and collective level.*
- *Economic*: related to potential financial damage and/or disruption of productive capacity.
- *Physical*: refers to the condition of physical assets including built-up areas, infrastructure and open spaces that can be affected by natural hazards. This dimension depicts locations in susceptible areas and deficiencies in the resistance of the exposed elements.
- *Cultural*: related to the meanings placed on artifacts, customs, habitual practices and natural or urban landscapes.
- *Environmental*: *refers to all ecological and bio-physical systems and their different functions*.
- *Institutional*: refers to both organizational form and function as well as guiding legal and cultural rules

Overall, these dimensions provide the initial basis for a holistic and integrative perspective on vulnerability. A deconstructive approach helps us visualize vulnerability from different angles and perspectives that involve also technological, anthropological, and psychological aspects. Some

[1] Available at: <http://www.desenredando.org/public/varios/2001/ehrisusd/index.html>

aspects have to be addressed with specific methods and modelling approaches. Physical and economic vulnerabilities must be addressed using probabilistic and deterministic approaches associated with damage scenarios and potential economic impacts: social and cultural issues of the vulnerability shall be assessed with reference to demographic, institutional and cultural aspects defined by indicators, population data, statistics and qualitative judgements. A holistic approach facilitates an understanding of vulnerability as a dynamic and changing circumstance or condition (Cardona 2001; Carreño *et al* 2007). 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.

3.3 Understanding exposure to damaging physical events

The *exposure* is the social and material context represented by persons, resources, infrastructure, production, goods, services and ecosystems that may be affected by a hazard event. It is the inventory of components of *society* and *environment* that are exposed to the hazard from spatial and temporal point of view (Cardona 1986, 1990; UNISDR 2004, 2009b).

If population and economic resources were not placed in potentially dangerous locations, no problem of disaster risk would exist. In fact land use and territorial planning are key factors in risk control and prevention. However, due to the intrinsically and fluctuating hazardous nature of the environment, increasing population growth, diverse demands for location and the gradual decrease in availability of safer lands, amongst other factors, it is almost inevitable that humans and human endeavor are many times located in potentially dangerous places. In fact, given that the same places are many times both endowed with natural resources and also periodically exposed to hazard (volcanic slopes, river flood plains etc), location in hazardous areas is all but inevitable. The art of land use and territorial planning, or other forms of rationalizing location is, therefore, to reduce to a minimum unnecessary *exposure* and *vulnerability* to damaging events. Where exposure to events is impossible to avoid, land-use planning and location decisions must be accompanied by other structural or non structural methods for preventing or mitigating risk. Land use plans must be based on location and vulnerability reduction strategies and methods (UNISDR, 2009a).

Clearly the starting point for land use and territorial planning is knowledge of the natural environment, its resource and hazard base, the carrying capacity and limits to human usage, amongst other factors. At the same time, natural and basic sciences may provide information and knowledge as to the limits of the natural environment when faced with diverse humanly promoted land use options and processes and the potential for new humanly induced hazards - e.g. the degradation of aquifers due to urban development; increases in run off rates due to use of asphalt and concrete, and needed urban flood controls; possible local climate changes due to urban growth and the heat island effect.

From the perspective of the social sciences, location is the product of differing economic, social, cultural and political rationales where information on the physical base of the land, carrying capacity, limits to growth etc are “data” or information filtered by social lenses and considered expeditiously or not according to convenience, social, economic and political calculation and needs, amongst other factors. The diversity of contexts to be found may be illustrated at an individual or family level examining two extremes (Lavell 1999).

Firstly, the economically well-off who conscientiously locate in areas known to be exposed to potentially very damaging event such as earthquakes and forest fires, due to the amenity value of these locations, and where they “reduce” risk through the use of safe building techniques, social protection mechanisms and insurance, for example. And, at the other extreme, poor families that locate in highly hazardous areas, due to the lack of access to the formal and more physically secure land market and where the risk of disaster is constantly traded off against the risk of everyday life such that even where they are offered relocation they refuse to move due to the access they have to other survival resources *in locus*. Other sectors of society are located between these extremes and manage other location rationales.

From a governmental angle, although control of hazard factors should be an intrinsic part of governance rationales it is well known that *the local, sub-national, national and international scales* in fact contribute enormously to unsafe location and increases in vulnerability. The granting of building permits in prohibited areas and the provision of basic urban services in areas highly exposed to hazards both serve to “institutionalize risk” and in the end form part of what may be called “implicit” urban policy. Under other circumstances and in other places governments strictly adhere to land use planning and hazard control location principles. Migration, development models, regional commerce, economic dependency, global trends and transitions, among others, are also key issues related to exposure and physical susceptibility at local level. Understanding this diversity of contexts and decisions is an intrinsic challenge for social science research.

As in the case of the study of socio-natural hazard processes, the relations between natural, basic, applied and social sciences in gaining an understanding of location, exposure and sensitivity may at times be one of sequenced inputs, the social interpretation of location and the search for control being based on a knowledge of the "natural" limits to location and the ways in which human intervention can change the nature of the environment and the hazards it presents. An important component of vulnerability assessment is thus the identification of drivers and factors that cause the degradation of ecosystem services diminishing the number and diversity of resources and strategies, which can eventually lead to increased impacts of hazards on the social-ecological system. When ecological resilience declines, ecosystems can shift into less desired states with diminished capacities to generate ecosystem services (Elmqvist 2003; Folke 2005) and the capacity of societies to anticipate, cope and recover from hazards can also be partially or totally compromised. In addition, vulnerable ecosystems may easily shift into undesired states with a diminished capacity to provide ecosystem services to society and increase the possibility that hazards become disasters (Adger 2005).

Seen from a more interactive stance it is once more with regard to research method, stakeholder participation and mechanisms for information and knowledge dissemination that more interaction between the sciences may be foreseen and planned for in understanding and intervening in location decisions. And, a lot of what information access is all about will inevitably pass through the filter of legal requisites and demands. Thus, one aspect of information generation and use is the way in which this is made available to collective or institutional primary decision makers (government and private sector, in particular). Another matter is with regard to the access to information afforded secondary, civil society and family level decision makers. Clearly the relations between social, natural, applied and basic science are fundamental in circumstances where social communication and democratic access to information are critical factors in helping reducing risk.

4 Differentiating risk and vulnerability

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) "risks, then 'are' a type of *virtual reality*, real virtuality." Beck cites Van Loon (2000) who writes: "Only by thinking of risk in terms of reality, or better, *a becoming-real* (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. 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 1990). 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 objectively associated with an activity or a phenomenon and as something measurable in probabilistic terms in order to identify well-defined adverse effects, one can order the risks according to *objective* measures of the probability and magnitude of damage, and resources would be allocated in order to deal with the greatest risks. However, if risk is seen as a social or cultural construction, then intervention would have to be based on different criteria and priorities, and should reflect *social values* and *preferences* for different life styles. These two positions represent the extremes of a spectrum of different positions regarding risk, and both could possibly be biased versions of reality (Renn 1992). Experience shows us that risk and vulnerability are multidimensional, and that differences in culture and social values call for different approaches. Experience shows us that there is no society in which a single criterion has been held to as regards all types of risk. However, the relativist position derived from social constructivism is difficult to justify in terms of its practical consequences when we observe that in many countries similar reduction standards and priorities have been established, despite notable differences in culture and society.

In summary, the conceptual frameworks used to understand and interpret disaster risk vulnerability and the associated terminologies have not only varied over time, but also differ according to the disciplinary perspective considered. Despite the refinement with which disaster risk is considered in the different fields of knowledge, there is, in reality, no singular concept that unifies the different approaches, or that brings them together in a consistent and coherent manner. Although researchers and professionals working in the disaster areas may believe that they are talking about the same concept, serious differences exist that impede the decision-making effectiveness; i.e. successful, efficient, and effective risk reduction implementation (Cardona 2004).

As stated previously, risk is the result of the interaction in time and space of exposed and vulnerable persons, their livelihoods and support infrastructures and, potentially damaging physical events. That means vulnerability is one core component of risk, while risk is the product of the interaction of a hazard event with vulnerable conditions. In this context, understanding risk minimally requires (ICSU-LAC 2009):

- Knowledge about hazards and of the processes by which human intervention in the natural environment leads to the creation of new hazards (socio-natural).
- Knowledge of the processes by which persons, property, infrastructure and goods and the environment itself are exposed to potentially damaging events—i.e. understanding exposure (location and physical susceptibility).
- Knowledge of the processes which contribute to the multi-dimensional vulnerability of persons and their livelihoods and increases or decreases in this social fragility condition— i.e. understanding of the allocation and distribution of social and economic resources in favour of, or against the achievement of resistance, resilience and security.

The conceptual framework proposed herein searches to present a consistent and coherent holistic approach of disaster risk contributing to the effective risk management by policy planners and stakeholders at all levels.

4.1 Risk equations

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* (UNDRO 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:

$$R = E \cdot S = E \cdot H \cdot V \quad \text{(given that } S = H \cdot V\text{)} \qquad (1)$$

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), Cardona 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 Milutinoviç (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[2]:

$$R_{ie} \;\Big|_t = f\left(H_i, V_e\right) \Big|_t \qquad (2)$$

This signifies that once the *hazard* or *threat* (H_i), 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* (V_e), 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* (R_{ie}), 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:

$$C_p \;\Big|_t = f\left(T_a, I_c\right) \Big|_t \qquad (3)$$

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, 1999a, 1999b). 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.

[2] This equation is a definitional circle as the well-known Newton's *F=ma* – the force equals to the mass plus acceleration – where acceleration can be definable by itself by independent concepts, whereas force and mass are co-defined; i.e. one depends on another. Hazard and vulnerability are also co-defined: one cannot be vulnerable if one is not threatened by hazard, and one cannot be threatened if one is not exposed and vulnerable. However, Wittgenstein pointed out that in any level of description the concepts form typically definitional circles.

5 Vulnerability and risk metrics

Risk is manifested in the existence of conditions that signify the probability of loss and damage in the future. Risk is manifest, latent and evident and may be subjected to measurement to the extent knowledge exists or can be generated on the presence and magnitude of diverse risk drivers. To the extent such information exists, an objective, actuarial type of measurement-evaluation- may be attempted equivalent to that which insurance companies exercise when deciding on catastrophic risk or health insurance rates for individuals or collectivities. Subsequently, for informing decision making processes, objective, actuarial risk must be subjected to considerations on perception, social, cultural and economic valorisation—that is to say, assessment.

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 *aleatory* uncertainty. These two types of uncertainty reflect the duality that underlies the concept of probability, and therefore of risk[3].

Probabilistic estimations of risk attempt to predict damage or losses even where insufficient data are available on the system being analyzed. Failure and event trees are used for the analysis, and the probability of damage is evaluated in systematic fashion. This type of 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 (UNDRO 1980; Fournier d'Albe 1985; Petrovsky and Milutinoviç 1986; Coburn and Spence 1992; Woo 1999; Grossi and Kunreuther 2005; Cardona *et al.* 2008a/b; Cardona 2010).

Once the expected physical damage has been estimated (average potential value and its dispersion) as a percentage for each of the assets or components included in the analysis, it is possible estimating various parameters or metrics as result of obtaining the Loss Exceedance Curve, such as the Probable Maximum Loss for different return periods and the Average Annual Loss or technical risk premium. These measures are of particular importance for the stratification of risk and the design of disaster risk intervention strategy considering risk reduction, prevention and transfer (Woo 1999; Grossi and Kunreuther 2005; Cardona *et al.* 2008a/b).

At present probabilistic risk assessment is the result of the evolution from early days of insurance to computer-based catastrophe modelling using advanced information technology and geographic information systems (GIS) for mapping. With the ability to store and manage vast amount of information, GIS became an ideal environment for conducting easier and more cost-effective hazard and loss studies (Maskrey 1998; Grossi and Kunreuther 2005).

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 and 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.

Such actuarial measurement and the subsequent construction of risk indicators will be based on an understanding of the mechanisms by which risk are constructed and on the existence of adequate, objectively verifiable and measurable "hard" core, physical, and "soft" core, social, information**.** That is to say, information on physical events and *hazard* contexts, on factors contributing to *vulnerability,* and on aspects relevant to *exposure*, are requisites for risk evaluation. Risk evaluation can not take place without this diverse information base deriving from natural, basic, applied and social science sources working in an integrated fashion from a common understanding of risk and its components.

"Hard" attributes or factors include *hazards* but also spatial and temporal *exposure* information for delimited territories or social groups on such aspects as: potential physical phenomena, their magnitude, intensity and return periods; the physical characteristics of places; the *susceptibility or fragility* of building materials and techniques; the value of installed infrastructure and production. "Soft"

[3] Such as it is defined by disaster risk modeling platform CAPRA (ERN 2009). See <www.ecapra.org>.

attributes or factors include information on social, economic and political variables affecting location and *vulnerability*; information on attitudes, beliefs and perceptions; information on levels of *resilience*, such as preparedness, human resources and capacities and capabilities to anticipate, cope and recover.

No single assessment methodology is suitable and able to capture all various features of vulnerability and risk. If on one side it is necessary to respond to the need for integrated vulnerability and risk assessment using quantitative, qualitative, traditional and participatory methods at different scales, it is also a challenge to combine different methodologies (Birkmann 2006b). Approaches include quantitative indicators, qualitative criteria as well as broader assessment approaches. A vulnerability indicator is "a variable which is an operational representation of a characteristic or quality of a system able to provide information regarding the susceptibility, coping capacity, and resilience of a system to an impact of an albeit ill defined event linked with a hazard of natural origin" (Birkmann 2006b). 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 et al 2003; Cardona 2006; Carreño *et al.* 2007a, IDEA 2005[4]). 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 *et al*. 2007b). The goal is not to *reveal the truth*, but rather to provide information and analyses that can improve decisions. Taking in mind the need of a holistic approach, in the annex a general description on methodological fundamentals for vulnerability and risk modelling using indicators is presented.

In summary, 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 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.

In addition, it is important to recognize that complex systems[5] 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 weighting or measurement of risk involves the integration of diverse disciplinary perspectives and this may usher in problems of communication and comparability. In other words, in order to measure risk and its management it is necessary a holistic focus (Cardona 2001, 2004, 2006). This type of comprehensive and trans-disciplinary 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

[4] Available at: <http://idea.unalmzl.edu.co>.

[5] This representation is based on a constructive rationality that allows the consideration of uncertain, incommensurable, multidimensional, and conflicting aspects and effects. It departs from the recognition that risk is a condition or state of the dynamics of a socio-ecological, non-linear, and dissipative system as a framework for interactions and for making integrated multi-criteria evaluations (macro and micro) and for decision-making in multiple variable environments.

established with regard to the prevention and planning actions to modify those conditions having a greater influence on risk (Carreño et al 2007a).

Nonetheless, whilst much information may exist for many areas worldwide, in general we are still lacking basic information at a large scale of resolution both on hazard and vulnerability factors. The challenges for social and natural science are still enormous as regards basic research and information gathering. Given the large numbers of communities at risk in any hazard prone area the challenge is not only with regard to information as such but also as regards the methods by which such information can be compiled. This inevitably gives sway to discussions and consideration or participatory, artisan or traditional knowledge bases as fundamental, complimentary measures to formal scientific research.

The development of easily accessible and understandable indicator systems is also a challenge where dealing with local decision makers as opposed to national government and private sector. Understanding information is a first indispensable step in fomenting adequate decision making at different levels. Thus, for example, the type and level of information relevant for a national governmental sectoral agency will be different to that required for local mayors, planning offices or construction companies.

6 Risk Governance

6.1 Disaster risk management

Disaster risk management may be understood as a series of elements, measures and tools directed towards *intervention in hazards and vulnerabilities* with the objective of reducing existing or controlling future possible risks. 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: Disaster management that involves preparedness, emergency response and reconstruction. Disaster 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 nongovernmental actors with the idea of dealing with risk and disaster. In this sense, good *risk governance* means disaster risk management based on, one hand, the involvement of the diverse social, institutional, public, and private forces and groups that exist, on a broad and inclusive territorial basis, and on the other hand, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken (Renn 2005). It follows, therefore, that disaster 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 occupy and utilize them, guiding human actions and activities that affect the environment and vice versa.

For the implementation of abovementioned is a need for a disaster risk management system. This system should be an open, dynamic and functional institutional and organizational structure created with the objective of promoting and facilitating the incorporation of risk management practices and processes in the culture and social and economic development of the community, with the full participation of the population and its organizations. This should be accompanied by adequate orientations, norms, resources, programs, technical and scientific activities and planning mechanisms

There is now an increasing awareness regarding the fact that risk is the essential problem and disaster a derived or associated problem. Risk and risk drivers have become central notions and concepts in the study and practice associated with disaster. This paradigmatic transformation has been accompanied by an increasing emphasis on the relationship between risks and disaster, and development planning and, consequently, with the environmental problem and sustainability. Risks and disaster are now increasingly seen as components or dimensions of development concerns and not as autonomous conditions generated by forces external to society (Lavell 1999, 2000).

Traditionally intervention in the disaster problematic has been considered in terms of the so called “disaster cycle or continuum” which identifies different stages or phases which require different types of intervention. The terms *prevention* and *mitigation* have been used to identify activities that attempt to *intervene hazards and vulnerabilities*, and thus avoid or reduce risk or future disasters and loss; they are related to the society’s *capacity to anticipate*. In addition, *preparedness* activities provide better options for *disaster management* prior to and during disaster, and are put in place prior to the impact of dangerous physical events. Emergency or humanitarian *response* attempts to guarantee human security and welfare immediately following the impact of different physical phenomenon and is related to the *coping capacity* of the society. Rehabilitation and reconstruction activities, on the other hand, attempt to optimally restore, transform and improve the economic, social, infrastructural and life style conditions in the affected zone, granting higher future levels of security through the implementation of activities and actions that control future risk. In this sense, the notion of *capacity to recover* (rehabilitation and reconstruction) has been imbued with the idea of future disaster prevention and mitigation; i.e. the capacity to anticipate. All these capacities and capabilities represent the desirable *resilience* to deal with disaster risk and disasters. Disaster risk management and adaptation mean, therefore, not only the *hazard and vulnerability intervention* but also the *resilience improvement* for sustainable development.

From the perspective of vulnerability and risk reduction is important to make emphasis that *corrective intervention* are related to processes that attempts to reduce "existing" levels of risk in society or in a component of society, product of the historical patterns of territorial occupation, production, construction of infrastructure, amongst other things. It reacts to and compensates for risk that already exists in society. Examples of corrective risk management methods or instruments are the construction of dams and dykes to protect population already located in the flood plains of rivers, the retrofitting of buildings against earthquakes and hurricanes, changes in cropping patterns in order to adjust to adverse environmental conditions, reforestation of river basins in order to diminish existing processes of erosion, landslides and flooding. On the other hand, *prospective intervention* refers to the anticipation or prevision of risk that may be generated with "future" development projects and investments. It comprises measures taken to guarantee that new risk factors do not appear with new initiatives in construction, production, infrastructure, transport and commercialization. Prospective intervention must be seen as an integrated part of development and project planning, whether these are developed by government, private sector or civil society. The final objective of this type of intervention is to avoid new unnecessary risks guaranteeing adequate levels of sustainability for new investments and thus avoiding the need for more costly corrective intervention later.

6.2 Decision making for risk management

The challenge for the natural and applied sciences is to provide relevant information to individual and collective decision makers, especially on potential consequences and possible strategies to reduce risk. However, basic scientific information is not enough. Effective risk management also requires a good understanding of the underlying vulnerabilities, as well as effective communication and dissemination of risk knowledge. As disaster risk is not an autonomous or externally generated circumstance to which society reacts, adapts or responds (as is the case with natural phenomena or events per se), but rather, the result of the interaction of society and the natural or built environment, it is in the knowledge of this relationship and the factors influencing it that effective risk management can be achieved (Susman *et al.* 1983; Comfort *et al.* 1999; Renn 1992; Vogel and O'Brien 2004). This requires varying types of relationships and coordination between social and basic, natural or applied sciences (ICSU-LAC 2009).

Previously we have suggested that the overall objective of research, analysis, understanding, evaluation, assessment etc. should be the provision of information and knowledge that facilitates and promotes decision making in favour of risk reduction and control. In this sense the three previously discussed aspects are all part of the needs and process of decision making. However, decision making seen as a theoretical process and decision making seen in terms of real life and decisions are two different things. And, unfortunately, we know very little as regards the real processes that have informed many significant decisions as regards risk management practice. Moreover, we are also lacking in terms of understanding the process of "no decision". That is to say, the process by which action was rejected by decision makers.

Decision making as an object of scientific enquiry may serve as a means of putting in perspective the three formerly discussed areas for research and interdisciplinary collaboration. The study of the decision making process, in both successful and unsuccessful cases, at different societal levels and in different societies, synchronically and diachronically, could, amongst other things, help enormously in fostering a better understanding of the socio-natural interface and the ways in which knowledge construction is better fostered by closer conceptual and practical relations between the disciplines and in their relationship to the users of information, the direct stakeholders in the decision process (ICSU-LAC 2009).

Risk mitigation (corrective) and risk prevention (prospective) interventions are achieved where decisions are taken to implement different schemes and practices. These decisions may be taken by organizations, governments, groups or individuals. Coming to a decision requires information and must be made in the context that encompasses the actors taking the decisions. Our knowledge of decision making associated with disaster risk mitigation and prevention is scarce. Why, under what circumstances, due to what motivations, using what information and what parameters are often time unknown factors. This relates to national government with regard to national policy, to local governments with regard to local plans and as regards particular acts such as retrofitting, dyke building, putting risk considerations in project planning processes etc.

An understanding of the complexities of decision making on various different levels in various countries, related to both *corrective* and *prospective* interventions would greatly help actors understand how things get done and on how to get things done. Understanding the relationships and roles of natural and technical sciences as compared to policy makers, economists and other social science based actors, would also help both sets of actors comprehend how they have and could collaborate in getting decisions taken. Our understanding of decision is many times incorrect and we assume that certain processes such as cost benefit analysis are significant in all decisions taken by government or private sector. This is not necessarily true.

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, it is necessary to develop less rigid planning models that allow 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.

7 Adaptation

The framework of Figure 1 includes all those elements widely accepted as part of risk and its management (hazards, society, risk, risk governance) by the disaster management community but also introduces the notion of adaptation. This is a major contribution moving beyond existing theoretical and organisational discussions on the relationships between Disaster risk Management and Climate Change adaptation to provide a framework for the derivation of detailed indicators of adaptation and how these might compare for example with existing indicators for coping and resilience. This is helpful in forcing a degree of detail and clarity in the choice of indicators and their input variables. The conceptual framework in Figure 1 does not follow the common distinction of coping/adaptation as one of timeframe (coping implying short term actions, and adaptation being longer term). Instead it makes a distinction between those acts that are aimed at the best ways of living with an identified hazard (resilience) and those aimed at efforts to adjust practices, goals and values to a new reality of uncertainty and a dynamic hazard landscape (adaptation). The utility of this approach and indeed the value added of including adaptation and coping in the same framework will be one of the key outcomes of the case study work in WP 3. Adaptation is in this understanding not only a product of those actors exposed to climate related hazards, rather it is the outcome of a wider range of actions undertaken by various stakeholders inside and outside the exposure zone of a specific hazard. Adaptation includes components on exposure reduction, susceptibility reduction and resilience improvements that correspond to the three components of vulnerability. Adaptation is described by those processes that: (1) allow or hinder self or external reflection on the appropriateness of actions taken to live with risk and (2) allow or hinder action to be taken to change the practices, goals and values of an actor at risk in the light for example of the uncertainty and extremes associated with climate change. However, adaptation is in this understanding not only a product of those actors exposed to climate related hazards. Those exposed to geophysical hazard will also exhibit adaptation in response to new scientific information or changing social contexts such as rapid urbanisation in earthquake prone locations. Both resilience and adaptation are likely to be described by indicators that include process and output. Process indicators might include for example evidence for social learning and self-organisation. Output indicators would note the existence of risk plans, insurance etc.

7.1 Climate change adaptation and risk management

Disaster risk management concepts and experience have been developed in the light of historical and projected future contexts of hazard and vulnerability. When dealing with climate related aspects this can be seen in the light of hazards associated with what may be referred to as "normal climate variability". Adaptation to climate change, on the other hand, has been developed as a notion and sought practice through other professional and institutional modalities as if it were a separate and discrete area of knowledge, directed to future climate conditions influenced by human intervention, using scenarios which go up to 50 or 100 years ahead.

This false separation of two clearly related topics is the product of historical and institutional reasons and must be dissolved in the interest of advances on both risk fronts—now and then. It is clear that the central problem for both communities is risk in society associated with physical, hydro-meteorological, hazards, the ways new hazards, or extremer versions of ongoing hazards, interact with exposure and vulnerability conditions to produce greater risk in society, and with regard to ways of reducing or controlling this risk.

Disaster risk management has developed principally with regards to existing risk—corrective risk management. However, the line of thought developed more recently with regard to prospective risk management (i.e. anticipating and controlling future risk) is clearly of absolute relevance to the so called *adaptation to climate change* problematic and can be used as a bridging concept between the two areas of reflection and enquiry. Adaptation means "adjustment" in natural or human systems to a new or changing condition; i.e. the ability of an individual or group to adjust to changes in the natural and built environment. Overall, adaptation can be anticipatory or reactive, autonomous and planned. Adaptive capacity requires techniques and strategies to be devised that enable society to absorb and deflect the impact of hazards (ICSU-LAC 2009).

Overall, there is the need to have compatibility between the terminology of disaster risk management and climate change adaptation. There are differences that only in the future can be resolved but more relevant terms can be associated without difficulties. Coping, for example, can be related to emergency response and defined as the actions implemented immediately following the impact of a hazard event, anticipated in the preparedness or emergency planning stages and preceded, in some cases, by readiness and mobilization activities, as a reaction to warnings. Coping or emergency response comprises an immediate reaction geared up to guarantee opportune attention for the affected population. Other example is the concept of capacity to recover and recovery that can be defined as the process by means of which adequate and sustainable living conditions are restored in the affected area or communities. This may be achieved by means of rehabilitation, repair, reconstruction or replacement of destroyed, interrupted or deteriorated infrastructure, goods and services and through the reactivation and promotion of economic and social development in the affected community. Finally, it is important to mention the notion of capacity to anticipate and its relation to risk prevention and reduction. Both can be defined as the ordered and coherent set of strategies, programs and projects that orient activities favoring the reduction, prevision and control of risk and emergency preparedness and post impact disaster recovery. The achievement of appropriate levels of security when faced with a range of risks, and reduction of the material losses and social consequences associated with disasters, leads to improvements in the quality of life and sustainability of the population. In other words, adaptive capacity, anticipation and risk mitigation are related to corrective and prospective intervention measures that change or reduce existing or possible future risk conditions. These comprise prevention-mitigation and preparedness measures adopted prior to the appearance of a threatening phenomenon with the aim of: a) avoiding the presence of the dangerous phenomenon, reducing its threat level or reducing the levels of exposure of the different social elements; b) reduce its effects on the population, infrastructure, goods, services and the environment, by reducing their vulnerability (IDEA 2005).

Research must be stimulated which, on the one hand, clearly identifies changes in the semantic, spatial and temporal patterns of hydro-meteorological hazards and accompanying exposure and vulnerability factors, including, very importantly, evidence of such changes associated with climate variability and climate change during recent periods (under the notion that climate change is now under way). And, as regards the ongoing processes by which populations in areas where climate can be seen to be changing today and which have traditionally been required to deal with climate variability extremes, have dealt with such contexts through historical or ongoing prevention, mitigation, risk reduction or adaptation schemes. Knowledge of ongoing processes of risk reduction and control will help enormously in understanding and promoting adaptation in the more distant future, within the overall context of more wide-ranging global and change. The options for such adjustment in the future rests on our ability to deal with today's problems and significantly control existing exposure and vulnerability trends, many, but not all, associated with poverty.

8 Difference between evaluation and assessment

Although clearly related, evaluation and assessment of risk are two different, if sequential aspects of importance for risk management. Whereas evaluation signifies the maximum objectification of risk in terms of probable losses and damage, assessment requires the placing in perspective of such losses with reference to the general life system and goals of affected or interested parties. This putting in perspective can be seen from an economic, social, cultural, historical, life style or political angle. Significant risk (that is to say, that for which a solution must and will be sought) will differ as a notion according to different social and psychological variables operating in different societal settings. An understanding of these factors is critical for both understanding risk construction but also the opportunities and options for risk management mechanisms.

Mechanisms for vulnerability and risk assessment vary from the strictly formal to the informal and subjective (but not because of that, unscientific) measures. Thus, whilst a government or private company may engage in cost benefit analysis in order to substantiate decision making, studies also show such organizations using less “formal” measures and subjecting decision and non decision to assessment processes based on strictly political or “emotional” characteristics (the notion of blame reducing policies fits here). Individuals and families will probably assess risk in varying different ways according to circumstances, income, social class etc.

Assessment in terms of what criteria are used will vary group to group, individual to individual. Poor communities will always go way beyond “assessment” methods and processes that take disaster risk factors as their point of departure. Therefore, for instance, where poor communities in developing countries reject relocation to “safer” areas when offered this option by local government, NGOs etc. such rejection is many times not based on strict evaluation of disaster risk but rather on the comparison between gains accruing to changed location and advantages of staying put—economic, cultural, social, historical. That is to say, disaster risk is compared to every day risk aspects in order to substantiate decisions.

With regard to risk assessment it is clear that many of the techniques are firmly based in social science methods and practices—they imply social and economic assessment in some way or another, whether formal or informal, objective or perceptive. However, whatever the technique or social criteria used as a base for assessment, this is always done in a context typified by an existing, objectively identifiable hazard context. The nature of the information available on these contexts, the availability of easily accessible and understandable information, the accuracy with which information is seen to be produced and the accuracy of risk predictions associated with this are all fundamental assessment parameters and inputs. Thus, assessment inevitably signifies a consideration of information, data, the ways it is generated, the means by which information is more easily accepted and confided in by users, mechanisms for user appropriation of information and the mechanisms for its generation etc.

Thus, even where assessment is a social technique, inputs for it and methods of achieving it are inevitably interdisciplinary. Active participation in the process of assessment and understanding of this by natural, basic and applied science practitioners can only lead to a more ample understanding of how such processes are enacted and, therefore, as regards the variables taken into consideration in decision making that go beyond simple scientific “fact”. With these, improvements in methods of data collection and data dissemination may or could accrue.

Lastly, despite what many believe, the design of a public policy like disaster 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.

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