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WP 2: Integration and Connection of Vulnerabilities

Del. 2.1.2:

Relation between systemic and physical vulnerability and relation between systemic, social, economic, institutional and territorial vulnerability

Reference code: ENSURE – Del. 2.1.2



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Short Description:

This Deliverable deals with the interaction between different types of vulnerability by following a systemic approach. It also investigates how systemic vulnerability receives influences from other domains of vulnerability. Relationships between different types of vulnerability and linkages among systems are revealed, using a theoretically informed case study approach.

Authors and co-authors: HUA (K. Sapountzaki, L. Wassenhoven, Y. Melissourgios), POLIMI (S. Menoni, S. Kundak), BRGM (N. Desramaut, H. Modaresi), MDX (D. Parker, S. Tapsell), PIK (J. Kropp, L. Costa), TAU (G. Kidron), UNINA (A. Galderisi, A. Profice).

Partners owning: HUA, POLIMI, BRGM, MDX, PIK, TAU, UNINA.

Contributions: HUA, POLIMI, BRGM, MDX, PIK, TAU, UNINA.

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List of Abbreviations

AFPS	Association Française du Génie Parasismique
AUA	Agricultural University of Athens
CDC	Center for Disease Control
CDM	Criteria-Development Matrix
COEN	Comité de Emergencia Nacional
CRS	Congressional Research Service
DoW	Description of Work
EPA	Environmental Protection Agency
HMSO	Her Majesty's Stationery Office
ICOMOS	International Council on Monuments and Sites
IEEE	Institute of Electrical and Electronics Engineers
ISTAME	Institute of Strategic and Development Studies
JNF	Jewish National Fund
JSCE	Japan Society of Civil Engineers
MCEER	Multidisciplinary Center for Earthquake Engineering Research
NMSU	New Mexico State University
NO	New Orleans
NOAA	National Oceanic and Atmospheric Administration
NRA	National Rivers Authority
OCHA	Office for the Co-ordination of Humanitarian Affairs
QOL	Quality of Life
UHI	Urban Heat Island
UN	United Nations
UNEP	United Nations Environment Programme
USGS	United States Geological Survey
WMO	World Meteorological Organisation
WTO	World Tourism Organization
WWF	World Wide Fund for Nature

1. Executive Summary

The main objective of this part of the Del 2.1.2 is to reveal the interaction between different domains of vulnerability, viewed from the perspective of a systemic approach. We know from the experience of several past disasters that physical damage is only one of the reasons for systemic failure. In this task an assessment has been made of the extent of physical damage as a relevant stressor for complex systems and the potential relation between systemic, social and economic vulnerability has been explored.

In the occurrence of natural hazards, according to the level of interconnectivity among vulnerability aspects, chain reactions alter the size of impacts which may extend all the way to a large scale disaster. Although the relationships among vulnerabilities are quite complex, it is obvious that these relations can be the cause/root of one another, but also of the transformation of one into the other. Ecological and institutional vulnerabilities in particular are the best examples to demonstrate that vulnerability has a dynamic structure, as shown in the case studies in Del 2.1.2. On the other hand, vulnerability of a territorial system is the appropriate framework to evaluate connections and influences between several vulnerability facets.

Notwithstanding the fact that systems have their own internal vulnerability, they are also exposed to, and affected by, external factors which might constitute the internal vulnerability of another system. In interconnected systems (here referred to as super-systems) the sum of these internal and external vulnerabilities forms the essence of systemic vulnerability. We can detect vulnerability either to stress or to losses, where the former is reflected in losses due to stress (hazard) and the latter is related to certain thresholds of losses being exceeded in "juxtaposed", i.e. systemically connected systems.

Response capacity, on the other hand, has strong bonds with exposure which is defined here as a function of location in the geographical, social, economic, political, psychological and technological space. Resilience of a system or a super-system affects both response and coping capacity and, through the latter, exposures too. This is so, because, by definition, resilience refers to an actor or system which is capable to develop inherent – or abstract from the environment – resources to be efficiently used for response and recovery.

A primary objective of this review is to look at how systemic vulnerability receives influences from other domains of vulnerability. Consequently, case studies are crucial in order to extract concealed linkages among systems. Moreover, even if physical vulnerability has great influence on systemic vulnerability, the development process or the root causes of physical vulnerability can be found too in social, economic and institutional vulnerabilities. Therefore this system of linkages points to the need of a comprehensive approach to analyze vulnerability.

The perspective charted in this deliverable makes it easier to define (or arrive close to) a definition of) the concept of resilience. Whilst definitions of vulnerability of systems can be given either according to those of sub-systems or from an overall view at the system level, response/coping capacity and resilience usually refer, or become more understandable when described in terms of the total capacity of combined systems in coping with the impacts of hazards and in recovering losses.

2. Introduction

The present Deliverable 2.1.2 is devoted to the investigation of relationships between systemic and other forms of vulnerability (physical, social, economic, institutional, territorial). An essential pre-condition for this objective to be attained is a thorough understanding – and an agreeable among contributing partners delineation – of the scope of the terms “System” and “Systemic Vulnerability” (by taking into account the focus of the ENSURE project). In particular, there is a need of answers to the following questions:

- Is “systemic vulnerability” identical to “vulnerability of a system” or the term can be used as expressing also the result of parallel action and interaction between social, economic, physical and other forms of vulnerability?
- How can we delimit systems as distinct vulnerability carriers? Or – in other words – what is the appropriate level or scale for systems’ identification, one that facilitates detection of relationships among different systems’ vulnerability and between a system’s and its subsystems’ or constituent elements’?
- What kind of systems are of interest as “inherent vulnerability carriers” (internal vulnerability) or as agencies of vulnerability influence on other systems (external vulnerability)?

The above queries are dealt with in Section 3.1, where relevant assumptions are also set. The titles and content of the four Chapters that follow, i.e. 4, 5, 6 and 7 indicate that Technical and Techno-human systems, Institutional systems, Ecological and Eco-human systems as well as Territorial systems have been selected and elevated as highly relevant to “vulnerability carrying”, “vulnerability balancing” and “vulnerability interchanging systems”.

Another issue for clarification is the content and meaning of the phrase “relationships among different forms of vulnerability”. What kind of relationships are we after? Are we in search of relationships of causality, relationships of influence or more dynamic relationships of successive activation of different forms of vulnerability, one after the other? The answer to this question is highly relevant to our end-objective of integrating vulnerability aspects and measuring the total potential in every case of carrying entity. Indeed in the case of a more dynamic relationship some forms of vulnerability may owe their generation and existence to other fundamental forms functioning as basic producers. Hence, Section 3.3 brings into question various possibilities of vulnerability relationships in order to be tested, confirmed, rejected or extended subsequently by the case studies that follow in Chapters 4, 5, 6 and 7.

The introductory and theoretical Chapter 3 deals with two more conceptual issues that proved to be worthy as methodological tools throughout the Report:

- The distinction between “vulnerability to stress” and “vulnerability to loss”, i.e. a conceptual device which at first exhibits the extent to which vulnerability is affected by or depends on hazard (or not) and secondly facilitates representation of dynamic relationships between the various vulnerability aspects (Section 3.2);
- The cognate to vulnerability or constituent attributes, i.e. “coping or response capacity”, “exposure” and “resilience”; these are involved in vulnerability interactions, probably as barriers or facilitators of vulnerability changes (Section 3.4).

Chapter 4 focuses on identifications of relationships between physical and systemic vulnerability that is how physical damage may affect systems either directly or indirectly. Physical damages on infrastructures and critical facilities may trigger induced effects and cause obstacles in response activities. Location and redundancy of emergency and public services are critical therefore they are key indicators of coping capacity of the entire system. On the other hand, lifeline disruptions, especially transportation, have medium-to-long term

impacts on both social and economic life of affected and surrounding regions. The case studies in Chapter 4 indicate how physical losses affect functioning of services and consequently coping capacity of emergency and recovery mechanisms; and also how long term systemic failures cause isolation and decline of settlements and wider regions.

Institutional systems and their inherent vulnerabilities are underlined in Chapter 5. Institutions, hereby we mention political and administrative systems, have, first of all, their own propensity to losses (in personel, equipment, movable and immovable assets etc). Besides, lack of planning at every level (management, mitigation, recovery, resources etc.) gives rise to additional internal vulnerability of institutional systems. Furthermore, coordination among agencies is another crucial component to define institutional vulnerability as well as resilience. Propagation of vulnerability of an institution to another and/or failures in communication may lead to further consequences following disasters. On the other hand, social habits and economic structure have also influences on how to manage institutional system. Reciprocally, institutional vulnerability triggers disruption of socio-economic life in direct or indirect ways.

Chapter 6 is devoted to vulnerability of eco-human systems and also refers to the effect of systemic vulnerability on social and economic structures and vice versa. Ecological systems are more vulnerable to some natural hazards such as wild fires and drought. Hereby, the emphasis is on causes and consequences of these two phenomena. Moreover, industrial accidents triggered by other natural hazards (such as earthquake, flood, landslide etc.) have collateral impacts on ecosystems due to release of chemicals and/or fires.

Territorial systems, as defined in Chapter 7, are the material and immaterial entities shaped by physical factors and social, economic and institutional forces. No territorial system can be identified as completely resilient or vulnerable. On the contrary, weakness and strength are usually next to each other in the system. Nevertheless, the vulnerability situation created as a result of synthesis and mutual interactions among the vulnerabilities of the constituent elements (or subsystems) of a territory might be considered as territorial vulnerability. Coping capacity and resilience are probably connected with the notion of territorial cohesion as long as they refer to all available resources of a given geographical region to deal with and to recover from disasters.

The aforementioned case studies given in Chapters 4, 5, 6 and 7 by turning to advantage primary or secondary published material testify, confirm/reject and extend theoretical assumptions laid down in Chapter 3. The concluding Chapters 8 and 9 recapitulate and highlight the most important findings of the Report regarding both conceptual tools for integrating vulnerability aspects and revisited terms and theoretical assumptions.

3. General concept and objectives

3.1 General framework and explanation of systems and systemic vulnerability

It is first necessary to clarify our position on the use of the term "systemic". In our view the term is central to our approach. We are concerned with systems and systemic effects. This by definition implies that we are concerned with relationships and feedbacks, which are the essence of a system. We are also aware of the fact that a system is made up of subsystems and is itself a subsystem of other systems, with multiple overlaps between systems and subsystems. Finally, we know that individual components of a system may belong to a

variety of systems and even that this property of belonging is liable to change and is activity-, time- and space- dependent. It may be dependent on other attributes too, some of which may be highly abstract, even symbolic and value-laden. Thus an external stress at a particular point in time may have systemic repercussions over the extent of systems which are not stable but depend on the circumstances of the particular situation at a given moment. The fact that in theory there are innumerable systemic impacts should not deter us from our objective of pinpointing those with recurring effects which are manifested as a result of hazard situations.

The use of the term “systemic”, e.g. when reference is made to “systemic vulnerability”, is not limited to vulnerability and associated chain-effects of engineering systems, lifelines and infrastructure networks, or to that of public facilities, such as hospitals, and of ecological systems. It equally applies to other complex “wholes” (social, economic, spatial), which clearly exhibit systemic behaviour. Hence, “systemic vulnerability” is not restricted to hard infrastructures or natural ecosystems. The starting point in the DoW where the relationships between different forms of vulnerability have been considered worthy to investigate was linked to an initial picture which is provided below (Fig. 1).

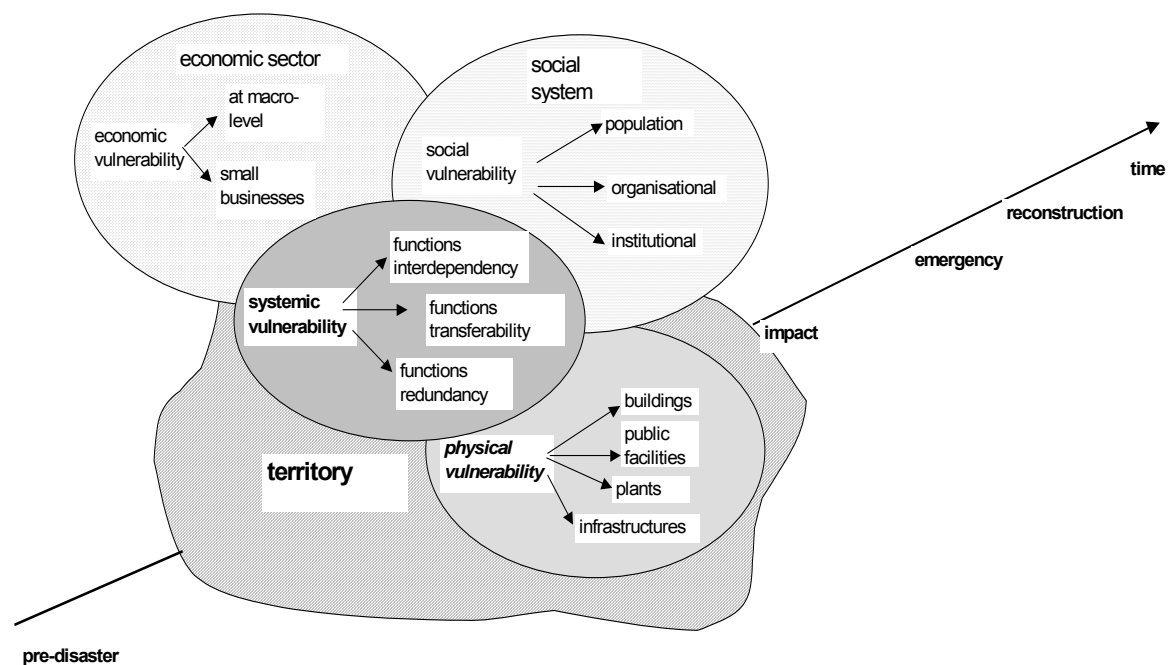


Figure 1: Relationships between different forms of vulnerability

This initial framework can be revised and transformed into a new representation as shown in Fig. 2. As indicated in this diagram, vulnerability facets have strong relationships among them, therefore this systemic condition makes difficult to measure vulnerability at a certain point without considering reflections from other components. The diagram shows a simplified evaluation of systemic vulnerability and its components. Physical vulnerability covers vulnerabilities of the built-up environment, including those vulnerable elements that may trigger na-techs. On the other hand, in physical vulnerability, there is also an interactive circle presenting collateral hazards triggering each other (e.g. collapse of a building triggering off fire or explosion caused by breaking gas pipes).

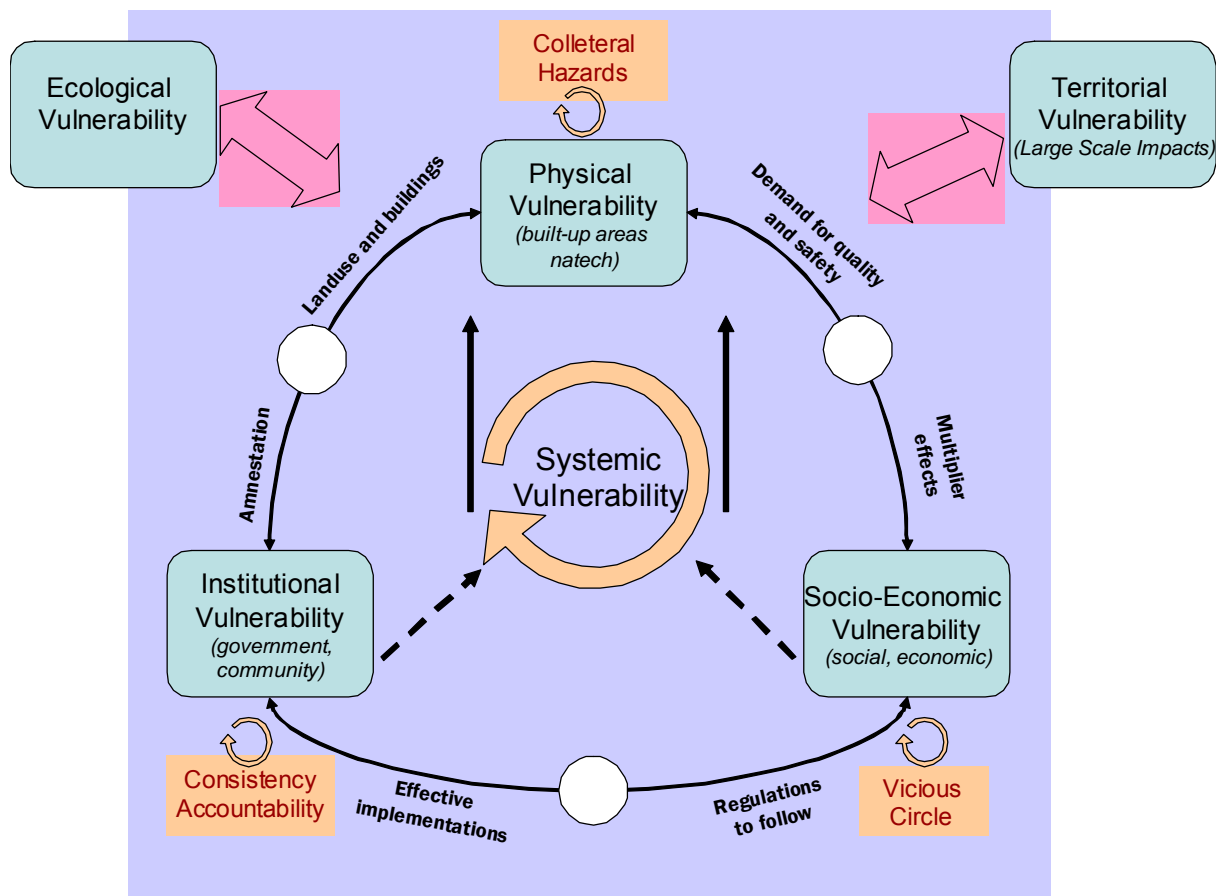


Figure 2: Interactions between different forms of vulnerability

With regard to socio-economic vulnerability, we can mention the existence of a vicious circle process whereby social development is connected with, and affected by, welfare from economic activities and vice-versa: economic development is fed by social integration, equity, democracy etc. Institutional vulnerability refers not only to governmental (or legal and statutory) structures but also NGOs which make a notable contribution to the institutional system. The contemporary governmental system requires transparency, accountability, responsibility, commitment, effectiveness, participation and democracy, all attributes of a "governance" approach. From the point of vulnerability, single authority and rigidly hierarchical systems usually tend to increase and propagate vulnerability at every level of social and economic life.

Systemic vulnerability is situated in the middle of these three main components cited above because it results from the contribution and of course inter-connectedness of the various components mentioned above. In the diagram the major interaction of systemic vulnerability is observed with the physical environment. However, as physical environment constantly receives feedbacks coming from both institutional and socio-economic vulnerability, it can be noted that systemic vulnerability presents a strong relation with these two as well. It can be argued too that the systemic character of the complex network represented in the diagram has a territorial dimension. Indeed, the grey area of the diagram could represent the territory within which these mutual interactions operate.

Looking at past disaster experiences, it can be observed how vulnerability levels grow dynamically through mutual interaction and how vulnerability facets affect each other. For instance, between physical and socio-economic vulnerability, there are strong linkages coming from transfers of physical to economic vulnerability which can generate multiplied effects. These multiplied effects are part of the economic impacts in which there appear

“countervailing forces” (i.e. decrease/increase) as shown in Figure 3. The relation between institutional and socio-economic structures can be looked at in terms of demand and regulations. Institutional structures produce regulations for socio economic development and community is the key actor for effective implementation. In the relation between institutional and physical structure, it is expected that the second is affected by regulations such as those stemming from land use planning and building codes. However illegally produced built environments have a deteriorating impact on the institutional context.

Territorial and ecological vulnerabilities can be evaluated within a spatially-bounded unit or at a macro-scale scale encompassing the various influential vulnerability components which may be part of wider ecological or spatial systems.

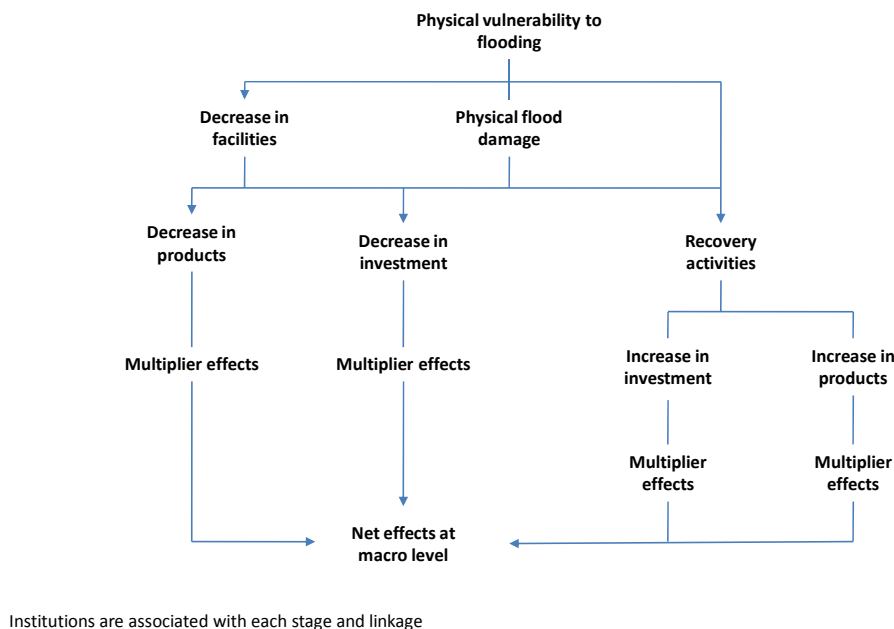


Figure 3: Transfers of physical vulnerability effects to economic vulnerability, and the multiplier linkage effects between economic processes and associated institutions

3.2. Vulnerability to stress and vulnerability to losses

Several authors remark the importance of distinguishing between vulnerability to stress and vulnerability to losses. The first can be viewed in our DoW proposal as physical vulnerability that is the propensity of a given object, of a system component or a person suffering direct losses and physical damage as a consequence of the stress provoked in the environment by the extreme event. As suggested in the *Armonia* project, physical vulnerability depends on the characteristics of the stress, in the sense that for example an artefact may be vulnerable to earthquakes but not to floods and vice versa.

Vulnerability to losses is somewhat more subtle, as it addresses the potential response capacity of systems to partial (or total) damage which occurred in one part of the same system or in parts of other systems with which connections exist. Going back to our DoW,

vulnerability to losses is embedded in the concept of systemic and functional vulnerabilities. The main idea in this case is that a system may continue (or not) functioning even though a part of it has been disrupted or even though systems from which it depends have stopped functioning. Systems' vulnerability depends in this regard on what Van Der Veen and Logtmeijer (2005) defined as "transferability", "interdependence" and "redundancy" that is relevant not only to economic systems but also to infrastructures, public facilities, community services, etc. Distinguishing between vulnerability to stress and to losses introduces a dynamic component in the analysis that is often lacking in risk assessment, where exposed systems are considered as fixed while their changeable conditions, particularly after a severe event, are rarely taken into account.

In looking at different types of vulnerability, one should also take into consideration time factors as well as phases of the disaster cycle when a given type of vulnerability becomes more prominent. In this respect, it may be useful to consider the scheme on the following page (Fig. 4) depicting sequences of vulnerabilities (to stress and to losses).

This framework has been conceived for seismic risk, though it holds validity in other cases too (which actually deserve to be investigated). What is represented here is a chain of damages deriving in a dynamic way one from the other to constitute a given event scenario. Objects manifest physical vulnerability, i.e. physical damage that may occur as the result of the physical stress and its impact. Induced physical damage depends also on vulnerability to secondary triggered hazards (like fires, na-tech, landslides, lahars, etc.). Systemic damage occurs as the result of some physical damage to objects that are crucial in given systems and in systems that are crucial to other systems.

To simplify an already very complex issue, we may assume that different types of vulnerability become more prominent in different phases of this chain. If we include in the chain also the "disaster phasing" in terms of pre-impact, post impact-emergency and post impact-reconstruction, we will have a more satisfactory and comprehensive understanding of interaction among vulnerabilities. The "complex chain" concept is central to a systems approach as it follows not only the systemic logic of component relationships within a system, but also that of systemic connections or "leaps" that link the given system with broader encompassing systems. It can be argued that these chains of interaction may be dependent on the importance and linkages of a component or system under stress with others and the economic, political or other conjuncture. Thus an extreme event incapacitating a major transport or energy terminal may have systemic chain-effects of an international political and economic nature. Whether this may appear as a comment on the argument about hazard – dependent and hazard – independent vulnerabilities is difficult to ascertain. This argument will be better addressed on the basis of empirical material which will be hopefully generated in the project.

The conceptual chain of events allowed us to derive the "story line" from the risk of a forest fire to occur to the time of its extinction. Climate contributes to almost all phases of the hazard. Type of vegetation and landscape structure play an important role on the fire risk, rate of spread and fire extinction. External causes such as the ones represented in the blue squares influence directly aspects such as fire lighting and vegetation leading to indirect but significant consequences on the hazard chain sequence. Fire fighting is an end line solution to deal with the hazard, on the other and, we see from the theoretic representation that more should be done in other stages of the hazard in order to minimize the adverse effects.

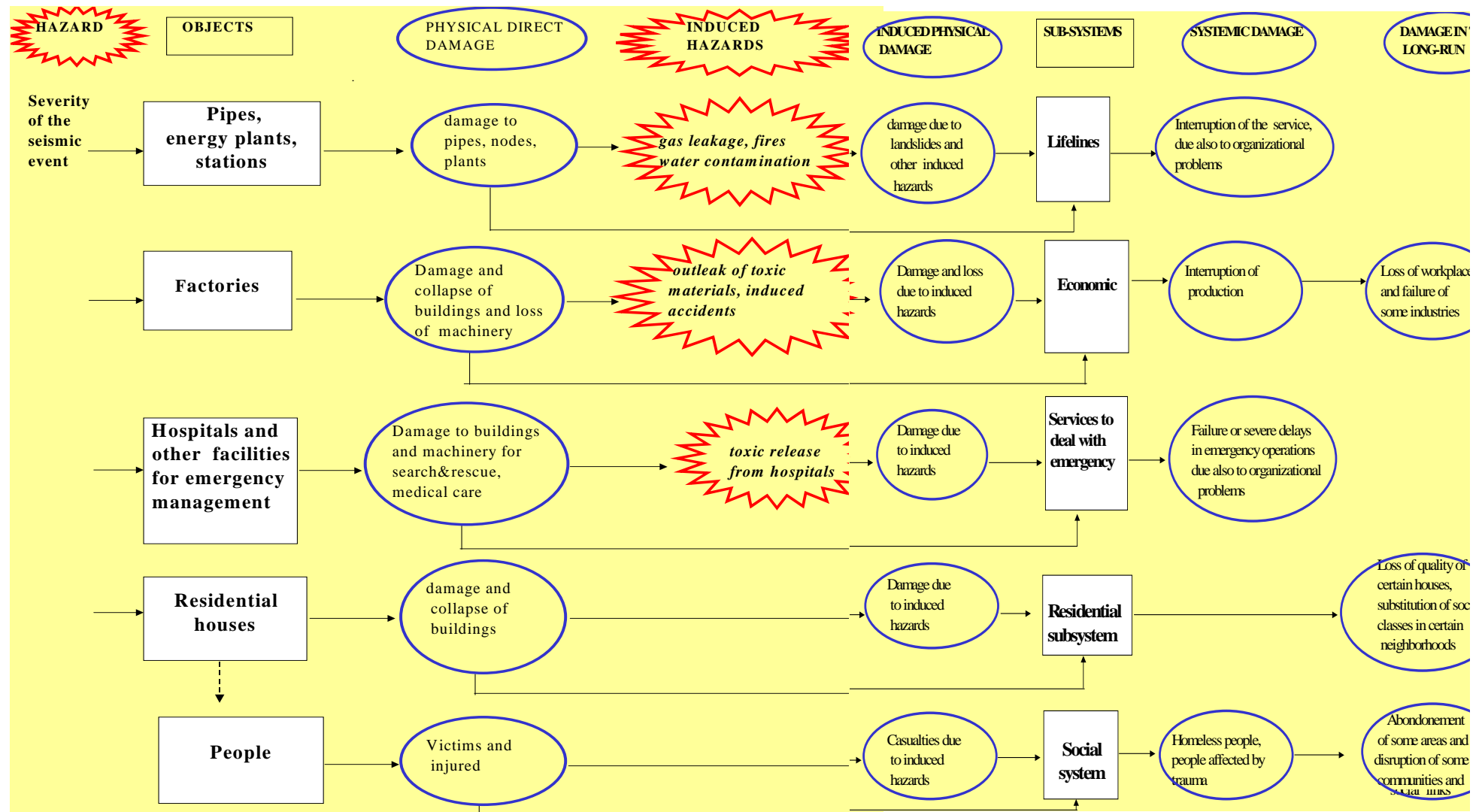


Figure 4: Complex chain of disasters

The impact chain identifies the main direct and indirect impacts of a forest fire. The impacts propagate much further into the economic and social system than usually reported. The threat for ecosystems does not only derive from the extent of the burnt area and it is not confined to the place where fire occurred. Threats to biodiversity depend on the frequency of forest fires and the impacts propagate in space affecting water courses and population. Population is affected differentially during and after a forest fire, furthermore, consequences in human health can be traced to locations distant from the occurrence site.

For the reason already mentioned above, it is worth to observe in detail how impacts propagate in time and space during and after the occurrence of a forest fire. Figure 5 is an attempt to describe with some detail the impact set in place by the occurrence of a forest fire.

Direct effects of forest fires can be perceived on infrastructures, ecosystems, air quality, residences and humans. Damage of infrastructures such as roads, communication and power-lines may have an additional impact of making difficult the coordination of fire fighting and possible evacuation actions. The immediate impact of a forest fire on ecosystems is the loss of habitat and vegetation; nevertheless, the secondary impacts after the fire is extinct are substantial and sometimes understated by the media and decision makers tending to focus much more on numbers of forests lost or number of ignitions. Loss of vegetation, and therefore loss of physical support and protection of the soil against weather related phenomena enhances the erosion process, leading generally to large inputs of sediments into the water courses. Due to lack of vegetation, the field capacity of the soil (the amount of soil moisture or water content held in soil after excess water has drained away) is reduced. If high amounts of precipitation occur after a forest fire, the immediate consequence is a higher risk of flooding on locations downstream since much of the water retention capacity of the soil has been lost. Forests act as mercury traps because mercury in the atmosphere (which comes from both natural and human-generated sources such as coal-fired power plants and municipal waste incinerators) collects on foliage. When the foliage dies, it falls to the forest floor and decomposes, and the mercury enters the soil. When the foliage burns the mercury is released to the atmosphere and then deposited in forests and lakes. The consequences of this release propagate in the ecosystem, for example, fish have a natural tendency to concentrate mercury in their bodies, often in the form of *methyl mercury*, a highly toxic organic compound.

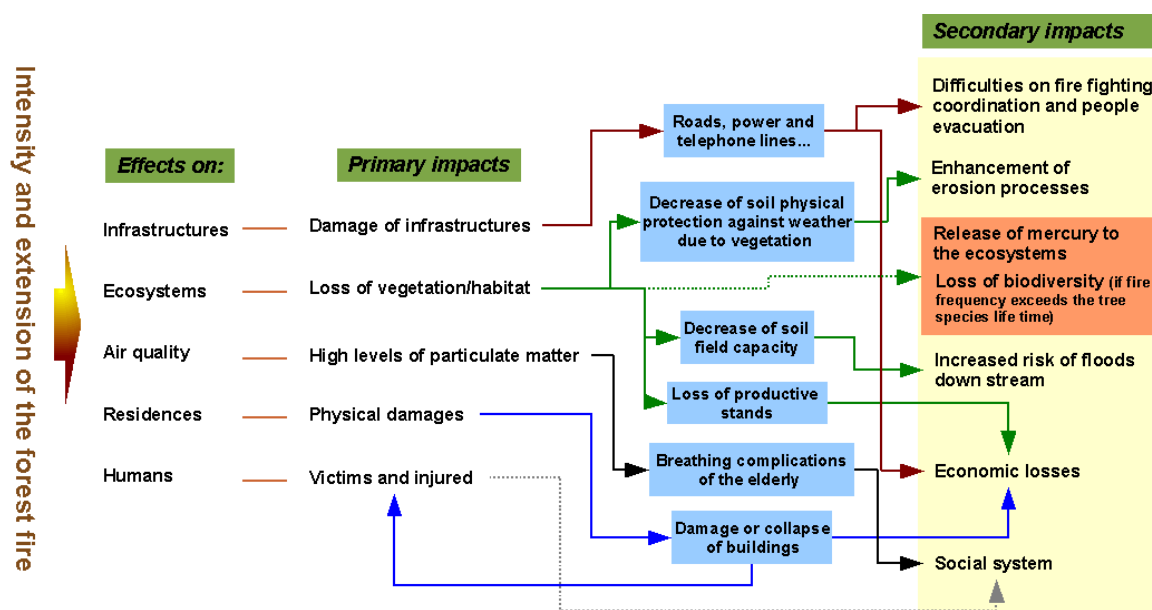


Figure 5: Complex impact chain due to the occurrence of a forest fire

The amount of particulate matter released into the atmosphere (due to the combustion of vegetation) has an impact on fire fighters and population directly affected by the forest fire. However, due to the aerodynamic properties of these kinds of pollutants (that allow them to propagate in the air) particulate matter can affect other individuals, especially elderly, in areas that are kilometers away from the forest fire.

3.3. Types of relationship between various versions of vulnerability

We have made it clear that our quest for “relationships” is inherent in our emphasis on systemic connections and effects. In the following chapters we are actually looking for ideas and material which will throw light on relationships. The meaning of the term “relationship” may sound a little opaque. For this reason we provide some observations and examples in full awareness that several other examples could be found. Such examples will hopefully be provided by all partners participating in this task and will help to formulate more precise definitions in the conclusions.

- One type of vulnerability may be the root cause or cause of another type: As an example, we may consider an economically disadvantaged region or state (i.e. with a low level of development and limited regional or state resources) incapable to invest in prevention and preparedness measures, suffering consequently from institutional vulnerability. In this specific case economic vulnerability is the direct (although not the root) cause of institutional vulnerability. However, even in this simple and straightforward case, economic vulnerability is not the necessary and sufficient condition for institutional vulnerability to disasters. The cause, i.e. economic vulnerability, does not lead unequivocally to the result, i.e. institutional vulnerability. The respective society may have a strong drive for building emergency mechanisms and planning prevention policies to avoid risks and disasters. Should this specific society decide to spend a large part of its limited budget to risk mitigation it will avoid then the condition of high institutional vulnerability to disasters.
- One type of vulnerability may transform into another type of vulnerability and / or vulnerability of one entity may be transferred to other entities (other components of a system, other sub-systems or other interconnected systems): As an example, entrepreneurs of Small Manufacturing Firms (within informal socio-economic contexts, which are usual in South European countries) after earthquakes and other disaster cases avoid statutory procedures (and the relevant costs) for proper repair of manufacturing buildings and proceed to temporary repairs with the help of low-paid labour of economic immigrants. To secure post-disaster viability of the firm, the manufacturers externalize repair costs and transform / transfer the firm’s economic vulnerability to physical vulnerability (of the manufacturing building) and social vulnerability (i.e. exposure of the firm’s workers to future earthquakes). These inflicted vulnerabilities may prove fateful in the next seismic event.
- Vulnerability relationships may follow / resemble the types of (structural) relationships existing within or among systems: dependency, interaction, competition, complementarities ...

In the case studies that follow it is worth attending the disaster phase wherein the described vulnerability interrelations do manifest. For instance, the reconstruction arena is an ideal field for such manifestations, especially as regards interrelations between institutional, socio-

economic, physical and territorial vulnerabilities because it is there and then where a struggle for vulnerability redistribution does take place.

Special attention should also be given to the means and catalysts of such dynamic processes because these are very relevant to mitigation policies. Highly relevant to such investigations may be the exposure and coping capacity attributes of vulnerability carriers. Consequently paragraph 3.4 is devoted to the explanation of these terms.

3.4 Exploring the meanings and potential connection between vulnerability, coping capacity, and exposure

Exposure in the language of the scientific community focusing on risks and disasters is usually considered in terms of the position of the threatened entity (or system) in relation to the position of the threat. Exposure in this sense is more or less a geographical attribute. However, threats come not only from extreme natural processes (the case of stress) but also from their repercussions, i.e. damaging, erosive or deleterious forces coming from the economic, social, political and technological “space” (the case of losses). Therefore, exposure in the widest sense could be taken as the position or “distance” of an entity in relation to the damaging forces of reference. To use an example, forests in the Mediterranean Region that have been inhabited by livestock farming communities if devastated by forest fires will have to find themselves exposed to flames during the fire and to grazing at the critical stage of re-sprouting. Indeed the distinction between vulnerability to stress and vulnerability to losses can be paralleled to the distinction between physical exposure and exposure to the more or less non-spatial inimical factors of the economic, social, technological, psychological and other domains.

While to the disasters’ community (or at least to a significant part of it) exposure is a property external and independent from vulnerability, on the contrary, to the climate change community exposure is an inherent property of territories and eco-human systems at least. This is because exposure is produced by and at the same time producing vulnerability.

Coping capacity refers usually to the capability to respond and minimize losses. It is basically a property referring to systems and actors with decision-making or adjustment capabilities.

In cases of lifelines and technical systems “coping capacity” is not a generally approved term. Usually, it is used instead the term “response capacity”. It can be reasonably assumed that response capacity of technical systems is a matter attached to their technical design and structural prescriptions. It is under investigation whether assessment of response capacity of technical systems can be achieved on the basis of accounting and determination of a series of critical thresholds.

In the case of systems with decision-making capabilities (i.e. social, economic, institutional, eco-human, territorial, techno-human) coping capacity is probably decisive for vulnerability treatment, curing, externalization, transformation, re-distribution and for whatever kind of vulnerability relationship to develop. Several of the case studies that follow investigate the role of coping capacity as potential catalyst or obstacle to processes of vulnerabilities’ interaction, transformations, transferences etc. In addition, these case studies offer arguments as to whether coping capacity is an inherent element of vulnerability or an external dynamic property independent from “the propensity to damage”. Finally these case studies offer hints as to whether coping capacity is a function of (a) risk culture (risk knowledge and experience and psychological predisposition) and (b) internal and external economic and power relations.

In post-disaster periods the coping capacity element is very active; hence the case studies referring to these periods prove to be fruitful in shedding light to the nature and essence of coping capacity.

Chapters 4-8 below include case studies and theoretical material contributing to:

- (a) The understanding of connections between vulnerability, coping capacity and exposure;
- (b) Recognition of the types of relationships that develop between systemic and other forms of vulnerability;
- (c) Developing tools to assess such properties as response capacity and exposure of territorial and other systems, as well as their impact on a system's vulnerability;
- (d) Addressing opportunities and challenges for integrating vulnerabilities (Chapter 8).

4. Relationships between physical, lifelines' and technical-human systems' vulnerability

The concept of systemic vulnerability is most commonly (and sometimes exclusively) used for technical or technical – human systems. Although we take the view that systemic behaviour is also typical of other "wholes" and "networks", the fact remains that there are several examples and experiences of such systemic vulnerability. Systemic vulnerability of techno-human systems can be divided into internal and external systemic vulnerability:

- Internal systemic vulnerability refers to how techno-human systems are able or not to continue functioning despite some level of internal-to-the-system physical damage (input = disaster impact) (this may also be termed as "functional vulnerability").
- External systemic vulnerability refers to how relations among systems may influence their capacity to function (the input in this case being losses or lack of functioning in related systems).

In this section we are therefore mostly interested in how physical damage may affect systems either directly or indirectly (as vulnerability to losses).

4.1 Interrelations between physical and systemic vulnerability before, during and post disaster in Carlisle

One example is given here of the interrelations between physical and systemic vulnerability during and post the flood event. The flood in Carlisle in January 2005 was one of the most significant to occur in England and Wales in the last few decades. Carlisle is a city with a population of approximately 100,000 people located in the County of Cumbria in North West England. Between January 6 and 8 2005, more than 200mm of rain fell on already saturated ground in the Carlisle area. Flooding of the Rivers Eden, Petteril and Caldew combined with surcharges to groundwater and sewer systems resulted in the inundation of approximately 1,900 residential and commercial properties (Figures 6 and 7, Environment Agency, 2005). Existing flood defences were insufficient to cope with the magnitude of the flood event and the flood waters remained in the city for four days. Three people lost their lives in the flood and approximately 3,000 were made homeless, many of those had to live in temporary

accommodation for periods lasting up to 12 months or more. The floods are said to have caused damage worth £250 million (Carlisle City Council and Cumbria County Council, 2005).

Key lifelines such as police, fire, ambulance stations and controls, 13 electricity sub-stations, telecommunication and media broadcasting, transportation and sewerage facilities were located within the flood plain and were flooded. One industrial estate in the city suffered flooding of over 4 metres depth in places. At this location the flood affected the city bus depot, the main electricity sub-station and sewage treatment works. The flooding of the key Willowholme sub-station lead to a power failure in 60,000 properties across the city. All landline telephones in the north of the city failed, including for '999' emergency services, and mobile telephone systems were also affected as high winds damaged VHF transmitters and receivers. Communications were disrupted throughout the city for several days, including the police UHF network; many of the emergency services were unable to communicate with each other to coordinate their response. Many people were unable to receive flood warnings from telephones, internet, television and radio. A local radio station operated 24hours a day and was the only source of information for those who had battery-operated radios. Roads and transport were also affected by storm damage to the road network, particularly from trees blocking roads, making access and search and rescue more difficult.

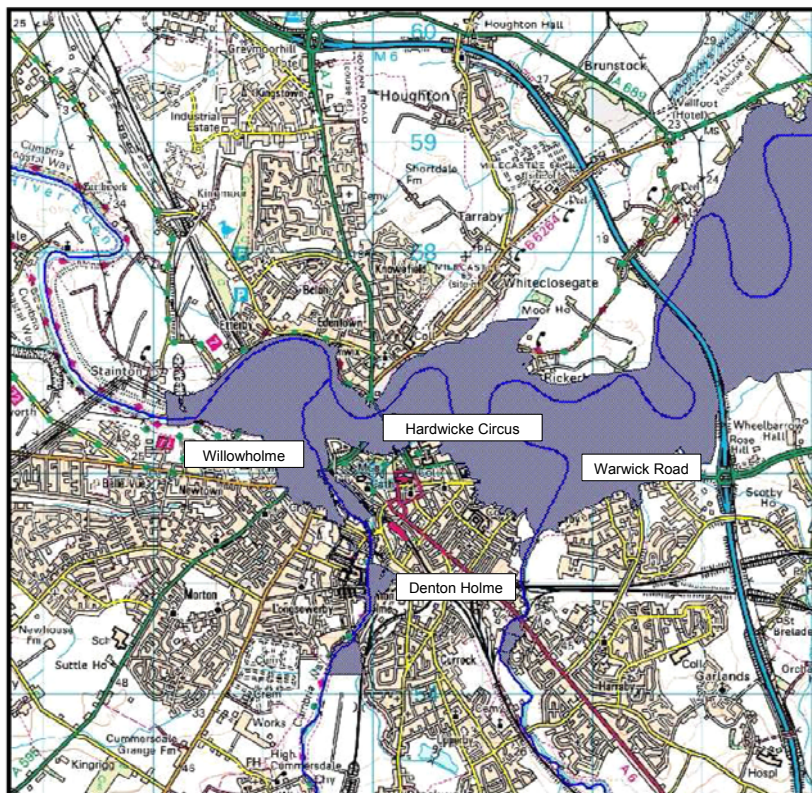


Figure 6: Map of Carlisle Floods 2005 (shaded area indicate extent of flood, adapted from Environment Agency, 2005)

In the city centre almost 500 staff at the Civic Centre (the local authority's corporate headquarters) had to be relocated to an emergency control centre at nearby Carlisle Castle, as their building was inaccessible and the floods left a large majority of staff without telephones, computing, printing and photocopying equipment; they also lost access to Emergency Directories, control centre information and contact lists. The voluntary sector played a vital role in recovery efforts, particularly in the immediate aftermath and, arguably, filled a significant gap in service provision that could not be covered by the public authorities.



Figure 7: Carlisle flood in January 2005

This case study is an example of the physical location (exposure of built environment) of key systems and lifelines (techno-human systems) within the floodplain in Carlisle which led to internal systemic vulnerability (functional vulnerability of infrastructure and public services); thus it illustrates a clear cause-effect relationship (Figure 8). This effect resulted in reduction in the coping capacities of institutions to respond during the flood event and in the immediate aftermath, as well as increasing the timescale to achieving 'business as usual' conditions. Not only did the emergency services and local authorities have to cope with being flooded themselves, but their response capacities were also constrained by failure of lifeline functioning (utilities, communications and infrastructure) causing operational problems. This example illustrates emergency institutions' own propensity to losses but also how this results into operational incapacities (internal functional), affecting adversely vulnerability of other social and economic systems.

Indeed these incapacities generated subsequent human exposure of residents in Carlisle to other hazards such as risk to life, security, and health effects. In the case of Carlisle, institutional coping or response capacity can partly be seen to have been a function of the risk culture as, due to flood defences being in place, there was little awareness of residual flood risk and thus appropriate preparedness strategies were not in place. This case study can also be used as an example of vulnerabilities internal and inherent to individual institutions (to stress and to losses (Section 5.1), as outlined in the multi-agency debrief report for the flood (GONW, 2005). It can also serve as an example of vulnerabilities arising from the interaction among institutions (e.g. in the incapacity to adequately interact due to lack of telecommunications and poor communication generally) (section 5.2).

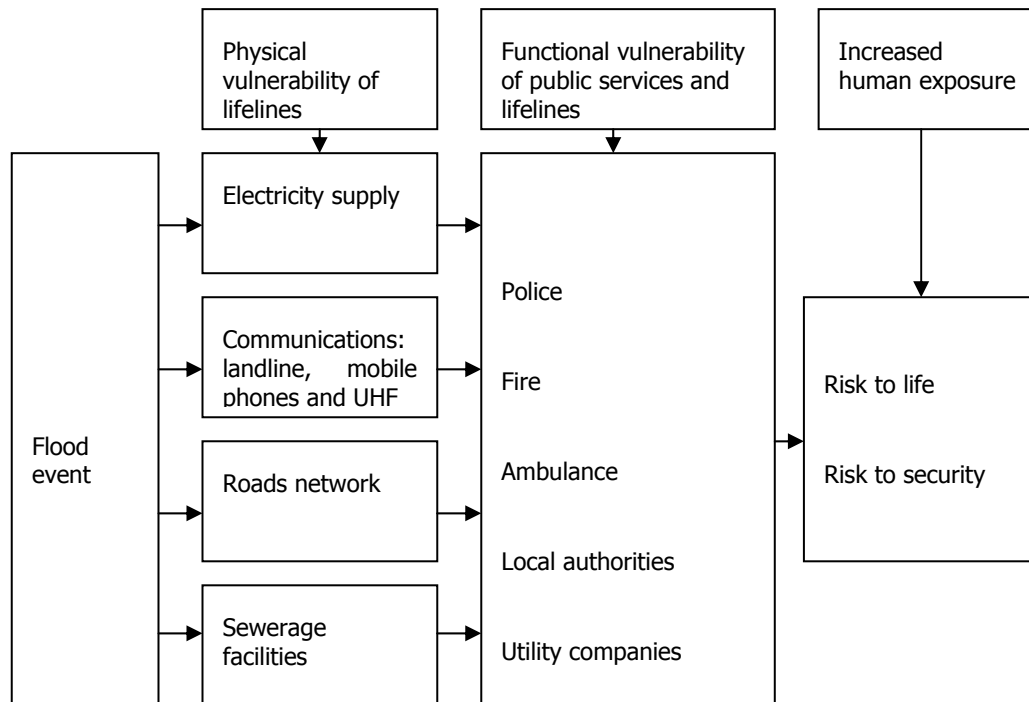


Figure 8: Relationships between physical, lifelines' and technical-human systems' vulnerability in Carlisle

4.2 The case of San Salvador – Interrelations between physical, systemic and institutional vulnerability in the emergency / relief period

During earthquakes, the elements of techno-human systems suffer damages, as a direct consequence of ground-shaking, but also due to the induced effects of earthquakes, such as soil liquefaction, landslides (e.g. El Salvador 2001) or fire (e.g. Kobe 1995). The damages/destructions of just a few individual elements could trigger considerable consequences for the functionality of the whole system (e.g. perturbation of the road systems during the 1994 Northridge and 1995 Kobe earthquakes, Chang and Nojima, 2001). Indeed, in normal conditions, urban communities rely more and more on complex technical systems to provide vital services. These networks turn out to be also essential for the emergency responses and the restoration of community activities after a disaster.

However, the linear structures of the distribution lifelines, such as electric lines, water pipes or roads, inherently exhibit at the same time high *exposure* and *physical vulnerability* to earthquakes but also to the induced-effects (landslides, falling structures...).

4.2.a San Salvador: Technical-human systems' vulnerability

In San Salvador (capital of El Salvador), the lifelines and engineering structures performed generally well during the two successive 2001 earthquakes. These relatively good performances (*systemic vulnerability*) can be partly attributed to the past disastrous experiences (natural and human) El Salvador had had to face: in particular the 1980-1992 civil war, the 1986 earthquake and Mitch hurricane in 1998 (Lund and Sepponen, 2002).

The 1986 earthquake had revealed the importance of seismic design (*physical vulnerability*) of lifelines, services and infrastructure elements to preserve the functionalities of the respective systems. Besides, the resulting massive destructions of decrepit infrastructures had given the authorities the “opportunities” to implement these seismic codes and, hence, to reconstruct new and more robust public infrastructures, which exhibited their reduced physical vulnerability during the 2001 earthquakes (JSCE, 2001).

In addition, the good behaviour of the electric systems in El Salvador’s capital was also backed up by the interconnection (redundancy) with Guatemala’s electrical system (19% of Salvadoran electricity comes from Guatemala), which, as less exposed, remained partially functional (AFPS, 2001).

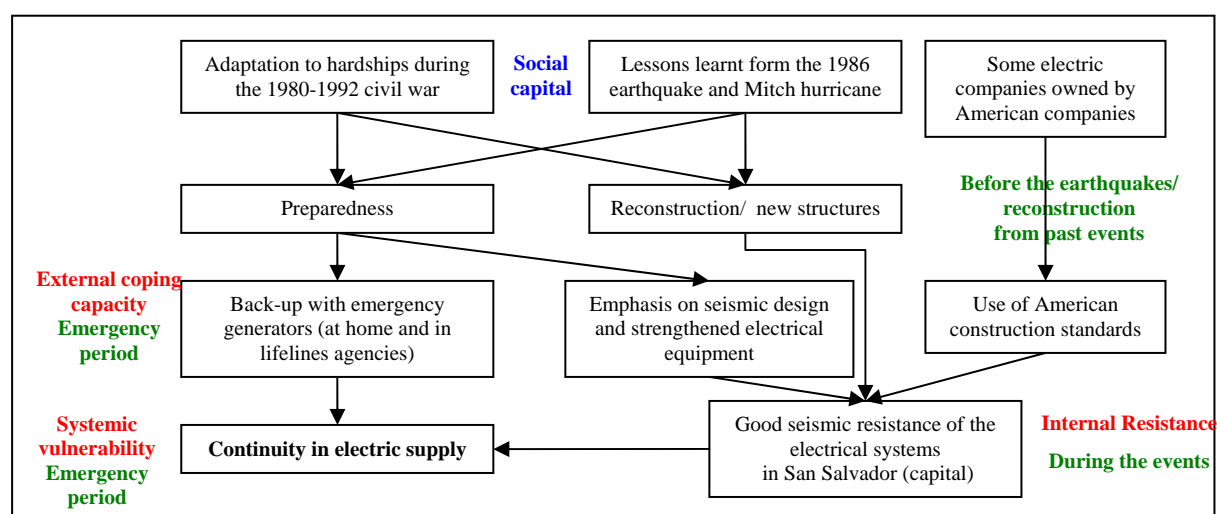


Figure 9: Decrease of internal systemic vulnerability of electric lifelines in San Salvador due to past experiences and improvement in resistance (cause-effect relationship)

(past exposure → increased Coping Capacity + reduction of physical vulnerability → reduction of systemic vulnerability)

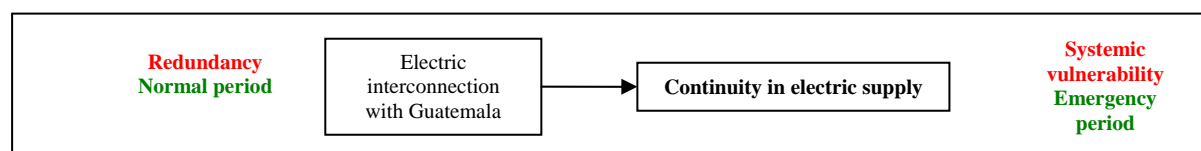


Figure 10: Decrease of internal systemic vulnerability of electric lifelines in San Salvador due to multiple sources of electricity generation

(Redundancy of energy generation → reduction of internal systemic vulnerability)

However, in rural areas, the situation was different: the lifelines and infrastructures suffered important damage, mostly due to the numerous induced landslides (645, see AFPS 2001) and falling structures. Indeed, as aforementioned, the linear structures of lifelines exhibit high *exposure* and high *physical vulnerability* to landslides. Furthermore, due to topographical constraints and to the lack of local development plans (*institutional vulnerability*), El Salvador’s lifelines are often constructed along ridges or edges of cut slopes, a condition increasing their exposure.

As a consequence, the destruction of electric lines, combined with failures of some generating plants in rural areas, have resulted in total electric outage in central and eastern regions (*systemic vulnerability*), for at least 3 days, made worse by the lack of emergency response and plans (*institutional vulnerability*) (Lund and Sepponen, 2002).

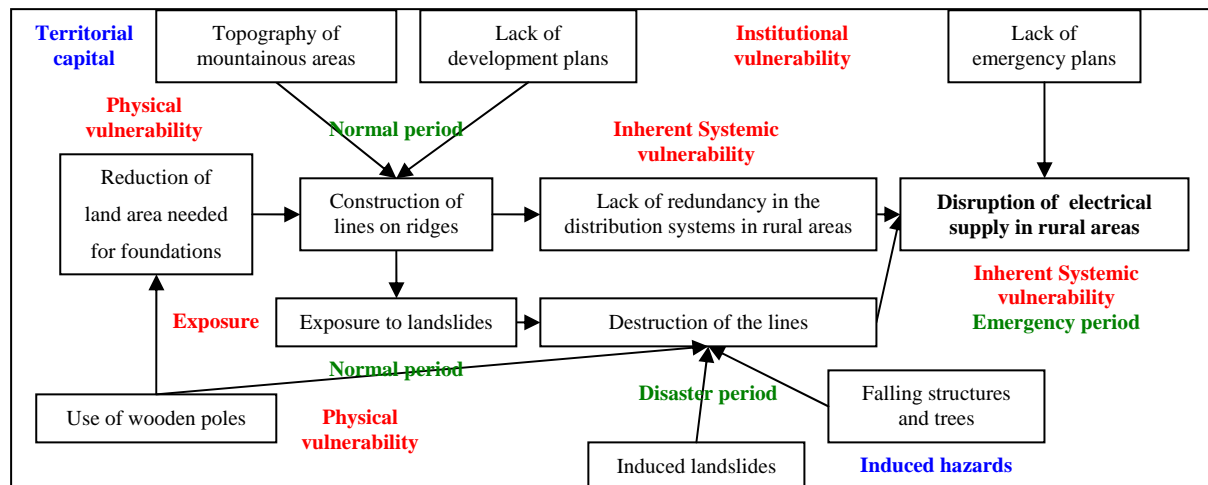


Figure 11: Internal systemic vulnerability of electricity supply systems in rural areas deteriorated by (external) institutional vulnerability

The consequences of the physical vulnerability of the pipes on the functionality of the water distribution systems were similar. Moreover, the dependence (*external systemic vulnerability*) of treatment and distribution facilities and pumps on electricity, exacerbated by the lack of emergency generators, aggravated the loss of functionality of the water distribution system.

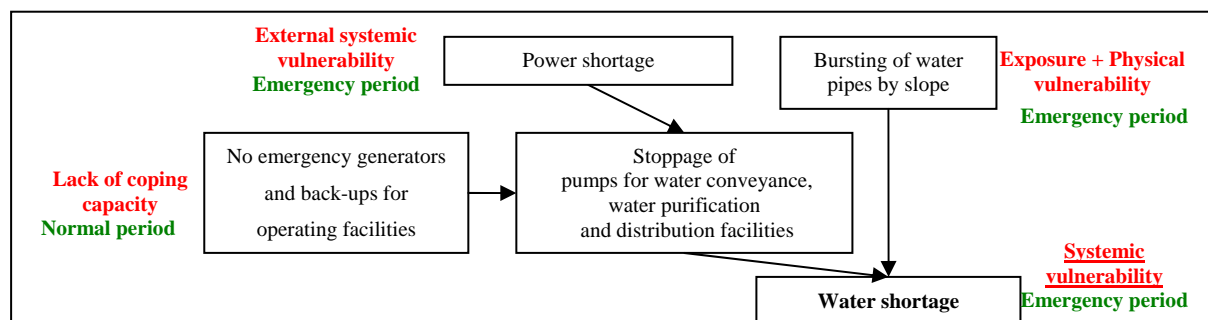


Figure 12: Systemic vulnerability of water supply in rural areas

The situation of the water system deteriorated after the second earthquake, when the treatment plant in Chacahuatal was severely damaged. This plant ceased to supply water to the San Vicente area, making more than 22,000 people dependent on the delivery of drinkable water by trucks. This form of supply was itself dependent on road functionality (Lund and Sepponen, 2002).

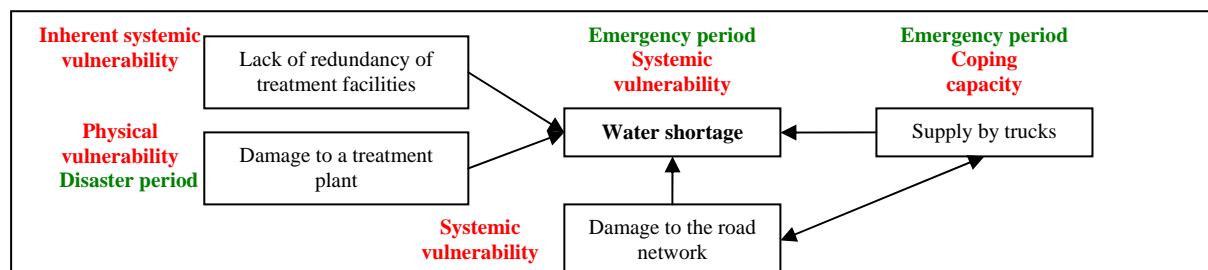


Figure 13: Transfer of systemic vulnerability from one system to another (transfer-transformation relationships)

The disruption of the water distribution system triggered chain adverse effects and losses on the human systems. For example, combined with physical destructions, loss of functionality of the water system made more than 66,000 latrines unusable, raising severe concerns about health issues: in particular threats of epidemics on an already affected population.

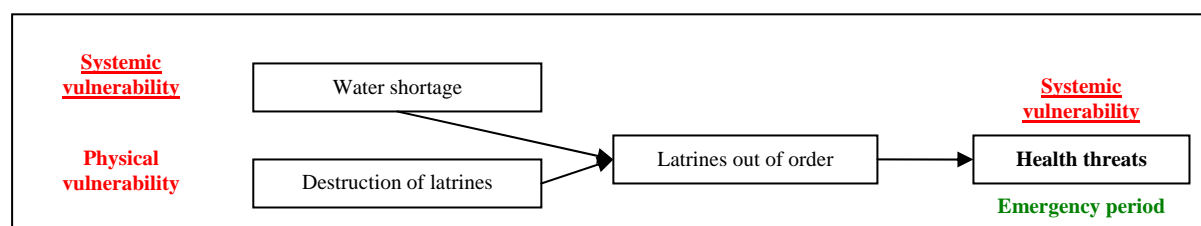


Figure 14: Human system vulnerability due to physical and lifeline systemic vulnerabilities (cause-effect relationships)

The transport networks were the lifelines most affected by the earthquakes and their induced-effects. The main Salvadoran highways (in particular, the Panamerican Highway (CA1), the backbone of national, but also South American economy, carrying the majority of passengers and freight traffic) were blocked for several weeks by numerous induced-landslides and rock falls at various locations (notably east and west of the capital). The scope of these obstructions could have been reduced by the implementation of slope stabilization programmes for critical roads. Moreover, lack of redundancy in the network (*systemic vulnerability*), combined with lack of alternatives to land transport (i.e. air transport capacity is very limited), compounded the consequences of the blockages. As a result, the drivers had to make huge detours, increasing time and costs. The estimated indirect costs accounted for more than 80% of the total estimated cost of direct damages to transport infrastructure (Bommer *et al.* 2002).

The disruption of transport networks made villages inaccessible to emergency and reconstruction services. Hence, people had to rely on neighbours for rescue and repair and some lifeline elements remained un-repaired only because of their inaccessibility, increasing the period of their dysfunction (*external vulnerability*).

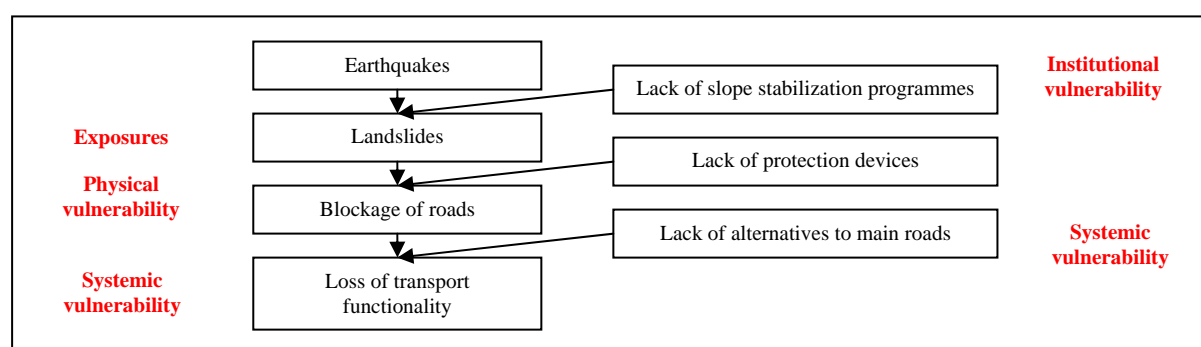


Figure 15: Systemic vulnerability of the road network

Though none of the healthcare buildings was totally demolished, the Salvadoran healthcare system suffered loss of functionality nationwide (*systemic vulnerability*). This disruption was certainly due to some structural damage, (*physical vulnerability*), but mostly to non-structural damage, i.e. to systemic failure of lifelines (*external systemic vulnerability*) and deficit in trained staff (*human capital*) (Boroschek, 2004).

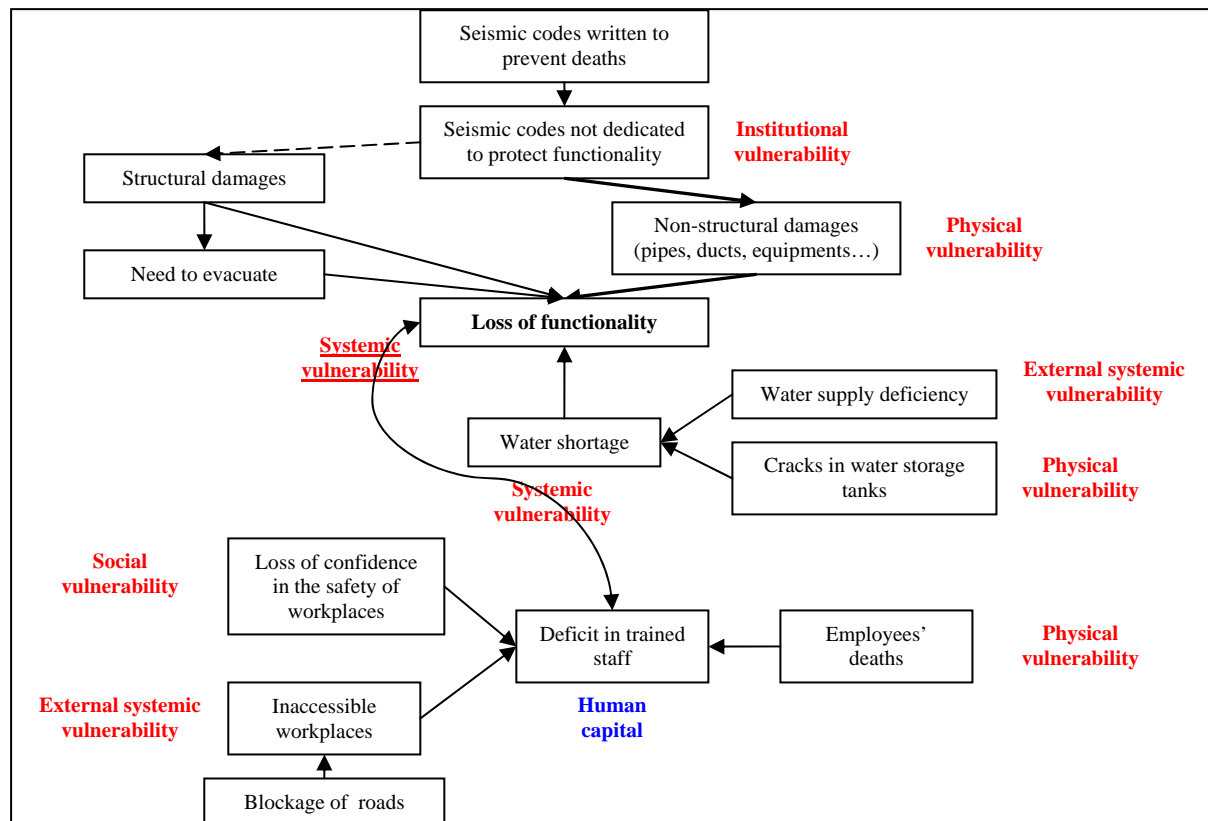


Figure 16: Systemic vulnerability of the healthcare system due to physical, social, external systemic and institutional vulnerability

Loss of functionality was exacerbated by the centralized structure of the specialized services of the healthcare system and the difficulty to transfer patients to other hospitals (34% of the existing beds at the national scale were temporarily lost), also due to the traffic disruption. One year after the events, 28% of the existing beds were still in field hospitals, and some medical services in the country could not perform appropriately yet (e.g. oncology) (Boroschek, 2004).

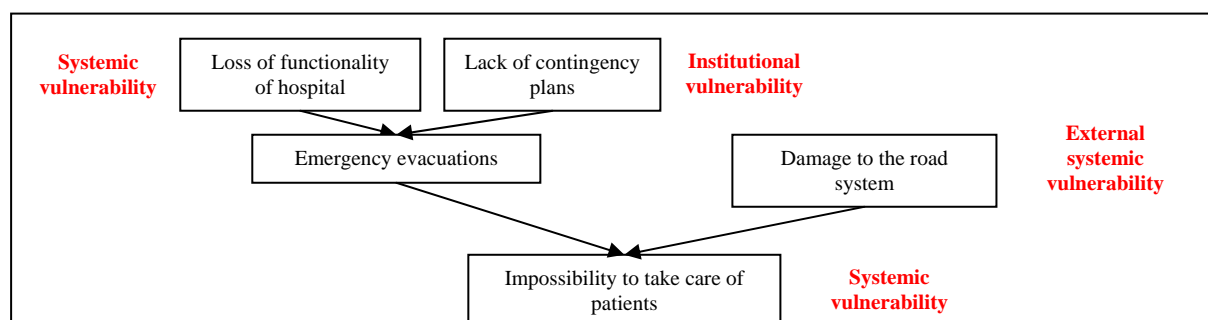


Figure 17: Large scale systemic vulnerability due to sub-systemic and external systemic vulnerability

As the above cases demonstrated, good performance of techno-human systems is highly dependent on the physical integrity of their individual elements. However, vulnerability of the techno-human systems facing hazard is not only the result of physical vulnerability of their components, but also the consequence of deficiencies in social, economic, institutional capital (external vulnerability).

5. Institutional vulnerability with respect to the accomplishment of risk mitigation

5.1. Vulnerabilities inherent to individual institutions: the Environment Agency of England & Wales and the Seismic Design Code of El Salvador

In this paragraph we will consider the forms of vulnerability that may develop in each individual institution considered separately from the others but perceived as a system. Institutions of our concern in the present chapter are basically those responsible for whatever risk mitigation either prior to the disaster, during or after it (i.e. institutions competent for prevention, emergency response, relief and rehabilitation). We should keep in mind that failure of these institutions to accomplish / realize their competences and duty may either stem from functional disruption or collapse (own vulnerability to stress and to losses) or from lack or inadequacy of the necessary resources and contextual preconditions (knowledge, human resources, technological resources, organizational effectiveness etc) which is vulnerability of their political/administrative role.

An illustrative example of the above issues of concern is the Environment Agency that was created as the flood and pollution agency for England and Wales in 1996. During 1996, the Agency received a Ministerial Directive making it the nation's lead agency for flood warning dissemination. This institution was severely tested by the floods of Easter 1998 in which it was found to have performed poorly (Bye and Horner, 1998). The Agency's flood forecasters failed to recognize the severity of the developing flood conditions and the Agency only managed to warn about 20 per cent of those who should have received a flood warning. Fortunately, no loss of life occurred as a result of warnings failure (although 5 people died during the floods and there were about 50 narrow escapes) but flood damage was much higher than necessary, and the shock, anxiety and health after-effects of the floods were magnified. The emergency services also performed poorly in these events largely because their response was poorly joined-up. The shortcomings stemmed from a range of problems: inadequate forecasting methods; failure to share best practice; inadequate floodplain mapping; inexperience of forecasters; failures of communication; insufficient inter-agency planning; and inadequate resources. The Agency was severely criticized as a result and became highly politically vulnerable at the time, such that it might not have survived. However, it did survive and the shock of criticism led to the development of a comprehensive strategy for improving flood forecasting and warning from which the nation now benefits.

Another relevant example comes from El Salvador and refers to the earthquake hazard. In El Salvador, a seismic design code exists, but there is no competent agency to ensure its implementation in private sectors. Similarly, the lack of legal capacity in municipal councils to apply their power of "eminent domain" to expropriate lands necessary for resettlement (Wisner, 2001) biased the competitions with lawyers defending private owners, preventing local governments to accomplish their rehabilitation duty. Hence, even if legal (national scale) procedures exist to accomplish risk mitigation, the local lack of means may impede their practical application. A general, formal and national emergency plan is also missing to organize rescue and repair. The COEN (Comite de Emergencia Nacional) was created after the 1986 earthquake, and is responsible for the prevention, but it benefits from only limited

means and has no infrastructure to provide help. At the national scale there is only a limited number of professional fire-fighters (less than 400) and none is specialized in seismic rescue, and this situation is worse at the local level.

Furthermore, there exists a contrast between the government's rhetoric declarations and the reality in the issue of decentralization. The central government acknowledges the necessity to enhance the capacity at the municipal and community levels but as the opposition parties are highly represented in municipal councils, national government is reluctant to give them power and capacity. Hence, municipalities are unable to respect and respond to their responsibility regarding local risk mitigation (inherent institutional vulnerability).

5.2. Vulnerabilities arising from the interaction among institutions

This is perhaps one of the most important forms of institutional vulnerability, deriving from the incapacity/unwillingness to coordinate and to cooperate. Sometimes this type of vulnerability is simply the result of a too much fragmented style of government and public administration, where at that the tasks of different departments and directorates overlap due to existing law provisions. But vulnerable institutional structures are also those which are over-centralized and bureaucratic.

5.2.a Flood warning and response in England during the 1990's

This case study traces the evolution of institutional vulnerabilities in flood warning and response evident in England during the 1990s. Although some institutional vulnerabilities still exist in this area of flood risk mitigation (Parker *et al.*, 2009), the particular vulnerabilities discussed in this case study have now been largely addressed by further institutional reform and response. The focus here is mainly upon institutional vulnerabilities exhibited during a flood event, although there is also a post-event dimension. In terms of the conceptual nature of institutional vulnerability interactions, this case study reveals the key points made in Table 1.

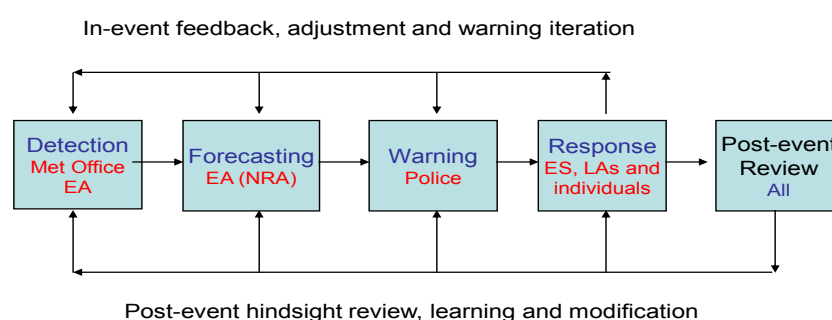
Flood warning and response are parts of a larger functional system which exhibits the characteristics of a chain with feedback loops (Figure 18) (Parker, 2004). Warning and response are the third and fourth components of this five-component system. The principal institutions (i.e. in this case the organizations or individuals) responsible for each component of the functional system are also shown (in red), as the system was until 1996.

We may consider these institutions to be an 'institutional system' designed for the purpose of detecting and forecasting floods, warning about them and ensuring satisfactory response. The warning component of this system involves the formulation of flood warning messages and their timely communication to the emergency services, local authorities and to those living or working in the flood risk area. The warning response component involves emergency actions designed to protect life and property from loss and damage, and may involve evacuation. The system was perceived by many of those responsible for different parts of it to have worked tolerably well from the time it was assembled (the mid-1950s) until the early 1990s.

Table 1: Key points made by flood warning case study

An 'institutional system' (comprising a group of organizations, connected together to perform a particular role) may well have more than one institutional vulnerability.

- Institutional vulnerabilities propagate along connections between organisations, from one to another i.e. one institution's vulnerability causes a problem and possibly (but perhaps not always) a vulnerability in another.
- Whether or not the problem caused by one institution passing on it's vulnerability to another institution causes the 'downstream' institution to exhibit a vulnerability depends upon the internal 'robustness' of the 'downstream' institution to absorb the problem without externalizing the consequence further downstream. In the example below, this 'robustness' has to do with the lag time between the flood forecast and flooding i.e. it is a feature of the physical process of flooding. In conceptual terms, this 'robustness' is very similar to 'response capacity' (i.e. also 'coping capacity').
- Sometimes, as in this case, the system resembles a chain, so that various institutional vulnerabilities (i.e. among more than one institution) ripple along the chain towards it's 'end'.
- Those 'exposed' to the institutional vulnerabilities in the case study are i) any 'downstream' institution and ii) those living and working in the flood risk area.
- Whether institutional vulnerability is transferred (i.e. passed on) from one institution to another depends to some extent upon the degree of 'dependency' which exists between the institutions regarding the particular risk mitigation function being performed. In the case study below, the institutions linked together appear to be highly dependent upon one passing a forecast or a warning to another, such that if this message is not communicated little can be done to avoid the consequences.
- Feedback mechanisms, both of which are learning mechanisms, exist within the institutional system described below, which – if they are activated properly - function partly to identify and reduce institutional vulnerabilities. To some extent, therefore, the system is self-regulating. Some feedback mechanisms become difficult to operate when the system components become 'tightly coupled' as they do in rapid-onset events.



EA = Environment Agency, previously the
National Rivers Authority (NRA)
LA = Local Authorities
ES = Emergency Services

Figure 18: The main functional and institutional components of the flood forecasting, warning and response system in England in the early 1990s

However, it appears that a rather uncritical culture surrounded this system. Little formal evaluation of it took place prior to the mid-1980s until certain enlightened individuals in the flood agency began to commission research on the system's effectiveness. The institutional system was held together by an administrative agreement (described by some at the time as a 'gentlemen's agreement') between the police and the flood agency, that the police would be responsible for disseminating flood warnings. This appeared to work reasonably well but, by the mid to late 1980s, research was revealing that the effectiveness of the police in discharging this role was variable, and sometimes poor (Parker and Neal, 1990). Delays by the police in responding to in-coming flood warnings, poor understanding of flood warnings by the police, other misunderstandings and competing priorities were some of the problems evident. In cases where the police's handling of a flood warning was delayed or otherwise ineffective, whether or not this had a demonstrable consequence in terms of flood warning response often depended on the lag time between the flood being forecast and flood occurring. Where this lag time was fairly long (say 24 hours) the consequences of delay could probably be reduced to zero, but they were more critical when the flood lag time was shorter (say 6-8 hours).

However, other vulnerabilities in the 'institutional system' were also present. In February 1990 the coastal town of Towyn in North Wales was severely flooded in a storm which breached its sea defences. The post-event inquiries revealed that the Neptune Warning Service operated by the National Rivers Authority (NRA) was flawed. In those days the NRA's flood warning control room was not staffed on a 24 hour basis, and it was not until 06.00 on the day of the flood that the office was opened. However, a flood surge forecast had been faxed to this office by the Meteorological Office (Met. Office) at 02.30. The NRA's duty officer telexed a flood warning to the divisional police headquarters at 07.06 so that over 4 hours of valuable flood warning lead time was lost before a flood warning reached the police. Other delays then occurred. A civilian communications operator at a key local police station failed to appreciate the immediate significance of the flood warning received. Two local authorities were also involved. When one local authority was contacted by the police, the only person available was a Council caretaker and it was not until 08.00 that a Council officer could be telephoned at his home. The other local authority could not be contacted until 08.53, 5 hours after the Met. Office had informed the NRA. Severe flooding of the town commenced at 10.00. The Welsh Affairs Committee investigative report into this flood concluded: 'The present workings of the system of transmitting information through Neptune is totally unacceptable and a recipe for delay' (Welsh Affairs Committee, 1990, xiii). In the event the emergency services had to evacuate about 5,000 people after flooding had taken place, rather than in advance of flooding. Many of the residents were retired, elderly people living on low incomes in one-storey homes. The after-effects of this flood were substantial with people living in temporary accommodation for many months. Unfortunately, this flood also appears to have brought some of the worst aspects of private sector institutions to the fore, with builders undertaking shoddy repairs, delays in insurance payments and loan sharks preying on the most vulnerable.

During the mid-1990s, the 'gentlemen's agreement' about the police's role in disseminating flood warnings began to fall apart. Police authorities were encountering funding constraints and increased demands to show performance against their statutory law and order duties. Disseminating flood warnings was not part of these statutory duties, and the police began to withdraw their support for the flood warning service causing an administrative crisis or vacuum in the institutional system. No organization now had responsibility for disseminating flood warnings. At the same time it was becoming more clearly appreciated that a principal weakness of both the functional and institutional systems for flood warning and response was the existence of 'intermediaries' in the flood warning communication chain. As a result, in 1996, the Government instructed the Environment Agency (the flood agency) to be the lead agency responsible for flood warning communication. This led to a major change in the

institutional arrangements for flood warnings and response (Figure 19), particularly the harnessing of information and communication technologies to communicate flood warnings directly from the flood agency to those at risk, without using intermediary agents.

Finally, Figures 18 and 19 indicate that there are significant feedback loops in the functional and institutional systems for flood forecasting, warning and response. There are two such systems: 'in-event' (i.e. during the event) and 'post-event'. In a slow-onset flood in particular there is scope for feedback to help 'correct' institutional vulnerabilities through communication between organizations. For example, in the case of a slow-onset flood on the river Thames in England in the summer of 2007, it was several days before the flood wave reached as far downstream as Oxford. This allowed the flood agency, the downstream local authorities and the emergency services to 'adjust' the series of warning messages and related information being communicated to individuals and other organizations in the path of the flood, in order to achieve the best performance. This is much more difficult to achieve in a rapid-onset event in which the system functions and institutions become more 'tightly coupled'. The 'post-event' process allows strengths and weaknesses to be identified and for improvements to be made to the system including reducing institutional vulnerabilities.

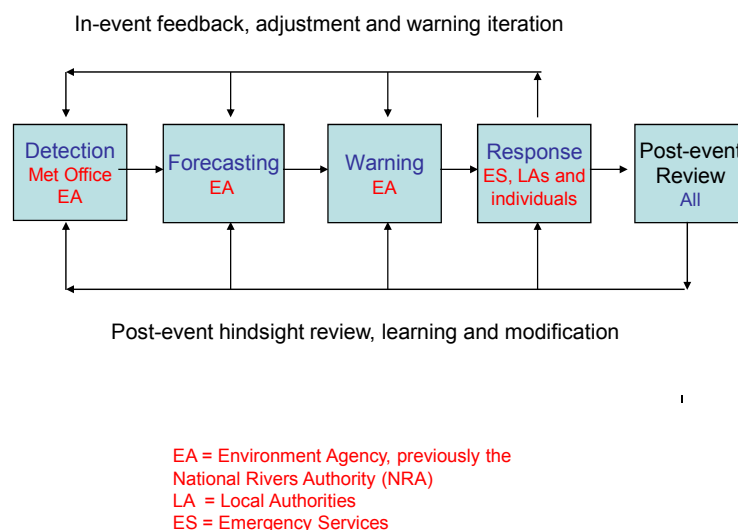


Figure 19: The main functional and institutional components of the flood forecasting, warning and response system in England from 1996 onwards

Up to now certain research efforts have resulted in specific tools developed to assess the 'condition' (i.e. health) of an 'institutional system' in terms of its ability (or 'fitness') to perform the purpose for which it was created. The 'Criteria-Development Matrix' (CDM) methodology was originally developed to evaluate the strengths and weaknesses of Europe's flood warning systems, including those in a number of countries (Parker and Fordham, 1996). It was subsequently further developed to measure and evaluate the condition or 'level of development' of the tropical cyclone warning system in the Republic of Mauritius (Parker, 1999a). The CDM method assesses the condition of a hazard warning system – viewed principally as an institutional system (defined broadly to include laws, organizations, administrative procedures, attitudes etc.) – according to five stages of development ranging from primitive/basic to advanced/sophisticated. Primitive/basic systems are inherently highly vulnerable whereas sophisticated or advanced ones are much less so. This tool provides a

predictive guide as to how likely it is that the institutional system for hazard warning will display vulnerabilities which will be transferred to other institutions, particularly those occupying hazard zones.

5.3. Vulnerabilities as triggered and triggering factors of social and economic vulnerabilities

In this section the relationship between “society” and “economy” on the one side and institutions on the other are explored so as to identify how they may influence each other so as to produce vulnerabilities.

As an example we may cite cursorily reconstructed lifelines and other public works after earthquakes or fire disasters in Greece due to improper damage assessment and technical studies (or the absolute lack of them) which will probably fail to resist subsequent stresses in the future. It is evident then that institutional vulnerability (with respect to non-accomplishment of risk mitigation) produces physical and territorial. This specific example indicates also that vulnerabilities of the reconstruction phase tend to be remedied without concern of vulnerability to future risks and hazards, i.e. to the disadvantage of vulnerabilities of the successively following pre-disaster stage (according to the disaster management cycle).

As regards institutional vulnerability triggered by social habits, examples of private solutions to social vulnerability with adverse impact on institutional may be considered. It is the case for example with the spontaneous establishment of tents in cases of post-earthquake emergencies, i.e. at scattered locations outside the provided, pre-planned public spaces for emergency sheltering. This spontaneous camping comes from those evacuees who insist on staying close to their place of residence. However, these camps complicate the supply of emergency services and reduce efficiency of the competent relief mechanism.

5.3.a The summer 2007 floods in Gloucestershire, England: Interaction between institutional and social/economic vulnerability in the emergency and recovery phase

The following example focuses on institutional vulnerability and its systemic interrelations with social and economic vulnerability. In the summer of 2007, England and Wales experienced exceptional rainfall resulting in the wettest summer since records began and extensive flooding. More than 55,000 properties (48,000 households and almost 7,300 businesses) were flooded, 13 lives were lost and around 7,000 people had to be rescued from the flood waters by emergency services. Thousands of people were left homeless. Although many flood defences were overwhelmed by the sheer volume of water, a compounding factor was the large amount of flooding in urban areas from surface water (pluvial floods) and the lack of capacity of drainage systems to cope with the volume. Essential services, power supplies, transport links and telecommunications were disrupted and the flood resulted in the largest loss of essential services since World War II and the biggest civil emergency in British history. Around half a million people were left without mains water supply and electricity.

The county of Gloucestershire was one of the most affected regions, where Castle Meads electricity substation had to be shut down leaving 42,000 people without power in the city of Gloucester for up to 24 hours (Figure 20). Loss of power meant that people could not receive information from TV, mains radio and the internet, and mobile phones could not be recharged, resulting in lack of communication ability. Transport networks also failed, leaving around 10,000 people trapped on the M5 motorway and 500 people left stranded at Gloucester railway station alone when the rail network failed. Demountable temporary flood barriers for the towns of Worcester and Upton on Severn were not able to be transported to where they were needed due to disruption of the road network, resulting in additional flood impacts in these towns. Institutional arrangements (and failures) with regard to the transportation of the flood barriers led to physical vulnerability with respect to the reduction of risk mitigation in Worcester and Upton on Severn, and subsequent social and economic vulnerability for many of those affected.



Figure 20: Flooded electricity sub-station, Gloucestershire

Loss of the Mythe water treatment works lead to 350,000 people being without mains water supply for up to 17 days. The loss of water supply led to 1,000 water 'bowzers' and 2.5 million litres of bottled water being distributed by local authorities in various locations. This resulted in the potential social vulnerability of affected populations, not just for those flooded but also for those affected outside the flooded areas, many of whom had to move out of their homes until water supplies were returned. Vulnerable people and those without transport were particularly affected and had difficulties in collecting water supplies. Moreover, lack of water supply posed potential risks to public health. Families with young babies were also warned by the Health Protection Agency not to use bottled water for babies' milk formulas, thus causing concern and stress to young parents. There were also arguments and tension within communities over the allocations of bottled water supplies.

The costs of the summer floods were nationally estimated at more than £3 billion in insurance claims alone, making the floods the most expensive in the world that year. The floods particularly resulted in economic vulnerability for those on low incomes who experienced serious financial problems as a consequence of being flooded. Moreover, in a study on the health effects of the floods by the Gloucestershire Primary Care Trust, it was suggested that the financial problems experienced were said to have affected mental health, particularly for young single parents who were reported to have suffered from stress while recovering from the flood with little support and while also having to work. In this case existing social and economic vulnerabilities were exacerbated by the flood resulting in poor

coping capacity. A subsequent Gloucestershire County Council Scrutiny Inquiry which looked at how the emergency services, local authorities and utility companies dealt with the flood event highlighted several critical local issues of concern, including:

- the inadequacy of flood warning systems: gaps in capabilities in relation to the systems (e.g. unsuitability for pluvial flooding); misunderstanding of flood warning codes, terminology and sequencing; dependence on long-term forecasting;
- the lack of knowledge of the county's drainage system (responsibility for which was split between many different agencies (local authorities, highways, water companies, internal drainage boards, Environment Agency) and vulnerability of drainage and sewerage systems to surface water (pluvial) flooding;
- vulnerabilities of single points of failure within the critical infrastructure system (Pitt, 2008).

Thus weaknesses (vulnerability) within institutions in relation to flood preparedness had resulted in exacerbated exposure to flooding, to impacts during the event and later during the post-flood recovery process, interrelating with social and economic vulnerabilities (Figure 21). Importantly, the loss of essential services and critical infrastructure extended well beyond the areas that were flooded, highlighting the importance of risk assessment and mitigation preparedness of infrastructure operators, and for calls for a more systemic approach to understanding the vulnerability of critical infrastructure.

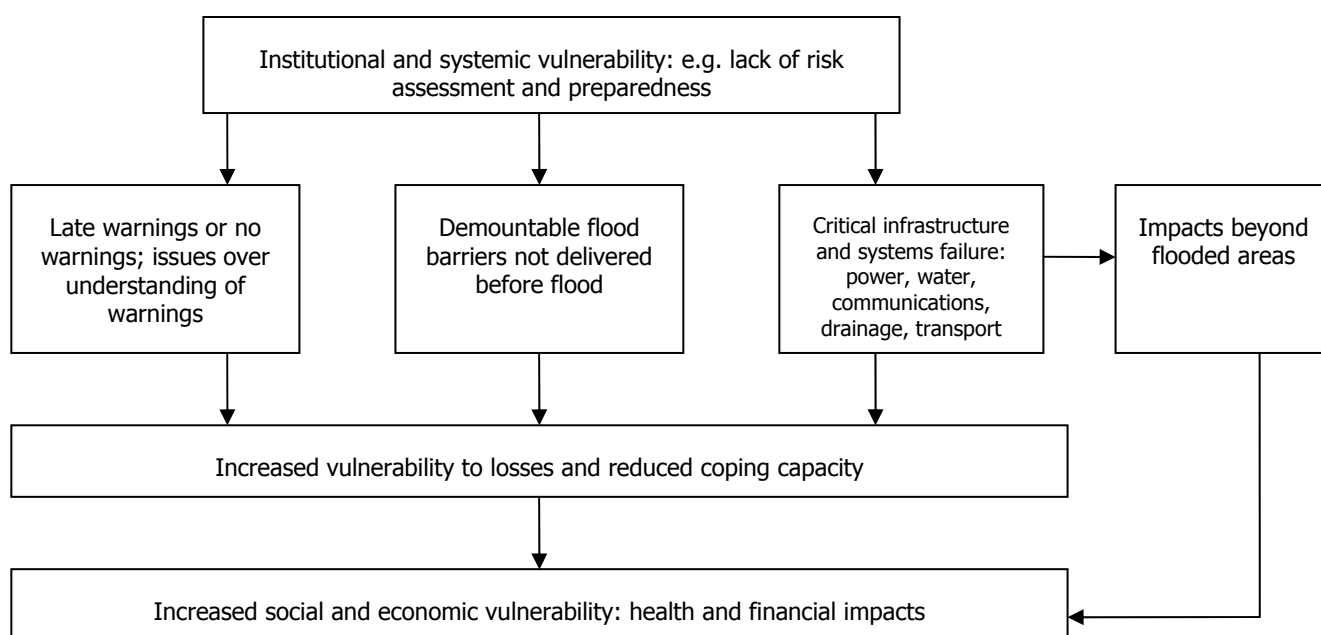


Figure 21: Institutional vulnerability and its systemic interrelations with social and economic vulnerability

6. Eco-human systems' vulnerability

Examples of ecological systems' vulnerability will be limited to forest fires and droughts. The essential query is the following: By what means ecological systems and sub-systems interact with technical and/or transfer vulnerability to social and economic entities and vice versa?

Here we are concerned with the two-way relationships: eco-systemic vulnerability → social or economic vulnerability and social or economic vulnerability → eco-systemic vulnerability. Again what is important is the means and the catalytic factors that facilitate such dynamic processes as cause-effect relationships, transformations and transferences.

Unlike other hazards such as floods or earthquakes, forest fires probability of occurrence and its intensity is at large extent shaped by human behavior and institutional decisions. There are several reasons why south European countries have suffered substantial impacts from forest fires in recent decades (see tasks 2.1 and 2.3 for physical, social and economic damages of forest fires), ranging from individual human behavior, lack of institutional coordination, political changes and even the relation of south Europeans with forest. These factors occur in different phases of the hazard, influencing the probability of fire occurrence, its intensity and its extent. There is also the role of climatic factors that should be considered as influencing most of the hazard phases, from risk to extinction.

In Figure 22 we attempt to understand the complex chain of events and relations influencing forest fires in the southern European countries. Fire is a complex phenomenon accounting with multiple parameters that evolve over different spatial and temporal scales. Despite this complexity, we can group the hazard phases into four categories; Fire risk, ignition, fire spread and fire extinction.

The first element in our list is fire risk. Fire risk is influenced by the climatic conditions and by the type of vegetation. Flammability of the vegetation depends on its moist content and it's influenced by the climatic conditions in place, mostly precipitation and temperature. Fire risk provides information on the suitability of the vegetation to burn, nevertheless, in order for combustion to take place ignition must happen. Ignition is triggered by fire lighting and depends both on natural and anthropogenic causes. In southern European countries the ignitions are at large extent derived from human action, both intentional or due to inadvertence. Changes in Mediterranean countries' demography with more people leaving to the cities and abandoning rural areas, the disinterest of forest as a resource of income or forest clearance in order to establish profitable development plans (e.g. touristic plans in Italy and Greece) influenced the rate of anthropogenic ignitions in southern Europe.

Once that ignition is started, vegetation, climate and landscape structure come into place to determine the extent and the severity of the fire. Lack of land use planning and financial incentives for forestry products lead to increase loads of biomass that where once managed. Abandonment of agriculture has led to the natural succession of vegetation, allowing the development of a more continuous vegetation mosaic. This continuum of vegetation in combination with high fuel loads from unmanaged forest makes more likely for a fire to reach high proportions once it is started. The final phase of the hazard is the fire extinction. This is the phase where usually countries put more economic effort in. We can see by the chain of events that fire extinction is an end line solution and that most of impacts can be avoided by the implementation of measures to prevent the fire spread and ignition or to keep the fire risk lower. Fire extinction depends on climatic factors, vegetation and also the efficiency of the fire fighting units. For example, it was noted that in Greece, the institutional shift of responsibility in fire suppression from the Forest Service to the Fire Brigade might have contributed to the extraordinary extension of the 2007 forest fires (see also Task 2.3 on physical and institutional vulnerability). When talking about impacts of forest fires, two different time frames should be considered. The primary impacts derive from the period when the fire spread occurs. Physical damage for population and ecosystems, economic losses and damage of life lines are some examples. After the fire is extinguished secondary impacts generally occur depending on the intensity and extension of the primary impacts. Some of these impacts are: enhancement of erosion processes due to the lack of physical protection of the soil by vegetation against weather events, increased risk of floods, and release of mercury to the ecosystems.

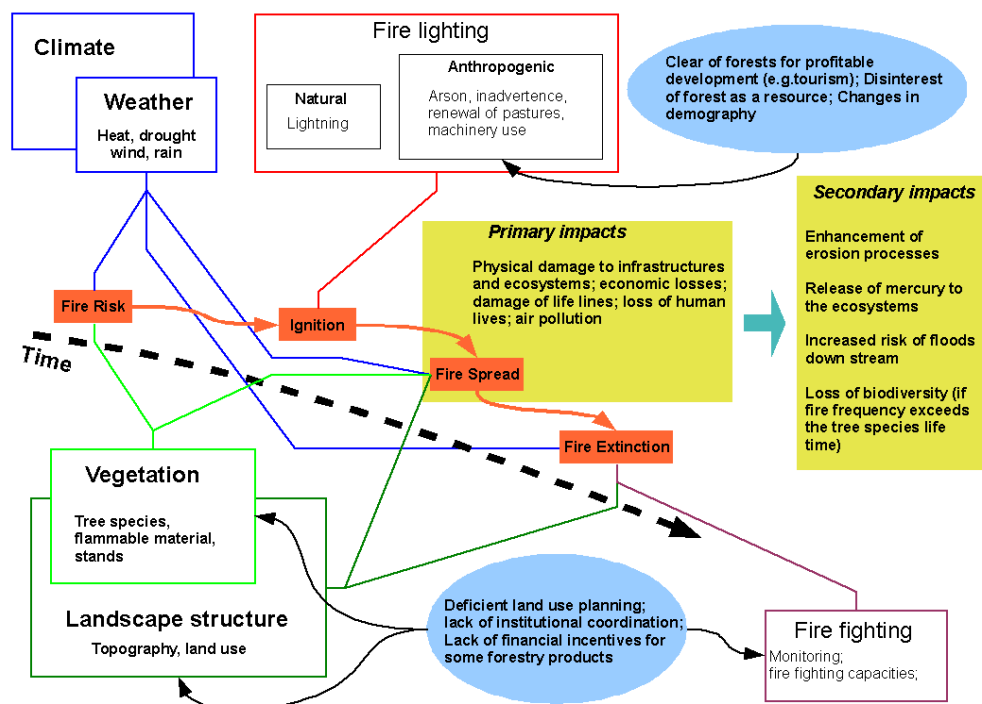


Figure 22: Conceptual chain of events and relations influencing forest fires in the southern European countries

With regard to drought, during drought periods, additional clear days and consequent extra load of radiation together with a decline in precipitation affect abiotic-biotic processes. The effects are both direct and indirect (Austin 2002).

The reduction of vegetation cover during drought periods results in an increase in the extent of bare areas (Balling *et al.*, 1998), consequently causing an increase in surface temperatures (Weaver and Albertson, 1944; Nicholson *et al.*, 1998) and in evapo-transpiration (Gardner, 1950; Rebetez *et al.*, 2006). It also leads to lower soil organic matter (SOM) and a reduction in the microorganism population (Kieft *et al.*, 1998; Borken *et al.*, 1999). Plant cover reduction during droughts causes an increase in the surface wind speed (Herbel *et al.*, 1972) which increases the loss of soil nutrients (West *et al.*, 1984) and promotes the exposure of hard subsoil horizons at the surface (Gile, 1999). Bare areas are also subjected to intensive rain drop impact leading to the formation of a physical crust (Le Houérou, 1996), which, in turn, promotes runoff (Cammeraat, 2004; Assouline and Mualem 1997), further intensifying water loss.

As a consequence, germination, fecundity and plant survival may be severely affected. Droughts will impede germination (Went, 1955; Snyder *et al.*, 2006) and will result in low seed production (Shreve, 1942; MacMahon and Schimpf, 1981). Plant mortality may take place (Guevara *et al.*, 1997; Peñuelas *et al.*, 2001) together with a change in species diversity (Gibbens and Beck, 1988) and composition (Weaver and Albertson, 1944; Schlesinger *et al.*, 1990). The recent vegetation shift in the southwestern part of the US was attributed by many authors to consecutive droughts during the last 100 years (Lohmiller, 1963; Gibbens and Beck, 1988; Bestelmeyer *et al.*, 2006).

High mortality of species is also observed in the Negev Desert following droughts. One of the most widespread shrubs in the sandy western part of the Negev, *Cornulaca monacantha*

suffered high mortality following the droughts of the late 1990s and the 2000s. The shrubby population at this habitat was severely reduced (Ram and Yair, 2007).

Drought may also result in the migration of plant communities further to the poles, where the environmental conditions are more favorable or may result in the penetration of alien invasive species into bare areas in forests (Holmes and Cowling, 1997).

At a global scale the reduction in precipitation during drought decreases spring and river flow (Boulton, *et al.*, 1992; Manga, 1999), lowering the level of the water table (Sophucleous and Perkins, 2000). It may also affect aquatic environments (Katsoulis and Tsangaris, 1994) and reduce water quality (Webster *et al.*, 1996; Roberts, 2002).

All the above may severely affect humans. Apart from a reduction in life quality, droughts may highly affect the economic base/income level. As far as the natural ecosystem is concerned it may reduce grazing as described in Figure 23.

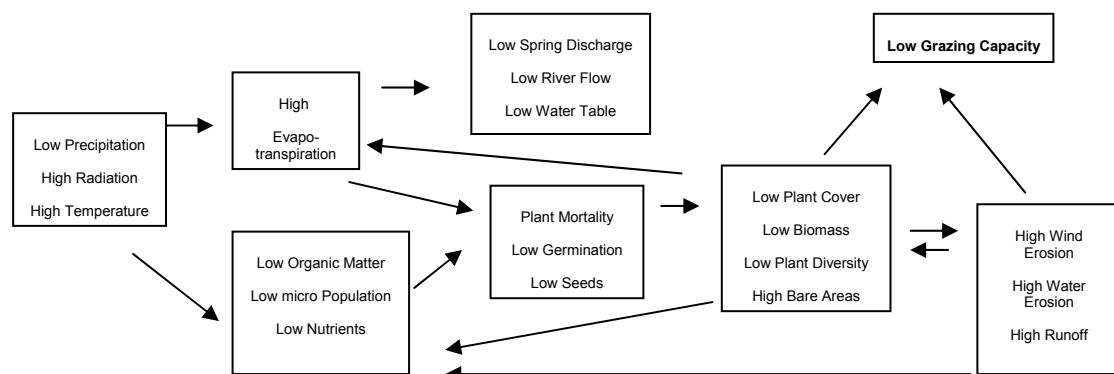


Figure 23: Physical vulnerability of the natural ecosystem following droughts.

For example, the shift in vegetation from grasslands to shrubs in the northern Chihuahuan Desert (northern Mexico and southern USA) resulted in a sharp reduction of the farmer's income in the Southwest due to a sharp decrease in the grazing opportunities. The decrease in grassland productivity in the area resulted in a substantial decrease in cattle heads (Grover and Musick, 1990; Conley *et al.*, 1992) and steep economic losses of the cattle owners (Conley *et al.*, 1992). In face of increased mortality, many rangers transferred cattle outside the impacted zones (Gardner, 1950). Vulnerability transfer is evident in these cases.

The droughts of the 1990s and the 2000s further increased farmer vulnerability. According to Ortega-Ochoa *et al.* (2008), the flora in the Chihuahuan Desert was substantially affected, resulting in soil degradation. Rangeland productivity in some areas fell below levels needed to sustain viable wildlife and livestock population. It had severe implications for the cattle industry, turning cattle operations into non-profitable enterprises.

The lack of natural vegetation causes changes in the household structure (De Bruijn, 1997), and encourages emigration of farmers from the drought area (Hampshire and Randall, 2000; De Haan *et al.*, 2002). Apart from high mortality of humans and domestic stock (Nicholson *et al.*, 1998), the droughts of 1970s and 1980s in the Sahel (Khalfaoui, 1991; Sumberg and Burke, 1991; Sivakumar, 1992) led to emigration of family members or entire families (Le

Houérou, 1996), changed the traditional ratio between the rural and urban population in the area, and triggered drastic changes upon cities and infrastructure.

Also in the Negev Desert grazing opportunities decreased substantially following the recent droughts of the 1990s and 2000s. Grazing in the open areas of the Negev was reduced substantially. Alternative solutions such as the purchase of grazing rights to fields following the harvest or grazing at Jewish National Fund (JNF) forests is becoming more and more popular, replacing the traditional method of herd wandering.

6.a The Case of the Northern Negev: Variations of eco-human vulnerability

The term systemic vulnerability is related here to agricultural systems and the relevant infrastructure, functional and institutional subsystems that have direct impact on agriculture crops. Constituent elements of the entire system are: the location of permanent and temporal settlements, water supply network (pipelines and reservoirs), water consumption and irrigation policy, agriculture policy and availability of lands for population and agriculture of different kinds.

Social, institutional and economic vulnerability greatly affect the eco-human system's vulnerability which can be considered also as territorial vulnerability. This is the case in Greece (Katsoulis and Tsangaris, 1994), Italy (Piccarreta *et al.*, 2004), Spain (Roberts, 2002; Fornés *et al.*, 2005) and Morocco (Swearingen, 1992). This also is the case in the Negev Desert. In the Negev, it may take place mainly in two rural populations within the northern Negev Desert, the Jewish population and the Bedouin population.

Institutional measures were initiated as a result of long periods of drought in the Negev: establishment of purification plants, new irrigation techniques, transformation to new cultivation methods and institutional support. Lag in the development of water installations aiming at catching runoff water and purifying sewage water increases vulnerability. A purification plant was recently established for the sewage of Jerusalem and the purified water was made available for Moshavim in the north-eastern part of the Negev. Likewise, three years ago a much higher degree in purification of the sewage water of Beer Sheva was achieved, facilitating also vegetable irrigation rather than only industrial crops. Still, desalination of water from the Cenomanic aquifer found in the Negev Desert is limited. It requires the removal of excess salts. While a local solution of allowing the salt to crystallize in shallow water ponds was adopted, the removal of large quantities of salt awaits future solutions.

Yet, many projects aiming at alleviating the hazardous effect of drought were initiated. In 1989, highly purified water stemming from the metropolitan area of Tel Aviv was transferred to the Negev, providing high quality water to over 80% of the agricultural settlements in the Negev. Many water reservoirs were established at the main wadis (natural dry water courses that fill up with flood water only during several days during the winter), and following a law passed in the 1990s all sewage water from all settlements had to be purified. In addition, in order to encourage cultivation in the northern Negev area prone to droughts, the "drought law" was passed in 1964, guaranteeing the cost return of unsuccessful crops following droughts.

Whereas public institutional involvement is high, so are civic institutions that will be dealt in another section of this report. Yet, these public (the Ministry of Agriculture for instance) and civic institutions (the farmer Association for instance) act to mitigate the effect of the drought by implementing new techniques such as no-tillage, machinery that increases surface storage (and thus water availability), new irrigation techniques that save water such as drip irrigation and new seed varieties, all of which are possible due to the high level of education of Jewish farmers. High levels of solidarity between the members of the Kibbutzim

and Moshavim facilitate risk taking that is necessary when new techniques are implemented for the first time with no guarantee of their success.

In the Bedouin sectors, the situation is more complex. Low solidarity among tribes and weak solidarity within the tribe, low education and low income all limit the ability to cope with droughts. Characterized by a low degree of economic diversification, their inherent economic inferiority and vulnerability stem mainly from a dependency upon a narrow range of rainfall-dependent agriculture crops which are particularly vulnerable to drought. This situation contributes to a high economic vulnerability that is highly intensified by polygamy and by the highest birth rate in the world. Thus, the low skill base of the Bedouin population may lead to low occupational adaptability and failure to shift occupation from agriculture to another form of employment, as takes place in the Jewish sector by either unsuccessful farmers or (and mainly) by their children. This situation may contribute to the economic vulnerability of the Bedouins and their difficulty to cope with continuous periods of drought. However, one may also argue that their "tradition of survival" makes them less vulnerable than the modern farmer in periods of economic shortage due to their lower financial burdens (bank loans and mortgage). Yet, economic stress especially in periods of economic shortage may intensify internal and external social strife.

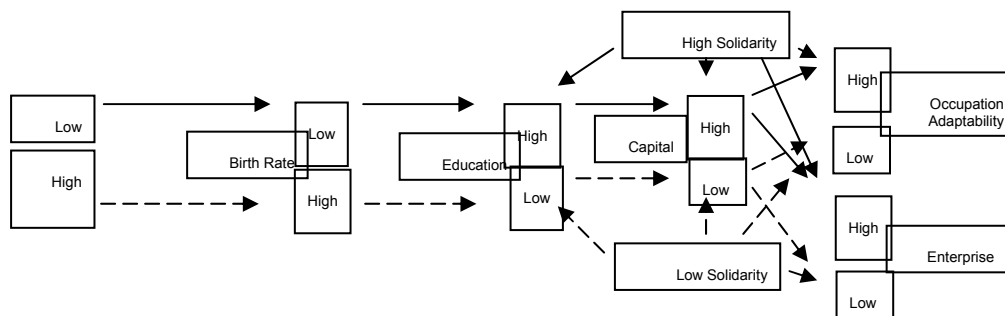


Figure 24: Eco-sociological differences between the Jewish (complete line) and Bedouin populations (dashed line) in the Negev.

In essence, while blaming the authorities for discrimination, cultural differences, may largely and principally account for the differences in vulnerability of the Bedouin population in comparison to the Jewish population, as summarized in Figure 24. Education and low economic status may be the prime factors to increase vulnerability to droughts. The high birth rate of the Bedouins that results in 10-30 children per household, all of whom rely only on one salary, does not guarantee high hopes for improved education and higher economic status.

Yet, different responses can be traced in Jewish society. High education, high economic status and high solidarity coupled with great readiness to explore new techniques make the Jewish agricultural population fairly resilient to droughts. With new purification installations, new projects aiming to desalinate seawater and to explore ancient aquifers, more and more open fields are irrigated. With new crops that can utilize lightly saline water of the ancient Cenomanic aquifer, more and more land is cultivated. However, one has to wonder about transference of vulnerability from the economic systems to the ecological ones (aquifer lowering etc).

Opportunities for Decreasing Vulnerability in Northern Negev

While the increase in temperatures may not necessarily negatively affect crop yield, water shortage may pose a severe threat. Efforts are thus directed towards the supply of adequate water amounts.

Several projects are concomitantly advanced: Seawater desalination projects at the Mediterranean coast, and sewage purification projects aiming to increase the quantity that is currently purified (75%). In addition, several projects are in different stages of planning and among them desalination of the water of the ancient Cenomanic aquifer in the Negev and expansion of the irrigated fields.

In the near future some main and local water systems may be operative in the northern Negev, as described in Table 2: (a) of drinkable water (which currently provides drinking water from the northern part of the country that is relatively rich in water and will be also used to transfer desalinated water from the Mediterranean), (b) of purified water that uses the purified sewage waters of Tel Aviv, Jerusalem and Beer Sheva, and will serve to irrigate agricultural fields (c) of the ancient Cenomanic aquifer that will provide brackish water to the central and southern Negev for the growth of orchards or crops capable of using this water, and (d) a salt line that will evacuate the excess salt to the Mediterranean Sea. In addition, local systems will operate that will use runoff water from local reservoirs or purified sewage water from the local small settlements.

Table 2: National, regional and local water systems that will be operative in the near future

Type	Extent	Status	Description	Remarks
Drinkable	National	Operative	Transfers water from the northern part of the country and desalinized water from the coast	The fraction of the desalinized water is still small
Highly purified (Shafdan)	Regional	Operative	Sewage from the Tel Aviv metropolis	
Medium Purified	Regional	Operative	Sewage from major cities other than Tel Aviv like Jerusalem and Beer Sheva	Three years ago The quality of the water was substantially improved
Medium Purified	local	Operative	Sewage from small settlements	
Good Quality	local	Operative	Runoff water caught in wadis	
Brackish	Regional	Partially operative	Partly desalinized and used as drinking water and partly used to irrigate crops adapted to brackish water	
Salty	Regional	Planned	Aimed to carry the excess salt that is produced during the desalinization process to the Mediterranean	Will facilitate large scale usage of the ancient Cenomanic aquifer

6.b The Mega-Fires of August 2007, Ilia Prefecture, Peloponnese, Greece: Eco-human vulnerabilities along the disaster cycle¹

Direct Losses

The forest fires of August 2007 that hit the Prefectures of Peloponnese could be recorded as the most catastrophic extreme event in the history of Greece after Second World War. Of the

¹ The present analysis is based on the documentary material found in the article "Private Resilience Responses against Collective Recovery Interests, The Case of Mega-Fires of August 2007, Ilia, Greece" by K. Sapountzaki and A. Papachatzis, prepared for the book *Community Disaster Recovery and Resiliency: Global Opportunities and Challenges*, by Miller D. et.al. (eds), to be published in 2010 by Auerbach/an imprint of Taylor and Francis LLC.

Prefectures of Peloponnese the most severely hit by the disaster has been the Prefecture of Ilia (Figure 25).

The disaster shocked the Greek society and its rationalization cleaved the lay public and political leaders in three groups. The first group attributed the disaster to an external "asymmetrical" threat (a view accommodating the governing political party). The second blamed the vulnerable and unprepared social and administrative structures and organizations. Finally a third group was formed by the adherents of the view that it was climate change and the extreme meteorological conditions that facilitated rapid fire spread and rendered suppression mechanisms incapable to cope with an event of such a scale and intensity.

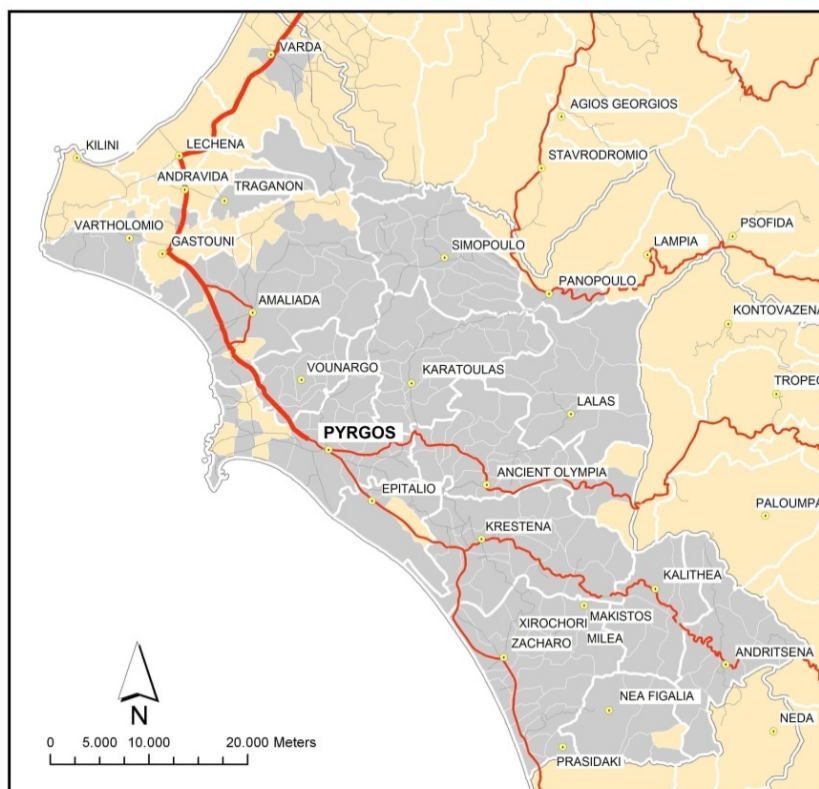


Figure 25: Ilia Prefecture: Political /administrative boundaries and basic settlements (Sapountzaki and Papachatzi, to be printed).

The Prefecture of Ilia belongs to the administrative Region of Western Greece. It covers an area of 2,681 km² (or 2 % of the total territory of Greece) that is divided into 22 Municipalities and hosts a population of 193,288 inh (census data, 2001).

According to the accountings of direct losses quoted in Sapountzaki and Papachatzi (to be printed) these have been indeed huge in terms of their size, area covered and represented value:

"The forest fires that ravaged Ilia caused: tens of losses of human lives and 6,000 homeless people; 168 municipal districts or 1994 km² declared as disaster areas-i.e. a territory representing 76% of the total area of the Prefecture-(AUA 2007); tens of thousands of hectares of burnt forest land representing 39% of the total forest land of the Prefecture (AUA 2007); thousands of hectares of burnt natural areas of significant value and unique bio-diversity, some of them under status of environmental protection - in particular Kaiafa's forest and lake, the Natura area around Olympia village and archaeological site and the plateau of Foloï with one of only few of the pure high oak forests in Europe- (WWF-Hellas and AUT 2007); severe infrastructure and building damages in most of the settlements of the Prefecture; huge losses in the livestock farming sector; damages in vegetal stock covering an area that represents 14,3% of the Totally Used Agricultural Area (burnt communal pastureland is not included); damages in olive-tree cultivations covering tens of thousands of hectares and representing 37,8% of

the total, also losses in grapevines, walnuts and almonds (AUA, 2007); disruptions and failures in basic lifelines, i.e. the road network, crossings and bridges, electric and water supply networks etc.; damages in farmers' fixed and movable capital (i.e. storages and sheds, mechanical equipment etc.); medium-term atmospheric pollution that spread beyond Peloponnese to the distant northern coasts of Africa."

Secondary Hazards and Losses

The recovery undertakings had to cope with not only direct losses but secondary hazards and losses (ecological, social and economic) as well (Sapountzaki and Papachatzi, to be printed):

"To begin with the illegal and uncontrolled dump sites scattered all over Ilia, under the catalytic effect of fires released solid, liquid and gas pollutants that caused short and medium-term soil and subsoil pollution, atmospheric pollution and pollution of surface and underground water reserves². In turn, these polluting processes affected water reserves that were formerly appropriate for irrigation and domestic uses and generated threats to public health. Secondly, forest fires intensified and expanded pre-disaster flood, landslide and soil erosion hazards due mainly to extinction of vegetation and uncovering of sloping agricultural and forest territories (AUA 2007); due to the consequent increase of runoff and reduction of water infiltration as well as increase of the capability of water for corrosion; due finally to eventual changes in the morphology of the drainage network. Furthermore, the risk of topsoil losses in Ilia is higher than ever as a result of soil erosion and drought hazards impinging upon the vulnerable burnt or re-sprouting land. Indeed the risk of desertification in Ilia is closer than ever due to recent forest fires, intensive agriculture and Global Climate Change (AUA 2007)."

To the above secondary ecological losses one should add social and economic ones (Sapountzaki and Papachatzi, to be printed):

"..... rural landscape degradation and destruction of valuable environmental amenities and tourism resources; disruption of incomes, closure of firms and disruption of the wider socio-economic life of the hurt communities; finally, long-term uncertainties and threats relevant to economic decline, demographic decay, displacement of locals etc".

From the above accounting of losses one can gather that first range losses out of the forest fire have been certain ecological and physical ones generated directly by the stress (i.e. loss of human lives, burning of forest ecosystems and natural areas, losses and damages in vegetal stock and livestock, release of liquid, solid and gas pollutants to eventually settle on soil and subsoil, in water reserves and the atmospheric environment, damages in the built environment, movable capital and the technical infrastructure etc). However, there are other ecological impacts and losses (and a potential of threat to human health) that are the outcome of the first range direct ones and their realization is due to vulnerability to loss. For instance, the detrimental impacts on the quality of potable water were due to systemic interconnections and dependency of the potable water supply system on the water reserves of the burnt territories.

All cases of social and economic losses these have been the outcome of vulnerability to loss, the indirect result of other losses (at first, of ecological and physical ones). More specifically and as Figure 25 indicates the ecological and physical losses of the first order generate not only ecological losses of the 2nd order but economic and social losses of the 1st order (both of them owing to vulnerability to loss). For instance, loss of input and disruption of the livestock

² Bulletin of Ecological Subjects, 9/11/07, Secretariat General of Communication and Information, Directorate of Analyses and Documentation, Department of Ecological and Cultural Subjects (in Greek)
www.minpress.gr/minpress/deltio_oikologikwn_thematwn_09_11_2007.doc

farming production has been a corollary of losses of forest land and in vegetal stock; similarly discontinuance of agricultural production emanated from loss of cultivations and damages in farmers' equipment and immovable capital.

All above losses in combination and in the long term are going to produce 1st order territorial losses such as demographic decay, structural changes in economic and social base of certain communities, abandonment of settlements, etc.

But losses do not finish with 2nd order ecological and eco-human ones and 1st order social, economic, territorial ones. Each order of losses either on its own or coupled with other orders of the same or different loss category (and hence vulnerability) may produce 3rd, 4th and so on order of losses. These latter are probably losses suchlike those of the 1st and 2nd order (differing only in terms of time of manifestation). For instance loss of jobs may occur again and again (at intervals) after a disaster and as a result of successive and combined losses and failures, increasing thus gradually the overall unemployment rate.

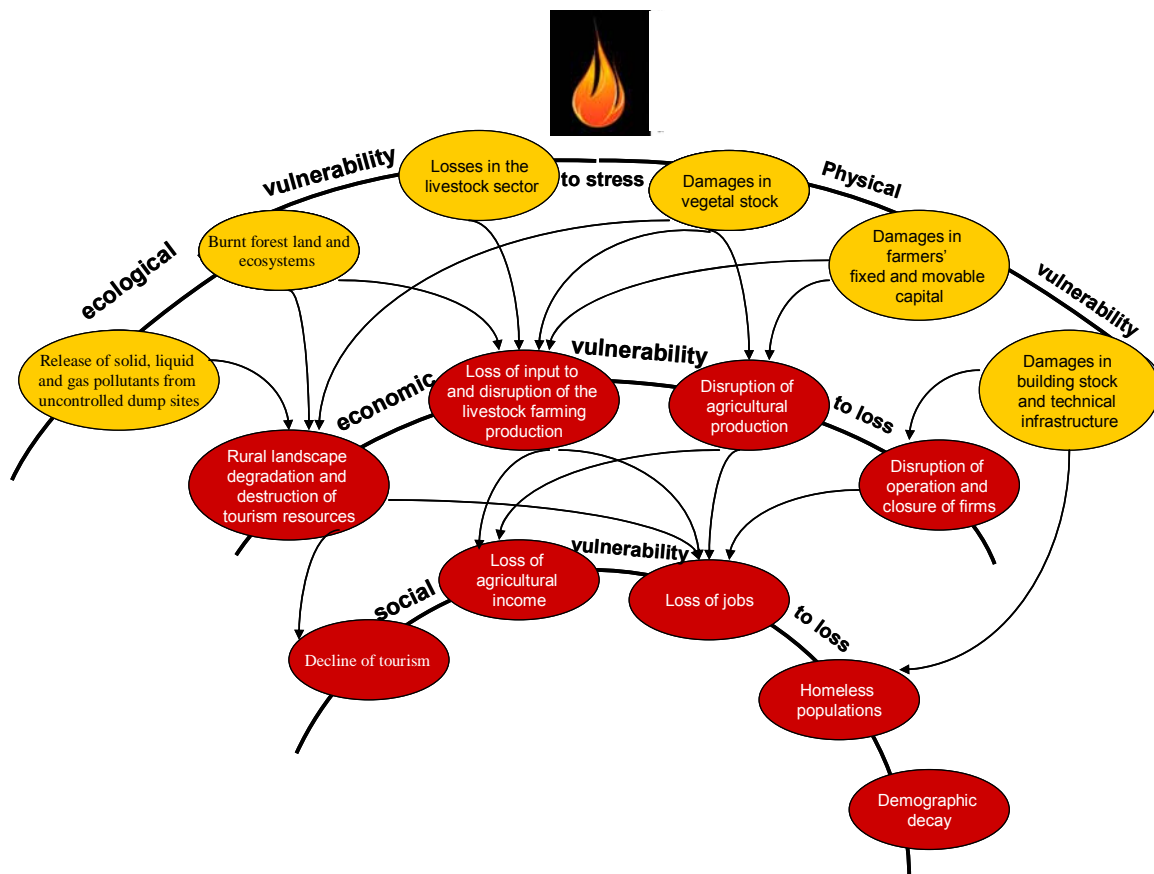


Figure 26: Forest Fires in Ilia, Peloponnese 2007: Graphic representation of causal relationships between ecological and physical aspects of vulnerability to stress on the one hand and economic and social aspects of vulnerability to losses on the other

In any case an important lesson from the mega-fires of Ilia is that vulnerability to stress is determined by the characteristics of the stress (i.e. intensity, time of manifestation, duration, geographical location etc) while vulnerability to loss depends on the extent of 1st order losses and more specifically on thresholds of losses. Only when these thresholds are surpassed subsequent orders of losses come into light (for instance only when building damages

surpass a certain limit making the buildings unrepairable, only then the respective households and population groups become homeless).

But what have been the fundamental origins of vulnerability to stress and vulnerability to loss in the case of the mega-fires of Ilia? Hence, it is important at this point to refer to the pre-disaster vulnerabilities of the eco-human systems of Ilia.

Pre-disaster vulnerabilities in Ilia Prefecture

The Prefecture of Ilia's GDP per capita has increased by 8.1 % in the decade 1995-2004 vis-a-vis an increase of 11.5 % at the national level. As a result while Ilia's GDP per capita corresponded to 66.7 % of the national average in 1995, it fell behind in 2004 as it represented then only 53% of the national average (census data, 2001). According to the description of the social and demographic profile of the Prefecture by Sapountzaki and Papachatzis (to be printed):

"In proportional terms the Prefecture as a whole retains population of productive ages (i.e. 15-64) constant but loses population of young ages (i.e. up to 14 years). Numbers of marriages and births decrease in Ilia and so do birth and fertility rates causing changes in population composition and population ageing. Certain researchers ascribe the zero natural population growth and the reduction of births to local unemployment, low salaries, lack of state welfare provisions to family and children and other socio-economic reasons. Indeed the rate of employment in the primary sector is 35.1 % a percentage that is more than double the respective national average (14 %) and unemployment has been higher than that of the national level. Some illiteracy and the generally low education level of the population add up to the social and economic vulnerabilities of the human capital of Ilia".

The communities of the Prefecture epitomize everything that can render a social and economic system vulnerable to threats and disasters in the sense of lack of capability to withstand impacts and losses and to cure them rapidly and effectively:

- Its low GDP signifies an economic system without reserves and pools of resources to appeal to in a crisis situation (lack of redundancy and resourcefulness).
- Population ageing entails limited capability for innovation (towards resilience), for learning capacity, for robustness; besides due to bodily weakness aged groups present problems of self-reliance.
- The almost unilateral development of the primary sector means lack of diversity, flexibility and redundancy.
- Unemployment and the low education level, implies lack of necessary resources for recovery, limited learning capacity, capacity for innovation, adaptability and self-organization as well as dependency on public welfare services.

One should add to the vulnerabilities of Ilia its institutional system's vulnerability owing to the inert and lack of drive for intervention on the part of the Local Development Companies as well as economic dependence of the Prefectural and Municipal Authorities on Central Government.

Vulnerable also has been the ecological system of Ilia, its natural assets and amenities and local cultural heritage. At a distance of 20 km east to Pyrgos (the Prefecture's capital city) and on a site within a valley between the Cronius Hill, the river Alfios and its tributary Kladeos lies the ancient Olympia (Figure 25), one of the most important archaeological sites of Greece and internationally, too. The monuments and their marvelous delicate setting have been protected by the Natura 2000 regime until this was breached by the flames of August 2007.

Sapountzaki and Papachatzki (to be printed) present in detail the vulnerabilities and exposures of the ecological system:

"... over-exploitation and waste of surface and underground water reserves, intensive agriculture and use of fertilizers, expansionary land uses and land use conflicts, plenty of scattered, illegal dump sites adjacent to forest vegetation and cultivated land, illegal and semi-illegal out-of-plan building developments, careless and harmful farming practices (e.g. burning crop remnants, woodcutting, trespassing, clearance works etc), droughts, floods and landslides."

What makes the overall eco-human (and territorial) system extremely vulnerable is dependency of the social / economic system on the ecological and vice versa (they sustain one another). Economic and social viability of the communities in Ilia depend on vigour and in any case satisfactory condition of forest and rural ecosystems due to the exclusively agricultural and tourist orientation of local economies. The other way around protection of the ecosystems from the various threats (drought, fires, clearances, land use changes, frost etc) depend on human action and institutional measures.

Curing and redistribution of vulnerabilities after the disaster

According to Sapountzaki and Papachatzki (to be printed), central government's response after the disaster was directed towards three target groups of victimized actors: the victimized citizens in general, the affected local farmers and affected local businesses and firms (Ministry of Economy and Finance, 2007).

However, in the lack of a comprehensive plan that would take into account needs and the interests of local communities, socio-economic activities and ecological systems as well and the appropriate leadership to implement it, diverse and distinct local actors made their own individual attempts to recovery. These recovery paths were opened via private resilience practices by utilizing resources that might be critical for alternative and sustainable recovery paths or paths of others.

At the end of August 2007 the Central Government established a Special Fund (ETAEA) to support the Affected by Emergencies in general. Actually the Fund was instituted to satisfy the needs of the affected by the mega-fires of August 2007. The Fund collected the donations, supplies and offers of the public, private and social sectors addressed to the affected by the disaster. As Sapountzaki and Papachatzki explain:

"The theoretical objective of the Fund was to finance recovery projects that would be in line with the proposed actions and directions of wider development plans promoting the recovery of disaster areas rationally, comprehensively and fairly. In actual fact, however and as the Fund's expenses indicate the collected funds are mostly used for the support of certain selective groups, for fragmented, independent measures or according to the will of the donors. This malign management practice seems to have stem (among others) from the lack of or delays in the elaboration of long term development plans while the beneficiary groups and communities pressed for the satisfaction of actual or allegedly emergency needs."

For one to understand the dynamics of vulnerability during recovery should first acknowledge that institutions are themselves vulnerable entities pursuing also their survival and recovery after losses (physical, economic and political losses too). Initially they are threatened by the physical damages in the administrative buildings and the public infrastructure at large; on top of that they are threatened by the shake of trust of lay public in state policy measures to protection against disasters. In a subsequent stage they are threatened by the economic repercussions of their promises and recovery expenses. Indicative is the case of central government's attitude towards victimized farmers and

livestock breeders after the mega-fires of 2007 as interpreted by Sapountzaki and Papachatzzi:

"Central Government's immediate response to the disaster by means of a series of unplanned direct funding measures and spontaneous promises was not based on assessment / anticipation of losses and short and medium-term needs. It was rather an effort to respond to mass media pressures and public feelings all the more so as public's discontent could put at risk the governing party at the oncoming (within a month) parliamentary elections. As a result first instance measures were later modified, specified, re-interpreted or cancelled altogether. Indeed nine months after the disaster a Joint Ministerial Decision³ introduced exemptions from the financial support measures that had been addressed to affected farmers and stock-breeders right after the disaster..."

Central Government intensified farmers' and stock-breeders' vulnerability in an effort to cure its own vulnerability. Truly, the whole process of recovery of Ilia after the mega fires of 2007 has been overwhelmed by several struggles on the part of various actors to obtain resources for themselves and engage these to achieve survival and recovery or even upgrade their respective socio-economic status to levels higher than prior to the disaster. Indeed, the stricken territory turned soon into an arena of multiple transferences of vulnerability from one actor to another entailing in some cases vulnerability transformations (with regard to the type of anticipated losses and the potentially confronted hazard too). Most prominent are the cases of conflicts between ecological and socio-economic recovery. Indeed, environmental rehabilitation has been hampered by the stricken social actors themselves in several ways (Figure 27). Indicative is the case of distressed olive-tree farmers who appealed to external, distant potential donors affording resources and means usable for recovery as presented by Sapountzaki and Papachatzzi (to be printed):

"...thirteen thousands of olive-trees were jointly offered by the distant Prefecture of Cyclades and the Aegean TV channel. As olive producers were advised to retain the burnt olive groves untouched in order to facilitate re-sprouting the beneficiaries had no available land for planting the donated olive-trees. Their only chance was to trespass and utilize for the purpose land under reforestation or natural regeneration."

In the case of Ilia the state with the help of resilience practices deceived farmers and livestock breeders and deprived them of the deserved support for recovery; hence the latter destitute as they were from the needed means for recovery attempted to abstract resources essential for the recovery of the ecological system (land, re-sprouting vegetation etc). These conflicts are not the only ones; there were also several cases of resilience causing tensions between long and short-term recovery and vulnerability as well as cases of private resilience responses with adverse effects on communal vulnerability and to other hazards.

It seems that during recovery vulnerability is basically a function of accessibility to resources (resourcefulness). In the case of the eco-human system we are concerned with, pre-disaster systemic relationships broke down and the involved actors attempted to build new ones by appealing to other systems and external sources and actors. It is indeed at this stage where spatial and temporal scale interactions, as addressed by Folke *et al.*, (2005) and Chuvrajan (2006), are of major importance and the only expedient method for the stricken actors to entrench new systemic relations and eventually new systems. However, shouldn't this appealing process to external resources return the aspired to, actors compete then with each other for the resources internal to the system (eco-human in the present case); the most

³ Joint Ministerial Decision No 258379/9.4.2008 (Governance Gazette Issue No 646/11.4.2008) of the Ministers of Economy and Finance and of Rural Development and Food.

powerful increase consequently their response capacity and decrease their vulnerability to the disadvantage of the underprivileged and powerless groups.

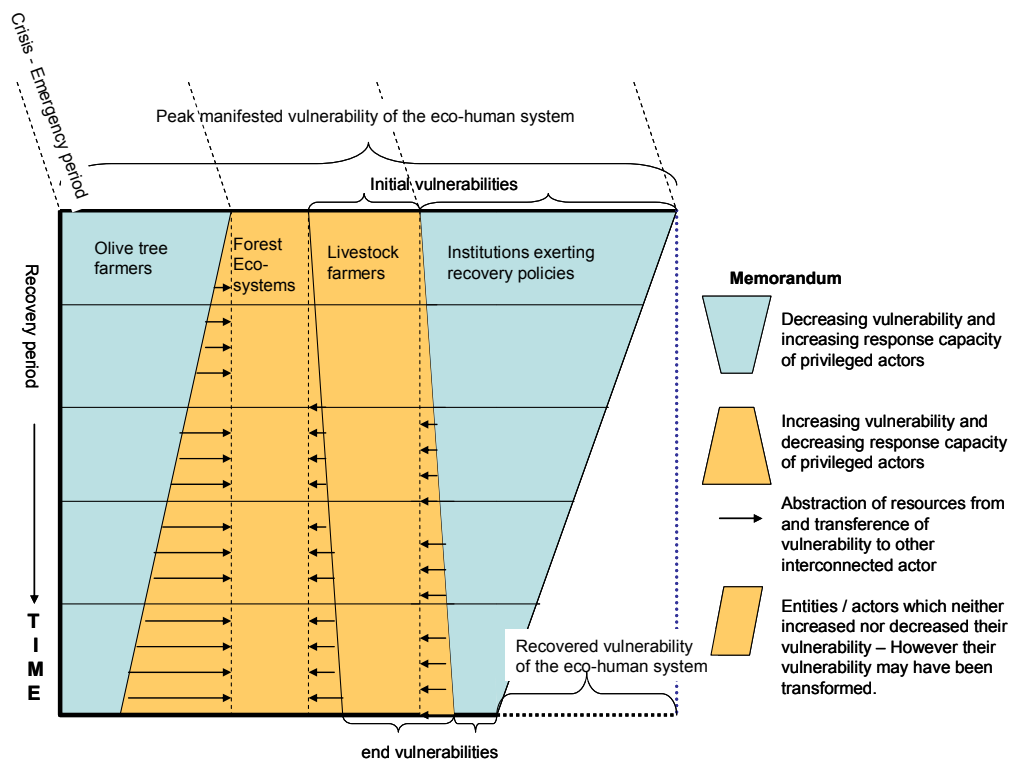


Figure 27: Forest Fires in Ilia, Peloponnese 2007: Graphic representation of vulnerability evolution of the eco-human systems in Ilia and of certain involved actors within (institutions, olive-tree farmers, livestock breeders, forest ecosystems) – Transferences of vulnerability from one to another.

6.1. Ecological vulnerability to physical stress (drought and forest fires)

Ecosystems may be vulnerable to some hazards, particularly when the latter occur in an altered environment (for example because of climate change). For example, even though forest fires are natural and may be even beneficial under given conditions, the repeated burning year after year may be a consequence of altered environment (accumulated vulnerability). Concepts of vulnerability and ecological resilience, discussed for example by Gunderson and Holling (2002), are taken into account in this section in order to address the relationship between ecological capacity to resist or undergo changes with respect to the type of stress we are interested in the project (natural hazards).

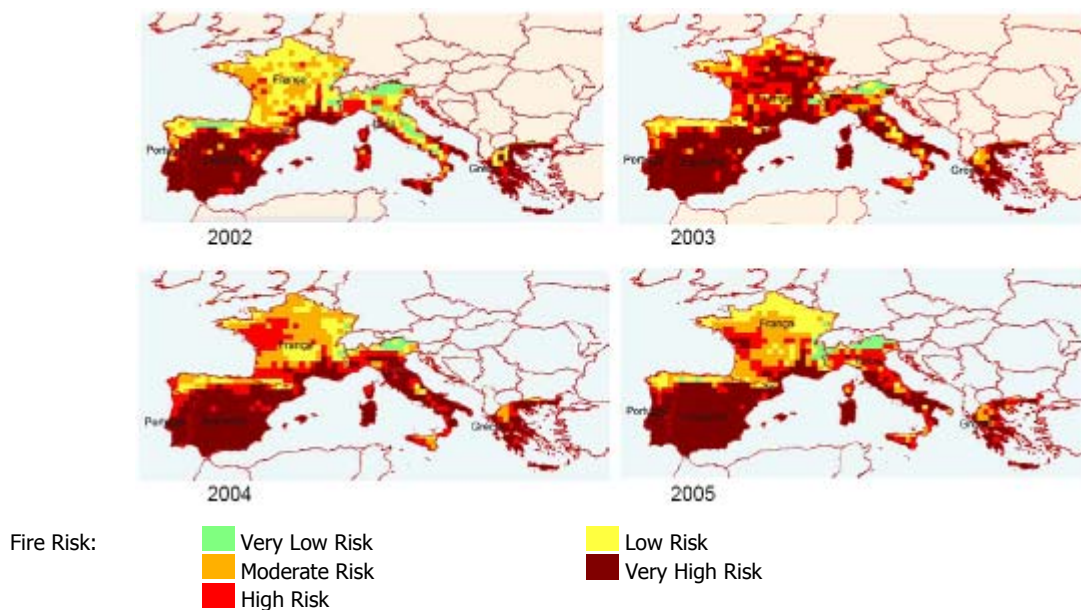


Figure 28: Fire risk in southern EU countries (2002-2005) - European Forest Fire Risk Forecasting System

Mediterranean countries are usually characterized by hot and dry weather during summer time. This climate decreases the water content in plants, leading to an increase of the inflammability of the vegetation. Most of Southern Portugal is characterized by a Mediterranean climate of cool and rainy winters and dry hot summers. The rainy winters provide soil moisture which, along with warm spring temperatures, leads to high primary productivity of forests. The dry hot summers negatively affect the water content of plants, leading to increased inflammability of the vegetation (Costa *et al.*, 2007). These two factors make the Portuguese forests particularly vulnerable to forest fires, especially in the summer season. The fire risk related to meteorological conditions in Portugal, as well as in other Southern European countries, is very high, as can be seen in the figure below (Figure 28). Meteorological risk has increased in recent years, especially in 2005. Other countries may instead experience dry winters, like Greece, making resinous pine forests even more flammable. Predictions of climate warming in the Mediterranean area (Giorgi and Lionello, 2007) indicate a consistent increase in air temperature and a decrease in summer rainfall, suggesting a future increment in water deficit. This in turn may lead to an increase in ignition probability and fire propagation during summer. Already in 2005 Portugal experienced a pronounced period of intensive drought, with rain levels mostly below usual averages. These climate conditions led to very high drought of forest fuels and hence to an increased risk of fire ignition and propagation.

The idea that Mediterranean type ecosystems are resilient to fire has been cited for long time on fire ecology literature (Trabaud, 1991). Resilience is understood as the pace, manner and degree of recovery of an ecosystem following disturbance (Westman, 1986). The earliest approaches to the study of fire effects on vegetation revealed that Mediterranean plant species are able to survive fire or reestablish after it. There are basically two main post-fire regenerative strategies of plant species. Either the species are killed by fire and depend on seed reserves to recover the population (*obligate seeder*) or they loose their above ground phytomass and recover vegetatively from underground organs (*sprouter species*).

Although vegetation in the Mediterranean in general is capable to cope with fire, when the life time of tree species exceeds fire return interval, the species that are unable to survive or reproduce after fire will eventually go extinct (Fernandes and Rigolot, 2007). Currently, fire

regime characteristics are known to set limits to vegetation resilience and determine to large extent the vegetation dynamics in the Mediterranean Basin. High fire intensity can reduce re-growth ability of seeder species and usually enhance soil erosion (de Luís *et al.*, 2003). Thus, it has also been observed to negatively affect vegetation recovery (Moreno and Oechel, 1994). High fire extent can limit the arrival of seeds from unburnt sites to most of the burn surface affecting negatively the regeneration of seeder species (Rodrigo *et al.*, 2004). Fire seasonality is also a major factor in determining the possibilities of success for post-fire vegetation recovery. For example, if fire occurs when the level of stored resources are low, the re-growth of resprouter species is diminished. On the other hand, if fire occurs when the seed banks are not fully developed or when seeds have already germinated, then the seeder species may be prevented from regenerating.

Another challenge for Mediterranean type ecosystems fire ecology is the issue of fire frequency. Mediterranean vegetation is thought to be able to recover when a certain time interval is allowed between fires. However, relevant compositional and structural shifts occur if fire intervals are particularly short (Keeley *et al.*, 1989). It's also argued that fire repetition at short intervals result in long-term cumulative effects on some ecosystems properties such as nutrient cycle and productivity (Carter and Foster, 2004). Wildfires also substantially alter the hydrologic and morphologic response of a catchment, triggering severe erosion on subsequent rainfall events.

In any case the potential for recovery of biotopes after fires depends largely on the effective protection of these areas from any future change in land use. Forest fires also lead to soil deterioration, causing large soil losses during rainfall and deterioration of downstream water quality. It is also expected that, if current frequencies of wildfires persist or increase, there will be some major consequences for soils and for run-off. Physical and chemical soil erosion increases with decreasing soil thickness, leading to decreased soil fertility and carbon sequestration capacity. Surface run-off can also increase the likelihood of floods (Pereira *et al.*, 2004). Empirical work taken forward by Wittenberg *et al.* (2007) added more information to some of the aspects mentioned above. The case study of Mt. Carmel in Israel revealed that Mediterranean eco-geomorphic systems are quite resilient, showing quick response, at least in terms of return to pre-disturbance states of vegetation cover, and hence of soil erosion rates. This is true not only in response to a disturbance caused by a single fire, but also for repetitive fire incidents. In addition following a single fire, vegetation cover reached pre-disturbance values within less than 5 years (Wittenberg *et al.*, 2007).

Torres *et al.* (2006) went further in identifying not if the post-fire vegetation recovers but also describing the spatial and temporal patterns of plant species richness in a burnt Mediterranean shrubland open forest at three different sampling scales. Results pointed that the vegetation community in the first post-fire year was spatially structured with a positive spatial cross-correlation between plant cover and species richness, indicative of areas with high plant cover and species richness and vice versa. The second year after fire, patterns became less evident and no clear spatial cross-correlations was detected at any scale. These results suggest that after a fire the community is structured as a result of the ecological memory of the system, which is not overridden by fire. In subsequent years the patterns are modified by the dynamics of the flora, particularly the annuals, producing lack of patterning (Torres *et al.*, 2006).

6.2. Ecological vulnerability to losses (Na-tech)

Ecosystems can be clearly damaged by technological accidents. Ecosystems' vulnerability to na-tech events provides a clear example of "vulnerability to losses". The latter addresses the

potential response capacity of ecological systems to partial (or total) damage that occurred in parts of other systems (namely the technological ones) with which connections exist.

A na-tech event can be defined as an “accident initiated by a natural disaster which results in the release of hazardous materials. This includes releases from fixed chemical installations and spills from oil and gas pipelines” (Kraussmann and Cruz, 2008).

In many cases, the triggering hazardous event does not directly strike natural resources. The impacts on natural resources depend on the damages, due to the triggering event, affecting industrial plants or laboratories handling hazardous materials, gas pipelines and so on. Nevertheless, it's worth noting that, in many cases, the everyday perturbations in natural resources due to human activities can be a factor which causes or accelerates or amplifies the effects of a natural hazard: “a natural event [...] can directly cause a technological accident [...]. The reverse is also true, with anthropogenic influences altering natural events such as flooding and storm” (Clerc and Le Clair, 1994). In the mentioned cases it is possible to define the na-tech as a “spiraling” event: for example “deforestation that eventually trigger natural hazards such as floods which in turn cause (...) the destruction of a chemical plant” (Clerc e Le Claire, 1994).

Adger (2000) refers to the “dependency of social systems on the environment itself”, highlighting that such a dependency “brings with it its own set of problems in the economic and social sphere”. According to Adger “the dependency of individuals within a resource system does not necessarily depend on reliance on a single crop or fish stock, but in some circumstances on dependence on an integrated ecosystem. This is particularly the case with coastal resources (...): fishing communities are best understood as dependent not on a single resource but on a whole ecosystem. If an oil spill affects a tourism beach then it will also affect fishing stocks and have other ecological impacts”.

As a result of these considerations the emphasis is placed on the need for a conceptual framework that “accounts for the vulnerability of coupled human-environment systems with diverse and complex linkages” (Turner *et al.*, 2003). Hence, given the relevance of ecological systems for human ones and in order to shed light on the heterogeneous and complex linkages among ecological and human systems' vulnerability, two case-studies will be provided. In detail, these highlight the vulnerability to losses of ecological systems and the consequences for social and economic systems. The selected case-studies are:

- the na-tech event which occurred in Baia Mare (Romania) in 2000;
- the na-tech event which occurred in New Orleans (USA) in 2005.

6.2.a The Na-tech event in Baia Mare in 2000

The first case was due to adverse meteorological conditions which raised the water level and caused the overflow of a dam located near the city of Baia Mare in Romania, where in 1999 the Aurul Company started to process water for extracting gold and silver using high concentrations of free cyanide. “It has been described as the worst disaster since Chernobyl. In January 2000, a retaining wall failed at the Aurul gold processing plant in Romania, releasing a wave of cyanide and heavy metals that moved quickly from one river to the next through Romania, Hungary, the Federal Republic of Yugoslavia and Bulgaria, killing tens of thousands of fish and other forms of wildlife and poisoning drinking-water supplies” (Cunningham, 2005).



Figure 29: The progress of the na-tech event occurred at Baia Mare (UNEP/OCHA, 2000)

It's worth remembering that Aurul company received fifteen permits before obtaining an Environmental Agreement to proceed. The Aurul activity was initiated in order to improve the environmental conditions of the developing area of Baia Mare, very close to old tailing ponds, that should be cleaned and recovered because of highly toxic, potentially chronically, leaking.

The company started its activity in May 1999 by processing an existing 30 year-old tailing dam located near Baia Mare city, to the west, close to a residential area. The failed Aurul tailings dam is part of an operation of retreatment of gold tailings from the old unlined Meda tailings pond. The tailings were pumped from the Meda pond to the Aurul S.A. processing plant, where sodium cyanide was added for the recovery of residual gold. After gold and silver extraction, the remaining tailings contained total cyanide concentration of 400 mg/L, with free cyanide concentration of 120 mg/L.

The na-tech event led to the release of 100,000 mc of cyanide-contaminated liquid as well as heavy metals, into the Tisa River. This plume travelled down the length of the river, into the Danube river and then into the Black Sea by which time it had become significantly diluted.

The European Union task force investigation concluded that the accident was caused by the inappropriately designed tailings dams, the inadequate monitoring of the construction and operation of those dams and by severe – though not exceptional – weather conditions⁴.

The accident had immediate and very severe impacts on a large number of plants and wildlife species in the river systems, killing tonnes of fish in these rivers and poisoning the drinking water of more than 2 million people in Hungary: ice on the rivers and low water levels in Hungary delayed the dilution of the cyanide, increasing the risk to municipal water supplies. High concentrations of copper, zinc and lead, leached by the cyanide, compounded the problem.

In detail, plankton in the Somes and upper Tisa River in Hungary (closest to the accident) was completely killed, and in the middle and lower reaches of the Tisa between 30-60% of plankton were killed by the passage of the pollution plume. Within days of the spill materials passing, phytoplankton and zooplankton had begun to recover throughout the entire river system (International Task Force Report, 2000).

⁴ <http://www.wise-uranium.org/mdafbm.html>

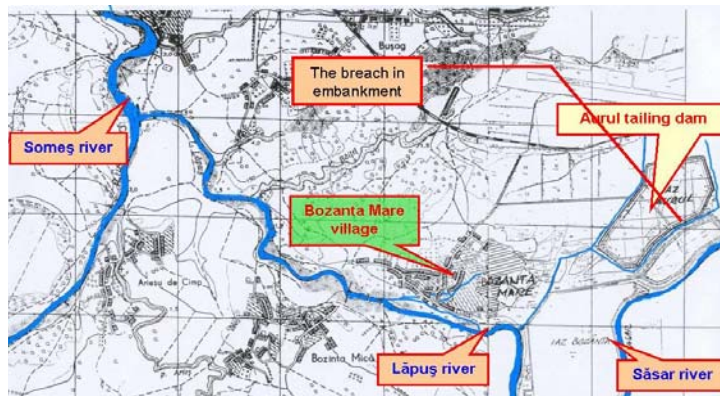


Figure 30: The location of the Baia Mare na-tech event (Bud et al. 2002)

The visible death of fish was a clear indication of the immediate impact of the accident: Hungarian authorities reported that a total of 1240 tons of fish were killed as a result of the spill. Moreover, some native protected and endangered species may have been finally eliminated by the spill.

On the contrary, the effects of the pollution on birds and mammals were limited: the ability of mammals and birds to perceive the presence of the cyanide and the fact that much of the river was covered by ice likely prevented large contact with the polluted waters (Bud *et al.* 2002). Once the plume had passed, water and sediment quality started to return to a normal state. As the plume consisted of dissolved materials, there was little deposition of pollutants. As a result, once the plume had passed, effectively no cyanide remained in the river or on river banks.

Nevertheless, the uncertainties related to the long-term environmental and health impacts of the accidents have been largely discussed. According to some scholars (Lucas, 2001; Bud *et al.*, 2002), they are unlikely to relate to cyanide, which has dispersed and does not bioaccumulate. Any impacts would be related to the heavy metals added into the sediments and soils of the Tisa ecosystem. All the evidence suggests that, as a result of the accident, heavy metal levels have not been elevated significantly in the river system. This situation needs to be kept under constant surveillance for heavy metals.

Furthermore, the na-tech event of Baia Mare is one of the paradigmatic examples of transboundary effects⁵ due to such events: the toxic substances, through the river waters, have "transferred" the consequences of a localized event to a very wide area. In this way impacts and consequences of the event have spread to the organizational setup of emergency response (involving different national States, different organization and so on), on the natural environment, on the population and on the economic activities of different countries.

Even though the event had no long term effects from the ecological point of view, it highlighted the risk for the environment and the public safety of the mining industry which represent, in turn, one of the most relevant activity from an economic point of view. The County of Maramures in which the area of Baia Mare is located, rich in mining and related industries, is of key importance to Romania from the economic point of view. Moreover, the

⁵ It's worth noting that The Convention on the Transboundary Effects of Industrial Accidents, aimed at protecting human beings and the environment against industrial accidents by preventing them, reducing their frequency and severity and mitigating their effects, was adopted in Helsinki on 17 March 1992 but entered into force on 19 April 2000.

accident had severe negative impact on socioeconomic conditions of the involved communities, since all the area was highly dependent on the natural environment for agriculture, fishing and tourism.

As regards the direct socioeconomic impacts, after the accident, "the unemployment of the Baia Mare area rose less than expected. Production of gold was suspended in Baia Mare, but Aurul kept all its employees. However, employment fell in industries that were dependent on products from Aurul S.A." (Kaszala, 2002).

With respect to the agriculture, the image of agricultural products from the region greatly suffered as a result of the spill, with a consequent loss of markets. The fishing sector, which is a relevant economic activity mainly in the Hungarian part of the river, was the worst affected one: "the damage had a serious impact on the fishermen's income and on the fish processing industries. In addition to the 1240 tonnes of fish stock killed by the pollution, a six month fishing ban was ordered in Hungary" (Kaszala, 2002).

Finally, as regards tourism, a reduction in domestic and international tourism due to the river pollution has been registered: canoeing activity decreased by around 90% after the event and, along the banks of the Lake Tisza, there was a 33% reduction in the number of German and Austrian tourists.

6.2.b The Na-tech event in New Orleans in 2005

The second case-study is the Katrina hurricane (Category 4) which impacted the coast of Louisiana and the city of New Orleans on August 29th, 2005. Storm surges due to heavy rains and intense winds caused several breaches in the hurricane protection levee network on the New Orleans (N.O.) lakefront and along the Industrial Canal (Colten, 2006), leaving nearly 80% of the city under water.

Katrina is a very relevant example of vulnerability to losses of ecological systems in case of na-tech events. Moreover, in that case, the alteration of natural ecosystems before the hurricane favored the flood event and, in the meanwhile, the multiple damages due to the flood significantly affected natural resources, inducing short and long term consequences which had, in turn, repercussions on the social and economic system.

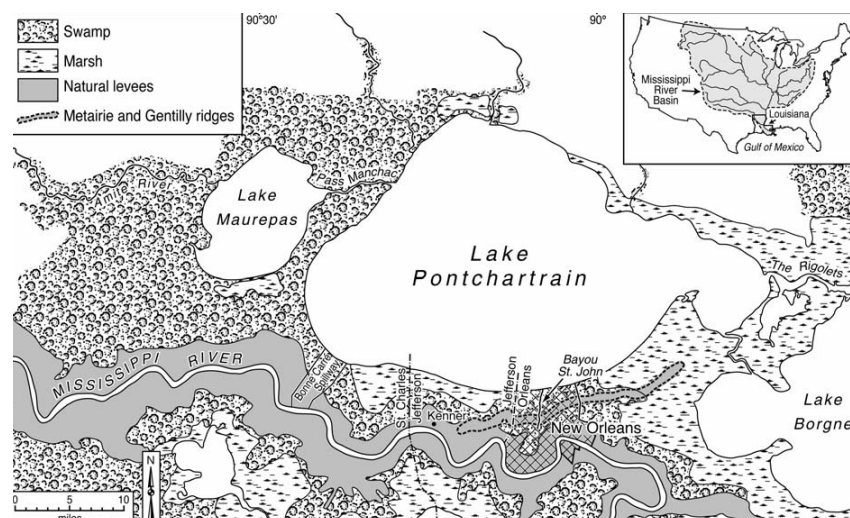


Figure 31: The wetlands along the Mississippi river before the spread of the urbanization (Colten, 2006)

With respect to the first point, many scholars highlighted that Katrina was not only a natural disaster: human activities played a relevant role in determining it, as in most of all modern disasters. The National Geographic Channel defined Katrina “one of the worst natural disasters in United States but also one of the worst man-made disasters” (National Geographic, n.d.) because human beings, since the colonization of the area, have progressively altered its ecological and geophysical equilibrium cycles.

Indeed, before the construction of the city of N.O., wetlands – together with cycles of renovation of soil by the Mississippi river – represented a natural barrier against storm surges and floods, because of their capability of retaining water.

For what concerns hydro-geological cycles, the soil in and near N.O. is a combination of silt, sand and clay. Over time, the soil becomes compact and sinks. Before human intervention, the Mississippi river flooded regularly, depositing fresh silt to replace the sinking ground. Moreover, the wetlands contributed to protect the land, too, because of their ability to absorb waters. Due to the construction of the city and the need of new land for urbanization, since 1930, over 19 square miles of wetlands and many natural habitats, have been destroyed (USGS, n.d.), the Mississippi river was canalized and the artificial barrier network against floods was built up (the levee network). Hence the renovation of soil and sediments was interrupted, the area of the city started to sink and flood risk became higher. Some parts of N.O., today, are 8 feet under sea level and the present rate of sinking is 3 feet every hundred years. As largely argued (Colten, 2006; National Geographic, n.d.) wetlands – not levees – really protected the city from floods and storm surges.

Furthermore, owing to the installation of many chemical industries, refineries, off shore and on-shore oil and gas extraction plants and pipelines, New Orleans and its surroundings became one of the most polluted areas in the United States and in the world, too. The area between N.O and Baton Rouge - the capital city of Louisiana - due to the presence of over 130 chemical plants and petroleum processors is universally known as “the Chemical Corridor” (Allen, 2003).

When the Katrina Hurricane struck the coasts of Louisiana, intense winds, storm surges and heavy rains impacted the protection levee network, which was not designed to withstand such an intense phenomenon. The failure of the levees caused the flooding of the city. The flood impacted many oil and chemical plants, oil pipelines and sewage network. Hence, many hazmat spills were registered. In one case, the impact of the flood on the Murphy Oil refinery caused the spill of more than 3 million liters of oil (Pine, 2006) in the high populated area (about 700,000 people) of Saint Bernard Parish.

In a short time, flood waters became a mixture of dead bodies, sewage liquids and chemical substances. To remove waters from the city, authorities decided to pump them into the Lake Pontchartrain instead of the Mississippi river, because the river is the main source of potable water for the city. According to many authors, these polluted waters had a great impact on the lake’s ecosystem, which was a fishing site and a tourist attraction.

About a month after the hurricane, when most of the city was dry, there were lots of problems concerning buildings and the return of people in their houses. Many buildings in Saint Bernard parish, in fact, were coated with a thick layer of oil and chemicals. Hence, people did not know if their houses were safe. Authorities, coordinated by EPA, began to analyze the situation. Later, in December 2005, the Center for Disease Control (CDC) and Environmental Protection Agency issued a report that concluded that the level of contaminants was not dangerous for people. But, environmental activists and people remained wary. Therefore, most concerns for activists and scholars were about the soil. Before the hurricane, sediments on the bottom of the Mississippi river were seriously contaminated by heavy metals (like arsenic, lead, chromium) and other chemicals that were the product of decades of pollution due to industries and agriculture. These substances were

relatively harmless in situ, but the storm dispersed and deposited them all over the city. When the city became dry, a portion of these contaminants were deposited on soil and, later, most of them started to become airborne. Besides, five of the most hazardous Superfund sites in New Orleans, which were contaminated by Dioxin and other toxic substances, were flooded.

For what concerns damages to ecosystem many studies provide a comprehensive assessment of toxic contamination of both the soil/sediment and the lake. One of them highlights the significant contamination of Arsenic and Vanadium and non-significant contamination of Cadmium, Chrome, Copper, Mercury and Lead at most sampling sites (Su *et al.*, 2008). Arsenic is a metalloid which represents one of the most toxic chemical elements in nature, which, once introduced in the natural food chain, has the capability to increase the probability for genetic mutations in fishes and other biological species. Vanadium is a metal that might cause neurologic and respiratory effects on animals and rarely on human beings.

For what concerns Lake Pontchartrain, according to many scholars and institutional reports, the pumping of flood waters and salt water intrusion by storm surges caused a relevant contamination. The analysis of the results of Acholonu and Jenkins (2007) showed that, one year after Katrina, over 50% of the chemical parameters tested failed to meet the EPA water quality criteria and standards. According to them, this showed that water bodies were still chemically contaminated.

Therefore, many authors suggested that the process of analyzing, preserving and restoring water quality is complex. "Although there have been numerous studies and reports that address water quality in the Basin (Lake Pontchartrain), not every scientist, regulatory agency or concerned citizen will agree on the true nature of the problem" (USGS, n.d.). This is particularly true for what concerns long term effects of pollution of the lake by Katrina and the pumping of polluted waters into it. Up to now, there is no common consensus among scholars about long term effects of the lake species and environment contamination. Kilic and Aral (2007) estimated that the lake requires about 80 years for recovering from the stresses created by the pollution.

It is difficult to quantify the multiple socioeconomic damages induced by Katrina, distinguishing the ones directly related to the physical damages to buildings, industries and so on and those due to the impacts of the flood on natural ecosystems. Nevertheless, as mentioned above, the long term effects on soils and waters will reflect on the environmental quality of all the area and, in turn, on its livability and its attractiveness for economic activities, especially for tourism.

In the scheme that follows (Figure 32) a conceptual map is shown, representing the complex chains of events – including the role of natural resources in increasing the severity of the events themselves – and impacts on natural resources and their consequences. Different systems and chains of impacts and damages are represented in different colours.

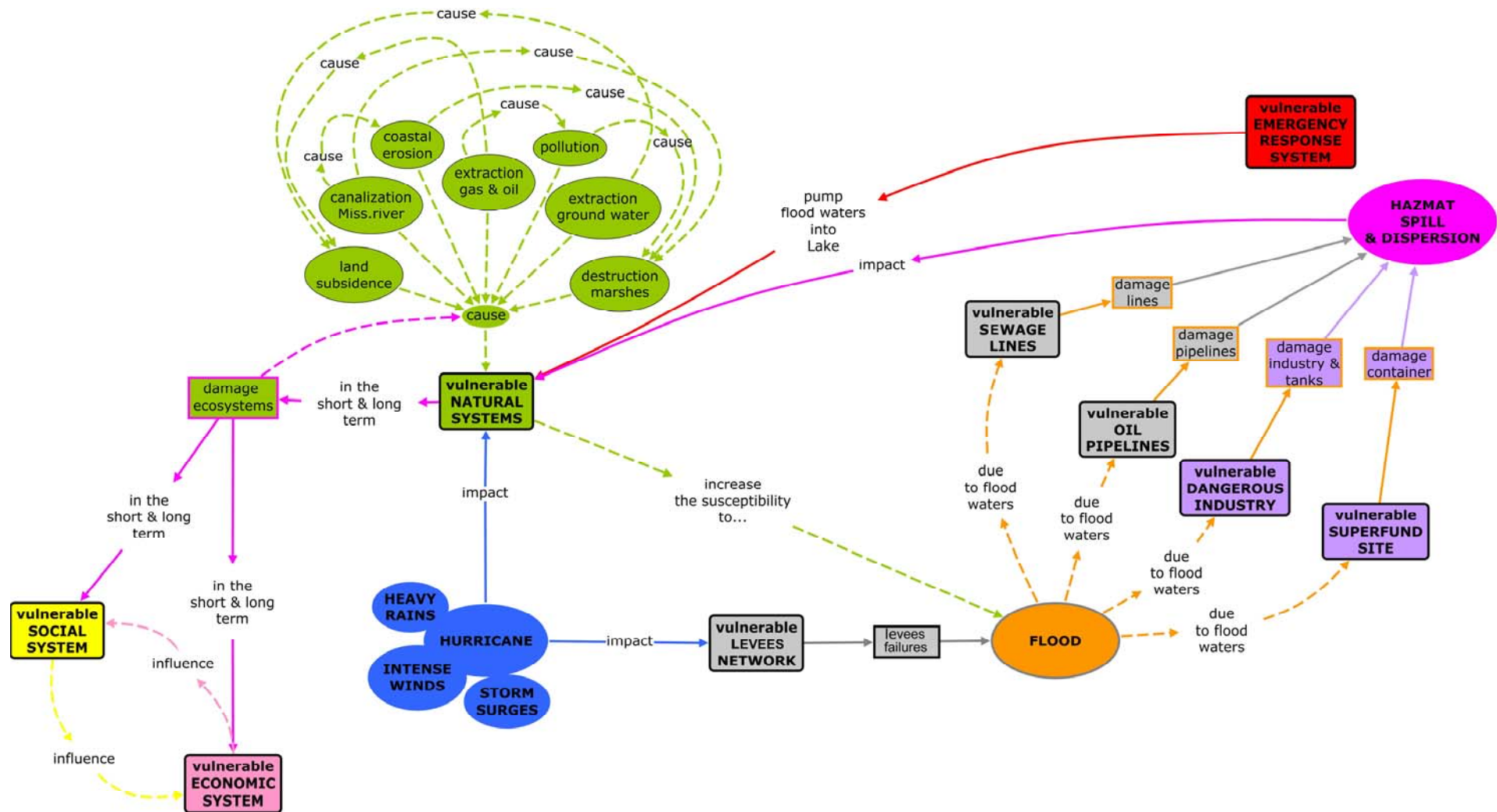


Figure 32: The conceptual map of the chain of events, impacts and damages (direct and indirect) due to Katrina, with specific reference to the different roles of natural ecosystems

7. Territorial systems' vulnerability as resulting from interactions among social, institutional, and economic vulnerability

Territorial systems are spatial entities connected with what has been described as territorial capital, i.e. a unique composition of social, economic, physical, institutional and other forms of capital. A territory, as a geographically demarcated spatial entity, is of course a system and as such it exhibits all the properties of systems described earlier. It is an open system with multiple overlaps. Only some extremely small and remote islands could be probably described as closed systems and even in their case this is ultimately an illusion. But the degree of "openness" is no doubt variable. Thus when we consider a "territorial unit (or component)", e.g. a settlement, rural area, transport node or industrial plant, hit by an external shock at a particular historical moment and in particular socio-economic conditions, the territorial system (or systems) over which the shock will propagate is bound to be different from that which will be affected in different conditions. A territory or territorial system is not just buildings, public facilities, plants and infrastructures, as already emphasized in the analysis of territorial capital in WP1. It encompasses socio-economic relations, institutional arrangements (which go a long way towards defining a territory's identity), shared values, even symbolic representations. All these properties of a territorial system (largely co-terminous with the components of territorial capital) are decisive in determining its exposure to risk, vulnerability and coping capacity in the case of disaster.

The authors of the case studies that follow, by taking advantage of the exposure and coping capacity terms (see Section 3.4), indicate how it is possible that vulnerabilities of institutions, social and economic systems and technical systems (i.e. subsystems of the territory) might affect spatial exposure, coping capacity potential and the potential mixture of losses (i.e. vulnerability) of entire territories. Furthermore they consider the intricate or paradoxical case that highly resilient social and economic (individual) entities may have an adverse impact on systemic vulnerability of communities and territories. The case studies utilize territorialism definitions and vocabulary (i.e. territorial capital, social, economic, human, relational, physical etc) to explore relationships between territorial and the rest forms of vulnerability.

7.a The Case of London: Pre-disaster systemically related vulnerabilities and exposures of a Metropolitan (territorial) system

London may be defined in various ways, but here we use the outer boundary of 'Greater London' as the limit (Figure 33): an area of approximately 10 million people. In London a range of hazards pose risks. London has a very long history of low and high impact hazard events with very low recurrence intervals. Estimated trends in risk, exposure, impact, certain elements of physical vulnerability and management response are set out in Table 2 (see also Figure 34). South-east England is more or less geologically stable. The region enjoys a mild, cool temperate climate. The climate has been perceived of as benign but this is inaccurate because of climate variability. The region occupies a battleground between ever-changing air masses and weather extremes occur, although they are infrequent. At least five types of flood risk occur in London, four of which are listed in Table 2, which excludes pluvial (surface water) flood risk, which is increasing problem. The most serious risk is from tidal flooding

which presents a low probability, extremely high impact risk. Most Londoners face a patchwork of hazards including flooding, but also including overcrowding, poor ambulance call-out times, unemployment, crime, pollution and so on.

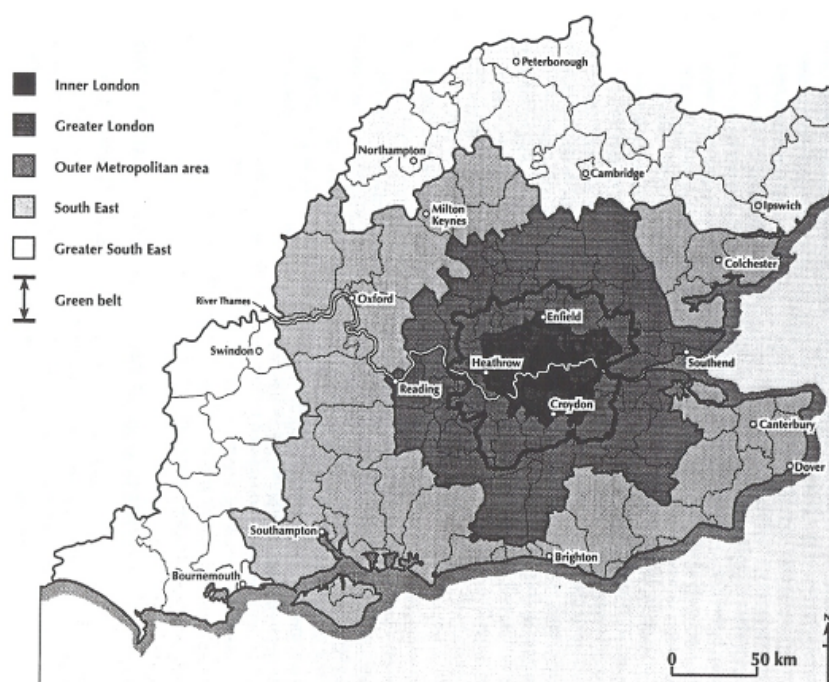


Figure 33: Definitions of the boundaries of London

Table 3: Estimated changes in major hazard factors for major hazards present in London between 1945 and 2045

Hazard	Risk		Exposure		Impact		Vulnerability of infrastructure		Vulnerability of Londoners		Management response	
	->50	50->	->50	50->	->50	50->	->50	50->	->50	50->	->50	50->
Sea level rise and tidal flood	+	+	+	+	+	+	+	+	-	-	+	×
Fluvial flood	+	+	+	+	+	+	+	+	-	-	+	×
Sewer flood	+	+	+	+	+	+	+	+	-	-	+	×
Drought	×	+	+	+	+	+	×	×	-	-	+	+
Subsidence	×	+	+	+	+	+	×	×	-	-	×	+
Windstorm	×	+	+	+	×	+	×	+	×	-	+	?
Fog	×	×	+	+	+	×	×	×	×	-	+	×
Snow	×	×	+	+	+	×	+	×	×	-	+	×
Air quality	×	?	+	+	×	?	×	×	+	?	+	?
Seismicity	×	×	+	+	+	+	+	+	×	×	+	×
Nuclear radiation	+	?	+	+	+	+	+	+	+	?	+	?
Hazardous wastes	+	+	+	+	+	?	×	×	×	+	+	?
Hazardous industrial sites	+	×	+	+	+	×	×	×	+	×	+	×
Transport	+	×	+	+	+	+	+	+	+	+	+	+
Crime	+	?	+	?	+	?	+	?	+	?	+	?
Hybrid hazards	+	+	+	+	+	+	+	+	×	+	×	+

->50 is the period between 1945 to 1995.

50-> is the period between 1995 and 2045.

+= estimated to be increasing.

×= estimated to be stable.

- = estimated to be decreasing/worsening.

? = trend is less certain, depends upon socio-economic and political events.

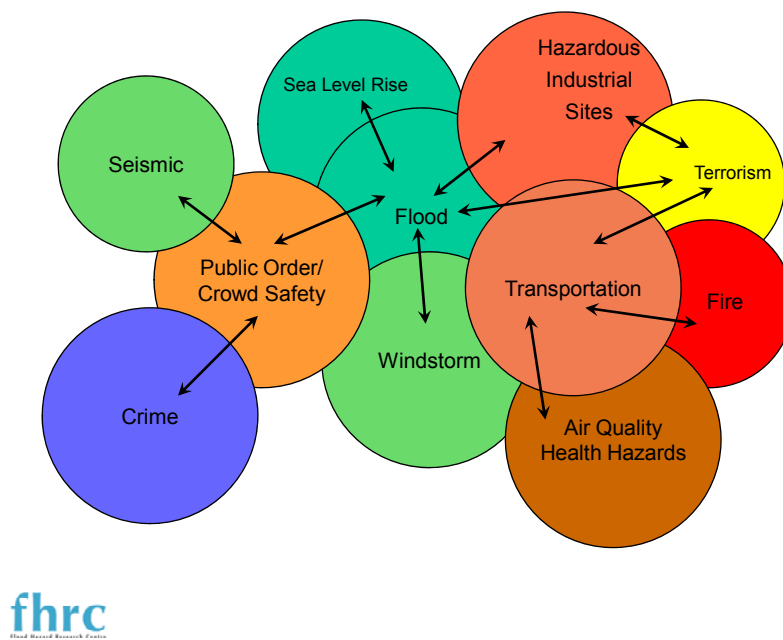


Figure 34: Na-tech and hybrid hazards present in London

Environmental hazards have played a significant role in the evolution of London's territorial capital (physical, social, psychological and institutional). The most visible are the development of new neighbourhoods as the city grew outwards from its original core. Throughout much of its history the vulnerability of individuals has been differentiated by class and wealth. Affluent classes have always sought to reduce their exposure by moving out of places that were physically or socially at risk. Generally-speaking the affluent moved out west, and the poor continued to live in the east. Medieval Londoners were intimately acquainted with threats to survival. As a result they created exclusive neighbourhoods, characterized by services and amenities not present in lower-class districts. West/east class differentiation is a pattern that has continued to the present day, although gentrification of the inner city has altered this so that, in some cases, the affluent and less well-off often now surprisingly adjacent to each other (Parker and Tapsell, 1997).

Part of Londoner's psychological capital is a world-weary posture of indifference to the vicissitudes of nature, mixed with a defiant 'carry-on-as-usual' attitude that can also be found in some other metropolises. In London this has its roots in the historic and recent record of extreme events of a natural, na-tech, blitz-related or terrorist nature. This 'psychology' has complex social vulnerability and social resilience dimensions: complacency on the one hand, and adaptability on the other.

London's physical development and vulnerability to flooding reflects the centrality of the tidal river Thames to its origins and growth (Parker and Penning-Rowse, 2005). Efforts to control tidal flooding date back at least 1,000 years, and London's growth has shaped the river, just as the river has shaped London. The port of London developed as a key element of the growth of the British Empire, and the commercial 'City' grew close-by next to the river. The dynamic, centripetal, lateral expansion of London largely ignored the fluvial flood hazard presented by the 14 tributaries of the Thames: flood risks exist in most of these valleys. The vertical development of London, especially the underground development (not only including the extensive 'tube' underground rail system), also largely ignored the flood risk and increased London's physical and economic vulnerability. Today riverside locations are highly sought-after and some of England's most expensive properties are located in the tidal flood

risk area, as well as a cluster of hazardous industrial sites (Figure 35). This is because of the commercial centrality of the river, the vibrancy of riverside London, its proximity to the headquarters of international corporations (some in the new 'Docklands'), and growth in the amenity value of the river and floodplain.

The growth of London has been strongly influenced by urban containment policies, especially the 'green belt' established in 1947, and population decentralization to a string of new towns outside of the belt. Urban containment has increased housing density in London, including in floodplains thereby intensifying flood exposure. Current policy is to plan for even higher densities using a social cohesion rationale. London grew rapidly along the 'Western Corridor' towards Reading in the 1970-90 period. The Thames runs from west to east through this corridor and its floodplains became more highly developed generating a major increase in fluvial flood exposure and local economic vulnerability. Here communities are largely wealthy and social vulnerability has therefore been limited to small pockets. From the mid-1990s onwards London's growth switched decisively to the east in order to address social and economic regeneration needs. The redevelopment of London's derelict Docklands, creating a new commercial hub, massively increased potential flood exposure (the area is defended against floods). The Thames tidal floodplain and its hinterlands have become the focus of the enormous 'Thames Gateway' regeneration initiative. This involves major infrastructure, housing and commercial developments, as well as the 2012 London Olympics site. The objective is to alleviate poverty, lack of opportunity and social disadvantage, but the risk is that flood vulnerability is potentially increased. Health status and financial deprivation are the social factors, which are most closely associated with social vulnerability here. The developments are partly in the flood risk area where rising sea levels are contributing to a huge potential increase in flood exposure. Much of the flood risk area is protected by the Thames tidal barrier and associated 400 km of flood defenses, but the standard of protection is reducing as sea levels rise and the defenses age, leading a need for a major new flood risk management strategy (Parker, 1999b).

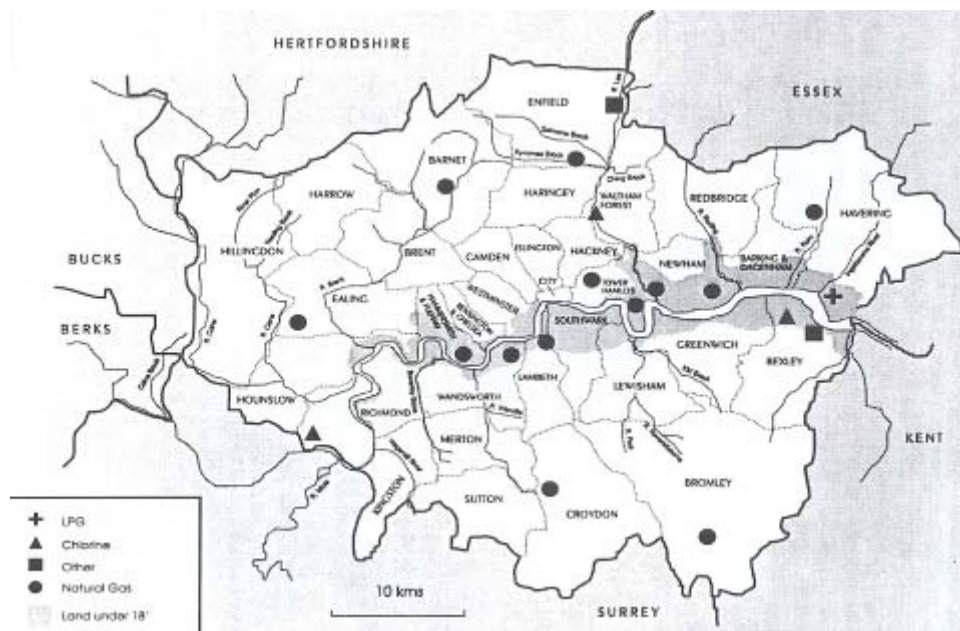


Figure 35: The river Thames floodplain and the location of major hazardous industrial sites in London

Arguably, there have been a number of institutional vulnerabilities which have contributed to current levels of vulnerability to floods. The redevelopment of Docklands during the 1980s was reflection of a private property boom, the deregulation of financial services, and

'Thatcherite' policies which denied that there was any such thing as 'society' (so no need for social policy either!). The more recent private property price boom (which ended with the financial crisis of 2008) also led to massive redevelopment of London's riverside areas. In all of this the relationship between development and increased flood hazard potential appears to have been largely unconsidered (Figure 29), and the private investor's gains from property development are only now leading to a realisation that flood protection expenditures must increase. Since the 1970s there has also been a marked increase in income inequality and social polarisation that now partly differentiates Londoner's experience of, and vulnerability, to hazards. Racial and ethnic minorities – strongly represented in the east – have been disproportionately affected. It is to address the problems faced by these groups that the potentially flood prone Thames Gateway initiative is taking place. The poor and those from ethnic minorities are currently largely protected from tidal flooding, so that any flooding that they may experience is likely to be caused by ageing drainage infrastructure and surface water flooding, and fluvial flooding.

London exhibits vulnerability and resilience side-by-side, and not just in the spatial juxtaposition of wealthy and poor. For such a high-tech society, life in London can be surprisingly prone to surprise systemic disruption causing chaos and temporary suspension of normality. Several major power outages leading to the loss of tube and rail services, and disruption of telecommunication have demonstrated as much. A major tidal flood overwhelming the flood defenses is a low probability but would lead to a similar, but longer duration, event. On the other hand, these surprising vulnerabilities can be contrasted with massive resilience in that London is a massively resourceful, entrepreneurial and wealthy city.

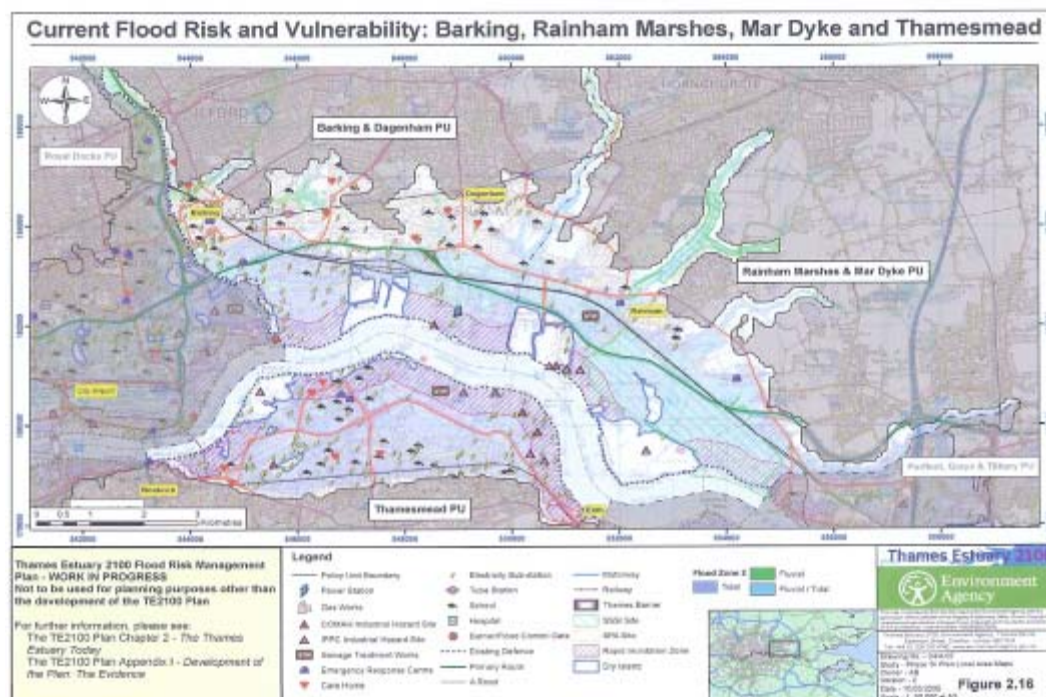


Figure 36: Example of a 'flood vulnerability' map produced by the Environment Agency showing the location of physically vulnerable sites in a small part of the Thames tidal floodplain in east London

7.b The Case of El Salvador: Territorial vulnerability produced in pre-disaster terms

At the intersection of 5 tectonic plates, located over numerous active fault systems and volcanoes and crossing the Intertropical Convergence Zone, territories in Central America are inherently exposed to hurricanes, volcanic eruptions and earthquakes, and to the induced hazards: flooding, tsunamis, landslides, etc... These adverse geophysical characteristics are aggravated by the geomorphology of this area: mostly irregular terrains with steep slopes. This natural instability of the physical milieu (*exposure*) was exacerbated by environmental mismanagement and ecosystem fragility. Indeed, the lack of effective land-use plans (*institutional vulnerability*) compounded by the high pressure on natural recharge areas resulting from residential, service and industrial growth, has induced rapid deforestation processes. The destruction of the land-stabilizing forests combined with change in land use patterns in rural and urban areas forced by previous disasters and the predominance of coffee monoculture (*economical vulnerability*) have made the slopes even more instable and so, increased the potential for landslides (*spatial exposure*). Another set of factors affecting environmental risks relates to the patterns of human and territorial occupation. These patterns aggravated the importance of environmental mismanagement, particularly as regards urban populations. Indeed, the urban population growth rate (due to high birth rates but also to rural exodus), the necessary population displacement due to past disasters and the lack of access to stable and safe land plots have led to the increasing occupation of highly vulnerable areas by the poor (*spatial exposure* and *socio-economic vulnerability*). A lot of urban development occupy gullies, riverbanks or unstable hill slopes. This natural propensity to settle in areas of environmental risk was compounded by governments (local and national) which, in many cases, ignore land use zoning regulations, grant building permits and provide basic services to urban squatter communities (*institutional vulnerability*). Risk is thus institutionalized and government agencies, at different levels, rather than addressing the problems, directly or indirectly contribute to their accentuation.

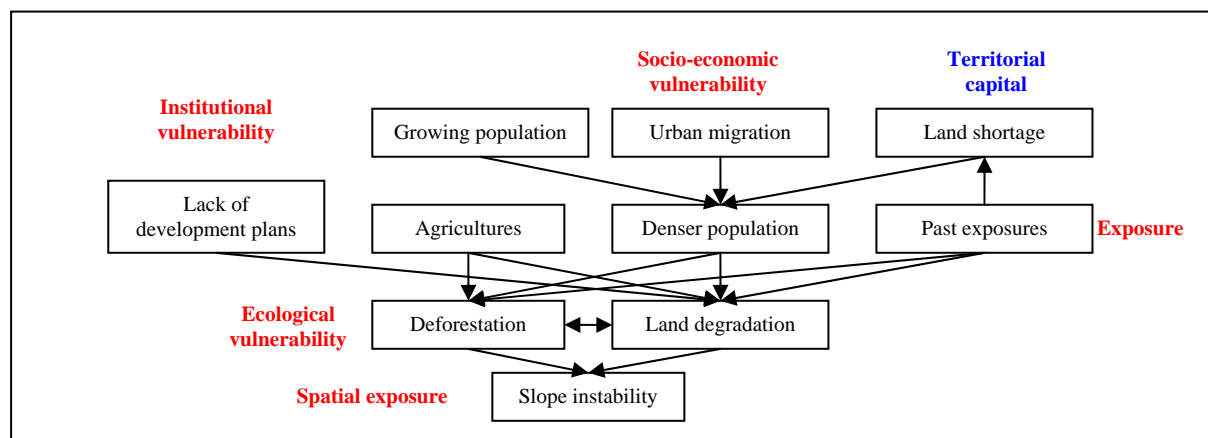


Figure 37: Environmental mismanagement leading to large scale exposure to landslide

Furthermore, this unstable physical milieu interacts with communities structure characterized by high poverty levels (*social vulnerability*); high housing deficits⁶ (quantitatively and qualitatively); high levels of morbidity, mortality and under nutrition; decreasing social expenditures and centralized governmental administrative, budgetary and decision making

⁶ Before the 2001 earthquakes, the deficit in houses was estimated at more than 500,000 missing decent dwellers.

structures (*institutional vulnerability*). All of these factors increase the vulnerability of communities by reducing coping capacity of exposed populations.

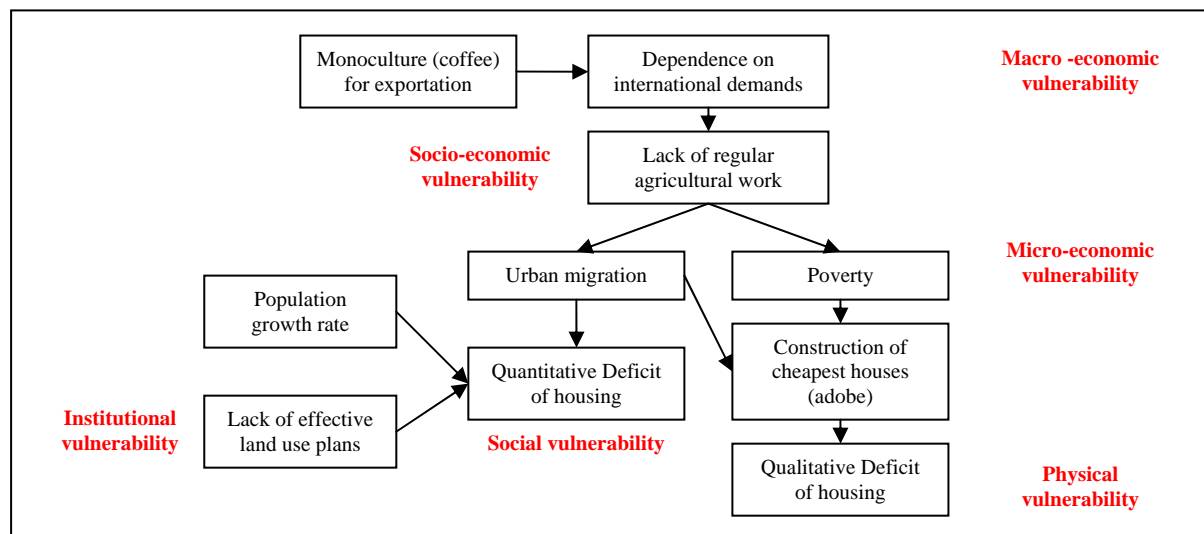


Figure 38: Quantitative and qualitative housing deficits and resulting vulnerabilities

Moreover, there exists a problem of risk perception, levels of risk acceptance, and, also, as regards the causal explanations (religious, fatalism...) given to the environmental risks faced by different communities. High levels of risks acceptance can be associated with the compensating advantages of vulnerable locations (easier access to land, proximity to employment opportunities, high productivity returns in terms of land use, or just the fact of no other alternatives). The earthquakes occurred during the coffee harvest. At this time of the year, agricultural workers (whose livelihood is highly dependent on coffee production) gathered near the coffee exploitations, often located on volcanoes and instable slopes, where many landslides occurred.

The risk perception and the causal explanation were biased by the distance between the causes of the environmental risk (often up the hill) and the impact areas (usually down the hill). These factors reduced the awareness of populations (*coping capacity*). They didn't feel implicated in risk issues, leaving this task to institutions, which didn't have the means to respond appropriately.

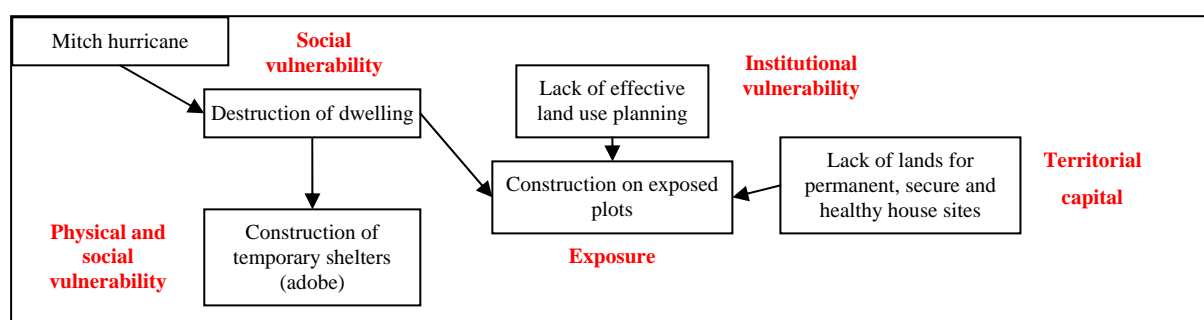


Figure 39: Social and institutional vulnerability resulting in territorial exposure

The Salvadorian landslide-prone lands have been compounded by exposed and vulnerable territorial development. Initially safe lands have been turned into unstable areas or at least into vulnerable areas due to their home-made dependence to technical systems.

7.c The Case of Athens exposed to heat waves: Territorial vulnerability along the disaster cycle

In the summer of 2007 Greece, and the capital Athens in particular, experienced three consecutive heat waves, each about a week long, and temperatures beating the previous record of 1916⁷. During the first event (19-28 June) temperatures rose to 44.8 °C at the National Observatory of Athens and 46.2 °C at the suburb of Nea Philadelphieia (Founda and Giannakopoulos, 2009). 18 people died in Greece of heat stroke in June and July. Compared to the loss of life during the July 1987 heat wave which claimed 2,000 lives in Athens alone (Foura, 2000)⁸, this figure is of course negligible. 2007 is exceptional because, on an international scale, it was the hottest year ever in the Northern Hemisphere and killed up to 500 people in Southeastern Europe (Moore, 2008). What marks the 2007 heat wave in Athens is the combination of record temperatures with the devastating forest fire which destroyed a large part of Mount Parnitha national park on the edge of the Athens conurbation (see contribution on forest fires in section 6) and with extensive blackouts, in many districts and suburbs of Athens, but also Thessaloniki⁹, which were repeated in July. The use of air conditioners, which had increased spectacularly following the 1987 heat wave, was obviously a prime reason. In July 2007, conditions were made worse by the collapse of power generating systems in neighbouring Balkan countries from which electricity is being imported at peak periods.

A heat wave can be simply defined as a "period of abnormally and uncomfortably hot and usually humid weather"¹⁰ or just as a "deviation from average temperatures" (Milligan, 2004: 38), in which critical factors are the "apparent" temperature and duration, which have adverse health consequences. Social and cultural practices, in other words local coping capacity, determine very diverse responses to extreme heat. "The fundamental criteria for the ... excessive heat watch and warning system requires daytime H_i [heat index] greater than or equal to 40.6 °C, with nighttime lows greater than or equal to 26.7 °C, for two consecutive days" (Robinson, 2001: 764). These criteria vary according to regional conditions. For several reasons, heat waves are not usually perceived and classified as a hazard, such as earthquakes or floods. As Klinenberg explains in his book about the lethal heat wave that caused 739 deaths in Chicago in 1995, heat waves receive little public attention because of the invisibility of their impact and the fact that they kill silently mainly the elderly, the poor and the marginal individuals (Klinenberg, 2002: 17). Because heat waves lack the "dread factor" of other hazards, the alarm is not raised in time (Milligan, 2004: 38-39). Their "legitimacy" as a natural disaster remains in doubt (Riebsame, 1985) and risk perception is low (Valleron and Boumendil, 2004), in spite of the vulnerability of a critical group, i.e. the elderly, children, the sick and the poor. Yet, in the United States more people die of heat than those dying from hurricanes, tornadoes, floods, or earthquakes (U.S. Department of Commerce, n.d.). In Europe, the August 2003 heat wave caused between 22,000 and 35,000 deaths (Milligan *et al.*, 2004: 37), or perhaps 70,000 (Robine *et al.*, 2008).

⁷ A great deal of our information was drawn from an analysis of newspaper reports, especially from the daily *Kathimerini*.

⁸ See also Stefanadis, C., Summer and cardiovascular danger, *Eleftherotypia*, 14.7.2009. Estimates of loss of life in Athens from the 1987 heat wave vary from 1,280 to 4,500. Mortality increased to double its normal values (Matzarakis and Mayer, 1991).

⁹ "2007 European heat wave" (www.wikipedia.org).

¹⁰ Glickman, T.S. *Glossary of Meteorology*, American Meteorological Society: Boston, 2000 (quoted in http://en.wikipedia.org/wiki/Heat_waves).

A heat wave puts to the test the coping capacity of public health and social welfare services, of electrical power services, as households resort to intensive use of air conditioning, and of government technical services, because of potential damage to infrastructures, e.g. to rail lines or water mains. Heat waves are a hazard that is certain to increase in severity as a result of global warming. "By 2050, under a relatively high emissions scenario, the temperatures experienced during the heatwave of 2003 could be an average summer. The rise in heatwave frequency will be felt most severely in cities, where temperatures are further amplified by the heat island effect" (Stern, 2007: 17). The fact that "heat waves are primarily an urban disaster" (Milligan, 2004: 42) multiplies their systemic effects because of the complexity, systemic structure and structural features of cities (clustering of buildings, non-sustainable construction, heat-absorbing surfaces, absence of green spaces, car traffic, atmospheric pollution, heat-emitting economic activities, presence of urban heat islands).

Climate change is bound to increase the incidence of heat waves. In addition to the reduction of greenhouse gas emissions, European Union policy is placing emphasis on adaptation to climate change¹¹, for which spatial planning has an important role, particularly in a city like Athens. In the 1990s Greece experienced a three-fold increase of heat waves in comparison to the previous 30-year period (Akylas *et al.*, 2005; ISTANCE, 2006). Towards the end of the century among the most serious disturbances will be the frequency of extreme weather events (National Observatory of Athens, 2005). Maximum temperatures in the southern regions of the country, including that of Athens (Attica), are expected to rise in 2071 -2100 by 7-8 °C. A study by WWF Hellas released in September 2009 predicts that in the period 2021-2050 Athens will have 10-15 more heat wave days in the summer. In spite of extensive media coverage and studies by independent agencies¹² there have been only vague government statements on the issue of adaptation and an absence of a national policy¹³. This is all the more serious since institutional vulnerability is a critical factor in the case of heat waves (Semenza *et al.*, 2008; Bernard and McGeehin, 2004; White, 2004), as the events of Chicago in 1995 and Paris in 2003 have shown. The underestimation of the lethal impact (Nash, 2008), especially of fatalities (Ostro *et al.*, 2009), may be an explanation of complacency. Yet, if, as predicted, the frequency and duration of heat waves is increased in Greece, the consequences, in the words of a leading expert, could be tragic: "We are in danger of mourning thousands of victims of heat waves in the next five years".

The literature abounds with examples of US and European cities which experienced severe and deadly heat waves in the recent past (Milligan, 2004; Naughton *et al.*, 2002; Ellis *et al.*, 1975; Nash, 2008; Bernard and McGeehin, 2004; Canoui-Poitaine *et al.*, 2006; Conti *et al.*, 2007; Kysely, 2009; Boyer *et al.*, 2005). The elderly were the main victims, with the "excess" death¹⁴ rate in Paris in 2003 reaching 140%. The policy of simply providing "cooling centres" and air conditioners¹⁵ proved inadequate. The importance of adaptation, particularly at the urban level, is evident (Huq *et al.*, 2007). The difficulty is to predict how populations, infrastructures, and the urban fabric, i.e. the impact "modifiers", will, and ought to, adapt (Kinney *et al.*, 2008). Urban planning and land use have a critical role in this respect (Clarke, 1972; Coutts *et al.*, 2008).

¹¹ http://ec.europa.eu/environment/climat/home_en.htm. See also Commission of the European Communities (2008b), *Regions 2020*, and the recent White Paper "Adapting to climate change: Towards a European framework for action" (Commission of the European Communities, 2009).

¹² E.g. the Economic and Social Commission (OKE) of Greece and the Institute of Strategic and Development Studies (Mylopoulos *et al.* and Wassenhoven *et al.*, 2009).

¹³ The creation in October 2009 of a new Ministry for the Environment, Energy and Climate Change may be the first step towards an effective national policy.

¹⁴ In simple terms, excess deaths are calculated as the difference of observed deaths and expected deaths, in comparison with the average of a previous reference period.

¹⁵ U.S. Department of Commerce / National Climatic Data Center, August 2007 Heat Wave Summary; Bernard and McGeehin, 2004.

For the purpose of our case study on heat waves and Athens the concept of the urban heat island (UHI)¹⁶, not just as a phenomenon, but as an analytical tool, is crucial. The process of urbanization tends to aggravate the negative effects of climate (King and Davis, 2007) and is directly associated with the major problem of the UHI effect (Rizwan *et al.*, 2008). The UHI is a human product, which of course acquires its properties through the intervention of natural processes, e.g. solar radiation. Heat islands provide a tangible measure of territoriality. They are also a systemic link between, on one hand, urban structure and urban land texture and, on the other, the weather-related phenomenon of heat waves, of which they reinforce the effects. In doing so they multiply the heat impacts in a number of directions by following systemic interconnections in the social, economic and physical environment. The UHI effect is not a feature of large metropolises only, but also of smaller cities (Unger *et al.*, 2006; Stathopoulou and Cartalis, 2007). The spatial distribution of the UHI effect is not uniform across a city (Saaroni *et al.*, 2000), which means that particular socio-economic groups are far more seriously affected (Harlan *et al.*, 2006, 2007).

Founda and Giannakopoulos (2009) carried out an in depth study of the heat waves which affected Athens in 2007 and confirm the consequences of intense urbanization and concentration of activities and their potential serious impact on the life of Athens and on human health, which is exacerbated by poor air quality. On the basis of the projections of a simulation model, they consider the summer 2007 as resembling those projected for 2071-2100, rather than those expected in the intermediate period 2021-2050. Santamouris (2005) estimates that the temperature difference between the centre of Athens and the urban fringe is of the order of 9-10°C, because of the UHI effect. Santamouris *et al.* (2007) measured the UHI ecological footprint and concluded that the city's ecological footprint, because of the UHI, is about 1.5 – 2 times the city's administrative area. Thus, here we have not only a clear indication of the enormous effect of the UHI, but also a measurement of its territorial impact.

The role of buildings and urban hard surfaces, as contributors to the heat island effect and, consequently, to the enhanced impact of heat waves, is enormous in the case of Athens¹⁷, because buildings in Greece account for 36% of final energy demand. Low income households tend to live in buildings inadequately protected against heat extremes and are therefore more vulnerable. In the summer of 2007 measurements were taken of interior temperatures in 60 Athens low income dwellings, not equipped with insulation, double glazing and air conditioners. The results prove their extreme vulnerability. Government actions to mitigate the effects of heat stress on Athens are in reality rather motivated by the need for energy saving or aimed at solving traffic problems. The related and worthy goal of developing public parks is a long term affair and is at the moment at a stalemate. Besides, the environmental beneficial effect of a park extends only to a limited surrounding zone (Santamouris, 2007; Zoulia *et al.*, 2009). We concentrate therefore our attention on the policy of improving the energy performance of buildings and, to a lesser extent, on isolated landscaping efforts to reduce heat absorption. In spite of the EU Directive 2002/91/EC on the energy performance of buildings (Council of the European Union, 2003; Commission of the European Communities, 2008a; Hondrou – Karavasili, 2005), it was not until May 2008 that the Greek Parliament voted a law on this subject (Law 3661/2008).

The implementation of the new law in practice remains to be seen, especially as far as new buildings and the certification of acceptable energy performance are concerned. With respect to the renovation of old buildings, a new government programme, revealed in July 2009¹⁸, is

¹⁶ For a definition and for the process of UHI formation see the website of the US Environmental Protection Agency (<http://www.epa.gov/heatisland/about/index.htm>). A detailed analysis of the heat island effect is also provided in Rahola *et al.*, 2009. See also King and Davis, 2007; Morgan *et al.*, 1977; Rizwan *et al.*, 2008.

¹⁷ See the work of the research group on Building Environmental Studies of the University of Athens, headed by Prof. M. Santamouris, from which we derived information for the present case study (Santamouris, 2005, 2007).

¹⁸ *Kathimerini*, 29.7.2009. See also the presentation of the programme in www.kep.gov.gr.

under way to subsidize to the rate of 30-50% building renovation out of national and EU sources, so as to achieve energy saving. Building operations which will be subsidized include double glazing, heat insulation, solar panels, use of cool materials etc. Urban renewal and landscaping operations might be more effective for increasing thermal comfort, but much more difficult to implement on a large scale. Limited projects have been announced for the central area of Athens, which belongs to the Municipality of Athens, the role of which at the time of heat waves is so far limited to providing emergency cooling centres¹⁹. The municipality is now about to implement a plan to improve the microclimate of Athinas street, a central commercial street, and Kotzia Square, where the old Town Hall is located. The plan involves planting and creation of green spaces, use of cool materials for paving, reduction of anthropogenic heat, shading of open spaces, use of earth to air heat exchangers, solar chimneys, heat pumps etc (Santamouris, 2007). Notwithstanding such rare and small scale initiatives, Athens remains a city highly vulnerable to extreme weather events and climate change.

A likely victim of the vulnerability of Athens to extreme temperatures is tourism. The potential consequences for tourism of climate change and temperature variations are causing concern and are being increasingly discussed in recent years (WTO, 2003). In the future, "tourism vulnerability hotspots", which include Greece and other Mediterranean countries, may well be avoided by tourists (Simpson *et al.*, 2008; Commission of the European Communities, 2008b). This calls for urgent adaptation (WTO, 2007a and 2007b), to combat the change in tourism destinations away from vulnerable regions²⁰, such as France (Ceron and Dubois, 2005) or, even more so, Greece. Shifting tourism demand to shoulder seasons is not a simple matter (Amelung *et al.*, 2007) because of institutional difficulties. Summer vacations in destinations, like Greece, may suffer not only because of heat, but also because of water shortages (Giannakopoulos, 2009). The possible long run effects of climate change on Greek tourism, even more so on the tourism industry of Athens, could be exceedingly harmful²¹, but they have not been so far the subject of public debate, in spite of warnings that "Greece will be one of the losers from climate change" (Ehmer and Heymann, 2008). Official, central government reactions to climate change effects on tourism are practically non-existent, although the problem is discussed in independent documents²².

Heat waves are a natural phenomenon the impact of which on cities is mediated through the form and spatial diffusion of urbanization, as well as the form and qualitative characteristics of urban structure, urban surfaces, buildings and infrastructures, in fact the entire territorial capital of the city. In fact *the spatial organization and the entire networks and spectrum of activities of the city interact in a systemic manner with the onslaught of heat*, with multiple repercussions on the urban population, economic activity and institutions, especially those charged with dealing with health care and emergencies. A medium through which this complex interaction occurs is the UHI formed on the surface and in the atmosphere of the city, as a product of the thermal properties of the urban fabric and hard structures and of the emissions of all urban activities (residential, transportation and production). *Vulnerability is created out of this complex web of interactions*. The UHI contributes to heat stress and makes the impact of heat waves more severe. But ultimately, both the heat island effect and

¹⁹ www.cityofathens.gr.

²⁰ See report of Swedish researchers of the University of Gothenburg (<http://www.science.gu.se/english/News>). Reference is here made to the FP6 research project "Urban tourism and climate change", funded by the URBAN-NET Pilot Call 2008.

(<http://www.science.gu.se/english/News>). Reference is here made to the FP6 research project "Urban tourism and climate change", funded by the URBAN-NET Pilot Call 2008.

²¹ See ICOMOS, 2008a, 2008b.

²² See two reports of the the Economic and Social Commission of Greece (OKE, 2008a, 2008b) and a report published by the Institute of Strategic and Development Studies (Wassenhoven *et al.*, 2009).

the externally introduced heat rise are outcomes of urban–industrial organization, of which climate change is also a partial result. The UHI effect is a typical feature of urban agglomerations and indirectly of the same economic and social process. Thus, *the web of complex systemic relationships widens and exposure and vulnerability escalates further.*

Caught in this web of interactions is the human, social and economic activity “content” of the city and the latter’s government structures and institutions. *This is where vulnerability is manifested and its symptoms become apparent.* The institutional element is itself subject to the choices (direct or indirect) of global economic and social processes. Its limitations, e.g. in the provision of effectively functioning lifelines, welfare protection, risk mitigation, health care, and emergency mobilization, are not independent of these processes, although they are admittedly influenced heavily by local political and social culture. *Government should be responsible, in our example through spatial planning and building regulations, for providing an urban environment which is resilient to heat stress.* The human “content” comprises social groups which are often especially vulnerable because of old age, ill-health, low income, inequalities and marginalization, properties closely correlated with their shelter and urban environment, through which heat stress is mediated. *These are the prime “carriers” of vulnerability.* The economic activity “content” may encompass sectors, which are sensitive to environmental comfort, because they depend on the choices made by clients. This is *par excellence* the case of tourism. These systemic interactions are illustrated in the following diagram (Fig. 40).

The urban system suffering from a heat wave is a case of *vulnerability to stress*, the latter affecting the population both directly and then indirectly through the effect on physical capital. *Vulnerable are first particular groups and activities, whose vulnerability is enhanced by the exposure to the impact of heat absorbed and later emitted by ill-constructed and equipped solid structures. Thus a chain sequence of effects is established* both pre-disaster, when urban structure and pattern are gradually developed, at the time of disaster, when the deficient properties of physical capital play an active role, and in the immediate post-disaster period, when people suffer from heat stress and the institutional response is put to the test. Exposure of urban systems cannot in this case be defined in relation to the position of the threat, except with reference to the condition which magnifies the threat, i.e. with reference to the UHI effect. In addition, the UHI footprint, defines the boundary of the territorial system at risk. *The coping capacity of the system once the process of a heat wave is under way is circumscribed by the resources available to those under threat*, which are usually limited because of their position in the social and economic ladder, and by the institutional capacity of public authorities, which as the experience of past heat waves has shown, even in rich countries, is often inadequate. Although there is certainly room for improvement, the fact remains that *a higher coping capacity presupposes mitigation actions which are very long term and costly*, because of the urban restructuring, renewal, building retrofitting and improvements required.

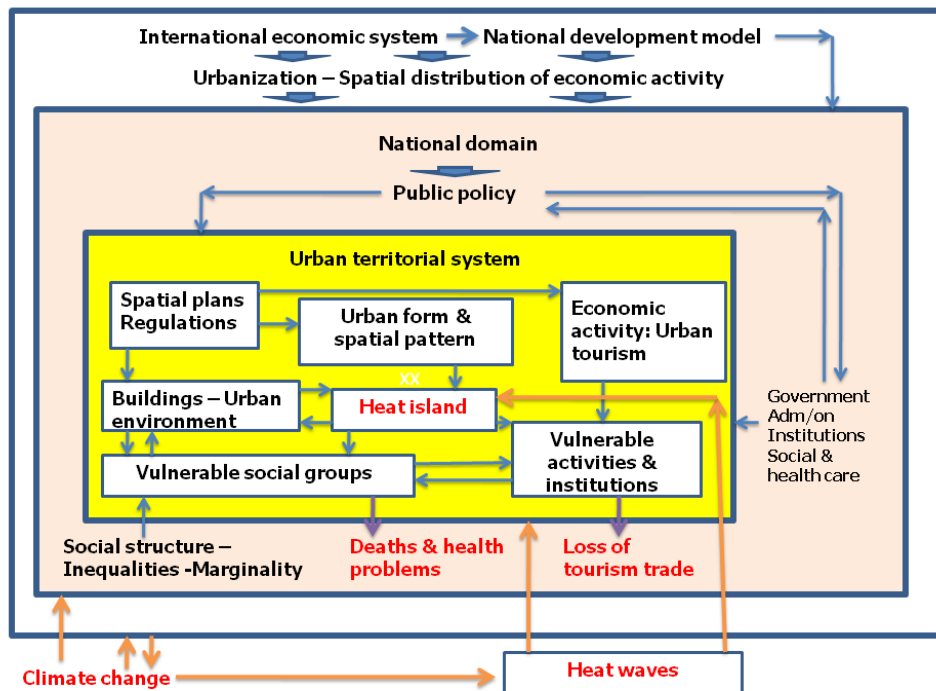


Figure 40: Systemic interactions of the effect of heat waves on the urban system

7.d. The case of Mexico city earthquake, 1985: Production and manifestation of territorial vulnerabilities all along the disaster cycle²³

On September 19, 1985, at 7.14 a.m. an earthquake reaching a magnitude of 8.1 R and lasting almost two full minutes hit the coast of Mexico, rocking its capital city. Mexico city was further devastated by an equally strong after-tremor. The next day, at 7.38 p.m. the city experienced a tremor of a magnitude on the Richter scale 7.5. According to Diane Davis's (2005) descriptions in her article *Reverberations – Mexico City's 1985 Earthquake and the Transformation of the Capital*:

"...The bulk of the damage was centered in the heart and symbolic center of the city, which held close to 20% of the entire Metropolitan area's population and contained a large variety of colonial monuments, key government buildings, educational institutions, medical centers and most of the city's major commercial and retail establishments, principal hotels and theaters. The main plaza that defines this historically central area is a large cement expanse called the Zocalo, which traces its origins to pre-colonial times and is now surrounded by the Presidential Palace, the main political and administrative offices of the Mexico city government and several historically significant Aztec ruins exposed during underground construction for the subway during the 1960's".

Continuing her accounting of the disaster Davis notes:

²³ The present analysis is based on the documentary material of the article "Reverberations – Mexico City's 1985 Earthquake and the transformation of the capital" by Davis D. (2005), in the book *The Resilient City*, by Vale L. J. and Campanella Th.J. (eds), Oxford University Press.

"...For days and sometimes weeks or longer, hundreds of thousands of people had no homes, no work no transportation, no food, no water, no telephones, no hospitals to visit for treatment of the wounded, no places to bury their dead and no reliable authorities to whom they could turn for assistance. This was the case, not just because of the high Richter scale magnitude of the earthquake, but because by hitting the center of the city, most of the services and institutions that sustained the city as a whole were disabled if not destroyed. This state of affairs owed to the history of urban development in Mexico which had preserved the traditional character of the center city, centralized its key institutions and services and prevented the outward movement of its residential population and public institutions.....But because the hardest hit area was the Metropolitan center –which was also the center of the entire country- a multiplicity of essential services, economic activities and institutions were at risk".

The above statement evidences the basic reasons for the Mexico city's immense territorial vulnerability. The mono-centric urban spatial pattern of the capital city and the mono-centric structure of the country's settlement system too have been the underlying causes of high exposure and vulnerability of both. The impacts and damages of the 1985 earthquake did not confine at all within the area affected by the tremors. On the contrary these expanded far beyond; actually the affected area covered the whole country's territory (Figure 41). Indicative is the example of public supply services (Davis, 2005):

"...Important communications and electricity providers were concentrated in the area decimated by the earthquake, and their disruption affected the administrative capacity to restore services to the entire Metropolitan area. Through the damage incurred by one single building in downtown Mexico city, local, national and international telephone service for the city was completely suspended.....A large majority of the city's electricity substations were also in these central areas, leading to power outages for an extended period of time. Also, almost all of the Metropolitan areas transport services were paralyzed, especially buses, since they crisscrossed the center of the city. Subway service was also disrupted, albeit temporarily, because it depended on electricity".

It is obvious that mono-centric and centralized lifeline networks and technical systems do not leave room for redundancy and/or alternative functional solutions. Once their centres or hierarchically higher nodal points are hit the whole systems and networks are put at risk and ultimately paralyzed. Indeed a centralized or tree designed technical system may turn a localized hazard into a territorial expansion of losses reaching regional, national even international scales. Furthermore, and as technical systems are interconnected with institutional ones, function of the latter is jeopardized by the failure of the first. Under such circumstances emergency institutions in particular lose their means and equipment for responding to the urgent needs of the victimized population.

Consequently, a chain of cause-effect relationships between physical, techno-systemic, institutional, social and economic vulnerability leads up (in the course of time and along the stages of the disaster management cycle) to successive generations of groups of vulnerabilities (that are systemically connected) with always expanding territories of reference. Physical vulnerability in the downtown area triggers off vulnerability of technical systems and lifelines basically due to their mono-centric historically consolidated pattern. The successor of the latter, i.e. vulnerability of the emergency response mechanism affects in turn the capacity of the victimized population to survive and recover (social vulnerability). At later stages social / economic vulnerabilities reproduce physical and so on. This chain of successive vulnerability waves starts with vulnerability to stress (i.e. building and technical infrastructure damages) and continues with various forms of vulnerability to losses.

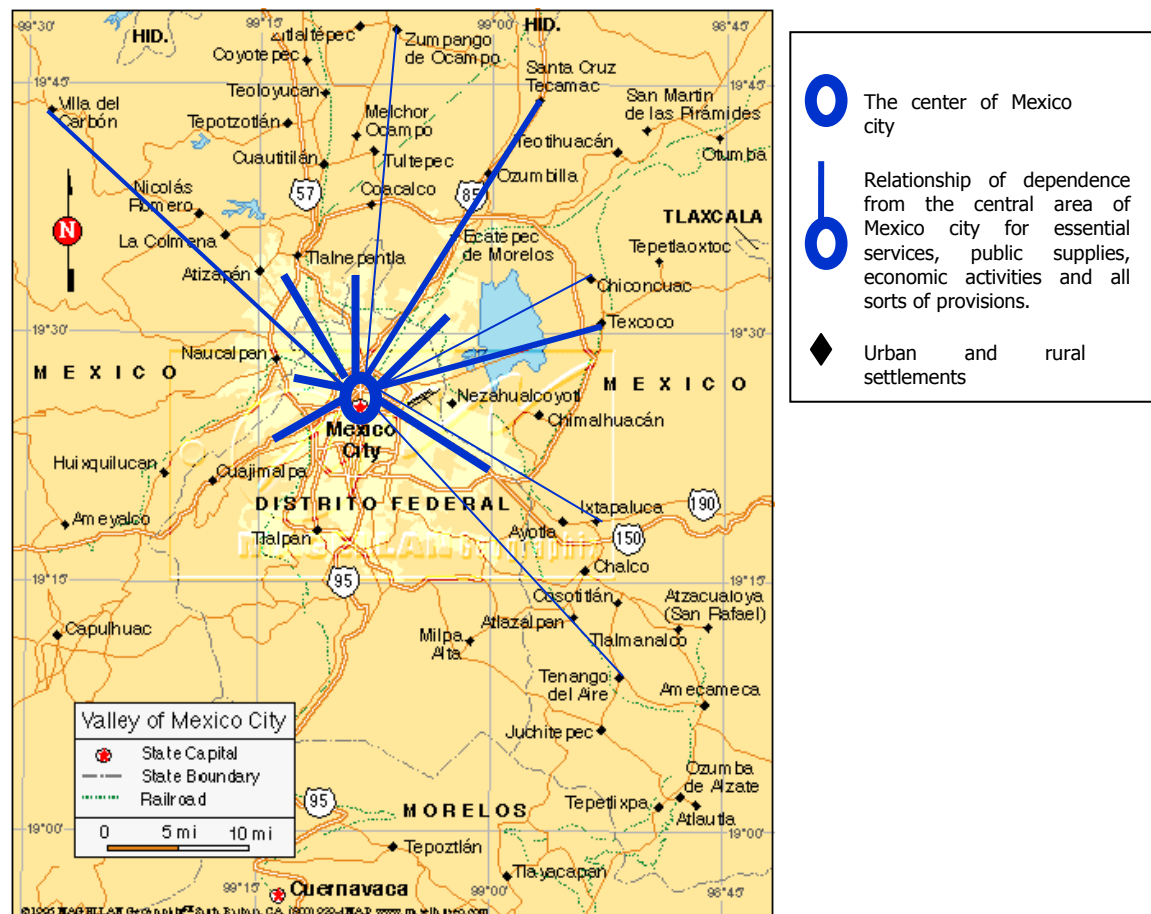


Figure 41: Diagrammatic representation of the mono-centric structure of Mexico City and the country's network of settlements

Figure 42 below illustrates the successive manifestation of vulnerability aspects in the case of Mexico city after it has been hit by the 1985 earthquake and how these systemically interconnected vulnerabilities altogether produce finally territorial vulnerability(ies). But what are the determinant parameters for the successive production of the several aspects of vulnerability and eventually the territorial one? We ascertained that technical systems' extended failure as a result of damages in critical central facilities was due to their mono-central structure and hence lack of *diversity and redundancy*. Successively, the emergency institutions were lacked the means and resources to carry out critical emergency operations. Their vulnerability and incapacitation in the emergency period has been the result of *interdependency* between technical and institutional systems; owing to this interdependency the latter lost their resourcefulness because of the failure of the first. Thereafter, the failures of the emergency and relief mechanisms to satisfy the needs of the disadvantaged groups coupled with government priorities giving precedence to macro-economic objectives and to the middle class areas of the city intensified and perpetuated social vulnerability of population groups in the poorer tenement areas (as these priorities caused problems of resourcefulness to the underprivileged groups) (Davis 2005).

Two crucial questions emerge at this point and as regards especially the recovery /reconstruction period:

- (1) How did the territorial system as a whole cope with its multi-faceted vulnerabilities in the medium and long term and how is overall territorial response capacity related to the numerous capacities (and vulnerabilities) of the actors / subsystems constituting the overarching territorial system?

- (2) Who / which of the several actors / subsystems did have the chances and the capabilities to remedy and recover from the losses and to get rid of their vulnerability, why and by what means?

Memorandum

Ph V: Physical Vulnerability
 TeS V: Technical systems Vulnerability
 Ins V: Institutional Vulnerability
 Econ V: Economic Vulnerability
 So V: Social Vulnerability

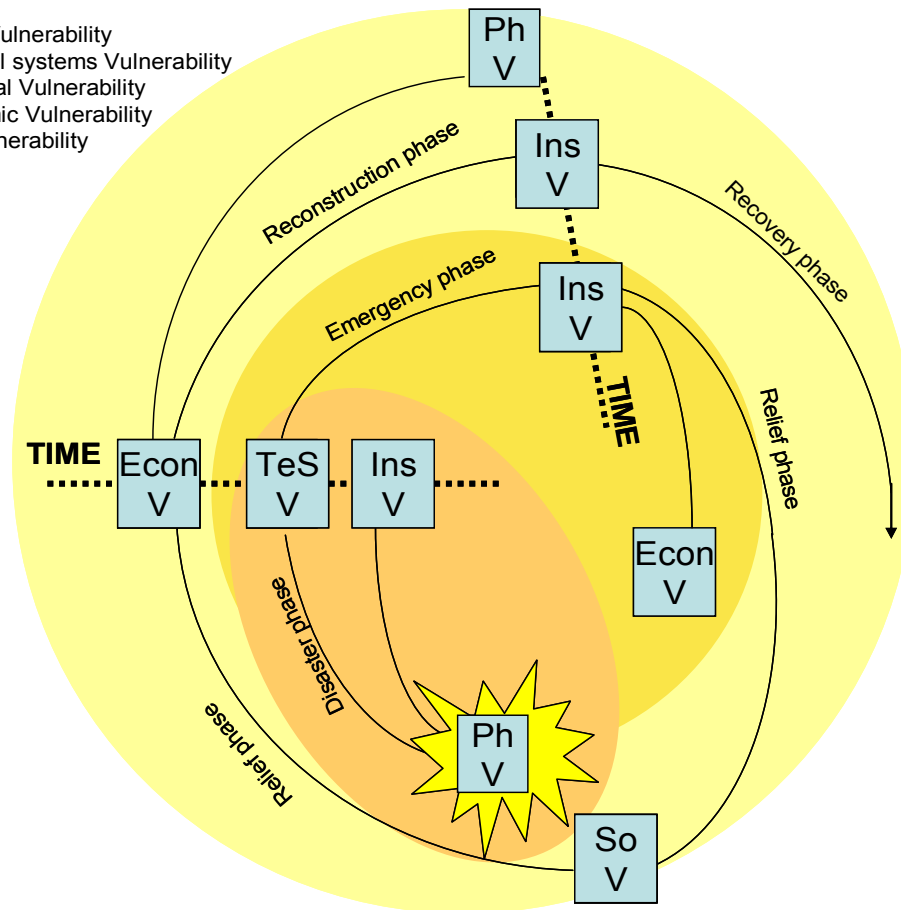


Figure 42: Production of Territorial Vulnerability out of cause-effect relationships between vulnerabilities of physical structures, technical systems, institutional systems, social and economic systems - Territories of reference of groups of interconnected vulnerabilities

We should probably start our thinking on these issues by setting forth some fundamental assumptions and suppositions to test them consequently:

- (a) The *response or coping capacity* of each actor is a function of the post-disaster capital (social, economic, institutional, political etc) reachable or accessible by this actor. With reference to a territorial system its total post-disaster response capacity depends on the internal and external to the system accessible capital (pre-disaster capital after losses) but not only on that; it also depends on the additional and extraordinary forms of capital that are latent or non-existent in normal periods and emerge only in crisis situations. These are resources either under private or social control. Examples of such extra resources are extraordinary recovery funds, networks of social trust and solidarity (place-focused or spatially dispersed), informal economic networks, social memory and knowledge and former disaster experiences, parallel structures of illegality, opportunities that arise from the disruption of formal / statutory rules, rights, licenses and prohibitions etc (Sapountzaki, 2007). Hence:

$TeReCa = f (PreCa_{al} + PostC) [1]$ where,

TeReCa: Total Territorial Coping or Response capacity

PreCa_{al}: Pre-disaster accessible Capital after losses

PostC: Post-disaster extraordinary (internal or external) accessible capital

- (b) Response capacity of a system of actors at a certain moment of the disaster cycle is equal to the sum of relevant capacities of the actors that make up the system at this specific moment:

$$TeReCa = \sum_{act} AReCa [2]$$

It is obvious that after disasters response capacity of some actors is superior to that of others. Indeed some actors are more powerful in engaging the necessary recovery resources to the disadvantage of others. In this respect, institutional agencies that are empowered to make decisions on appealing (or not) to external resources and on the allocation of recovery assets to the several actors in need of recovery, these agencies determine to a high degree the various levels of response capacity across the territorial system. It seems that in the case of Mexico its highly centralized political system allowed the President to obtain the absolute authority to decide on recovery priorities and allocate accordingly the available funds.

Indeed recovery trajectories of thousands of actors and their vulnerability (regarding their coping capacity and own potential of losses in the recovery period) to secondary and subsequent hazards too has been determined and conditioned by the authoritarian political regime. By his decision President Miguel de la Madrid rejected initially and accepted only later foreign aid (i.e. external economic resources), "subsidized" specific interests and objectives by inevitably depriving or dealing unfairly with others. As long as post-disaster accessible resources are finite those actors who over-benefit from them dispossess others from their fair share. Among the actors struggling for recovery and mitigation of own vulnerability are the same the political decision-makers, the governmental institutions themselves. Inevitable as it is, their decisions regarding flows of recovery funds do good to their own survival and self-sustenance after the disaster as well as to their supporters (the economic elite, the members of the governing party etc). This is confirmed by Davis (2005) incontestably: *"...Even as it dragged its feet on housing, a much more concerted effort was made by the government to rebuild or recover the major offices of the ruling party and the government, many of which had been seriously damaged or destroyed."*

Moreover, Davis makes mention of noteworthy examples of government exploitation and abuse that were exposed by the earthquake. Among them was *"the initial decision by authorities to use some of the earthquake reconstruction aid to repay Mexico's foreign debt, something that was seen as helping the country's financial institutions and elite at the expense of the thousands of (mainly poor) citizens who were left homeless"*.

All in all vulnerability of the various actors at the recovery phase is closely connected to their potential and ability for recovery (or the lack of it) because lack of this potential entails further losses. This potential for recovery (response or coping capacity) in turn is a function on the one hand, of material (mostly economic) resources and assets, which are finite and manageable mostly by the powerful institutions and the economic elite both inside and outside the stricken area; on the other hand it is a function of immaterial resources (social networking, innovation, experience and memory etc) which are mostly carried by the victimized actors themselves.

While territorial vulnerability up to the emergency phase can be represented by the spiral like expansion of losses and impacts to several actors and carriers (buildings, infrastructure networks, institutional systems, social and economic systems) covering multiple and

overlapping territories, in the relief / recovery / reconstruction periods territorial and its constituent vulnerabilities evolve in a radically distinct way. In the recovery / reconstruction period, vulnerability gradually falls owing to the numerous response efforts (and capacities) within the system but not at the same rate for all actors within the system (Figure 43). It may even occur that some of these exhibit vulnerability increase -in the course of time- owing among others to new or secondary hazards. In the course of recovery, territorial vulnerability remains a function of the total capital (economic, social, cultural, political etc) available at that time to the actors of the system for recovery (see equations [1] and [2] above); hence territorial vulnerability at a specific moment in the recovery period might be expressed by the sum of vulnerability of these actors who share the total response capacity. By the term "actors" here are entities with decision-making capabilities and powers (e.g. persons, households, businesses, institutions, social groups, techno-human systems, eco-human systems, even smart technological systems). It is obvious that the above suggestion does not imply that territorial vulnerability is something like the sum of social, economic, institutional, systemic, physical vulnerabilities given that each actor (which may be a sub-system) is featured by and manages actor's own group of vulnerabilities (for instance a household normally carries physical, social and economic vulnerability); besides, actors overlap (e.g. a person is an actor on its own but may also belong to a business or an institution).

But this distribution of post-disaster capital is not equitable and does not occur once and for all. A continuous struggle and competition for granted recovery resources is taking place throughout the recovery phase. Whoever / whichever manages to engage and employ a larger part of the available post-disaster capital he/she/it achieves higher rates of vulnerability decrease as well as lower eventual levels of vulnerability. On the contrary those actors who are deprived of the prerequisite for recovery means and resources may find themselves in a worse-off position at the end of the recovery phase (i.e. un-recovered and faced with new vulnerabilities to secondary hazards) (Figure 43). Their only possibility is the development of own mostly immaterial resources (e.g. inventiveness, support from family members and informal social networks, etc).

It is exactly at this point that the notion of resilience is actively involved. Davis (2005) ponders for long about the meaning, content and implications of resilient attitudes in the case of post-disaster Mexico. First of all she acknowledges resilience attitudes in all cases of vulnerability actors or carriers: a territorial system, a social group, an institutional system etc. Indicative are the following extracts from Davis's article:

"The story so far underscores the possibility that in the Mexico city case, the notion of resilience might be applied as much to the people as to the city itself.....In the face of trauma, there are always multiple resiliences, and different people and different activities may be resilient in ways that do not necessarily contribute to recovery. Not only can conflict emerge in the face of multiple resiliences, but the more specific evidence from the case of Mexico city shows that it was precisely the resilience of some of the most corrupt and unjust people and institutions in the capital that made the post-earthquake recovery and reconstruction efforts so dreadful, at least initially. Indeed, among the most resilient forces were the local police, the army and the political leadership of the PRI, which governed the city and the nation. In the days and weeks immediately after the earthquake, these groups actively struggled to reinforce their own positions and practices, using the earthquake and the trauma it produced among citizens to strengthen their power base".

Secondly, Davis insinuates that resilience might be defined as the ability of an actor / system (a) to develop inherent resources and means usable to recovery and/or (b) to extract from the social, economic and ecological environment (legitimately or illegitimately) means and resources and engage and commit them for the purpose of own recovery or improving own

position. Beyond doubt these attitudes end up with unfair distribution and redistribution of means, response capacity and vulnerability among the numerous actors of the territorial system. Some actors upgrade their social and economic status even at a level higher than their pre-disaster one (reducing thence own vulnerabilities). Others do not ever recover or find themselves at the end of the recovery period at a far deteriorated condition than at the beginning of the recovery effort (see Figure 43).

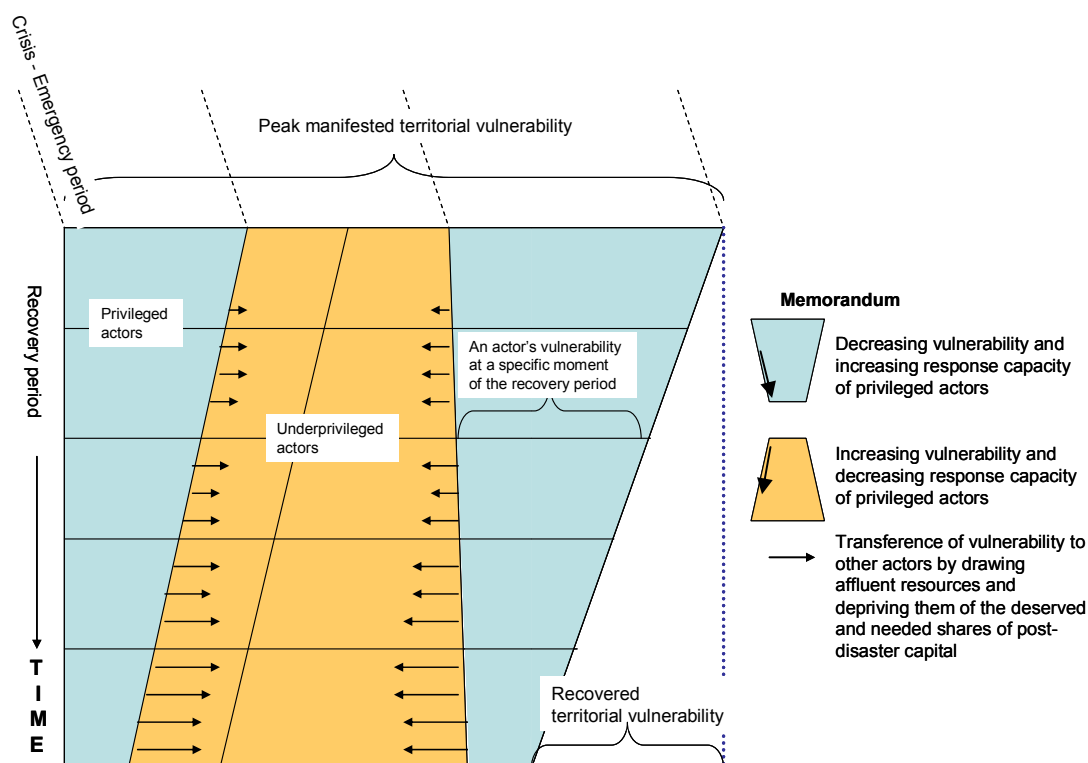


Figure 43: Diagrammatic representation of a probable evolution of territorial vulnerability in the recovery phase and of the parallel evolutions of vulnerability of the involved privileged and underprivileged actors

But not only authorities, citizens as well proved to be resilient in their own fashion in the case of Mexico disaster (Davis 2005):

"Ultimately most of these offensive postures backfired, because citizens continued to mobilize and to decry government incompetence and heavy-handedness, despite subsequent efforts to show some responsiveness to the crisis and to the overall concerns of citizens..... It may have been precisely the bull-headed resilience of the authoritarian PRI and its corrupt policing and administrative apparatus that led to the defeat of the ruling party in both the city and the nation several years later. That is, the eventual defeat of the PRI emerged in the context of the struggle between resilient citizens and this surprisingly resilient state. Thus it might be more accurate that the desire of each to direct or dominate the recovery and reconstruction process together led to the political transformation of the city and the nation".

The case of Mexico city disaster cycle that started in 1985 (actually long before that year) and endured for more than two decades brought to light the historically entrenched multi-faceted vulnerabilities of the Mexico capital city's territory. Once the stress (i.e. the seismic hazard) reached a critical threshold, physical vulnerability was the first to manifest itself (extensive damages in critical buildings at the city centre). Afterwards and as physical losses reached another critical threshold all sorts of vulnerability to losses (techno-systemic,

institutional, social, economic), one by one manifested themselves by means of lifeline failures, institutional failures, social and economic losses. As the disaster comes into scene, every manifested aspect of vulnerability leads up to the manifestation of another and the whole potential of losses reaches its peak somewhere in the emergency period (though some types of losses take much longer to unfold). Thereafter, total loss shrinks and vulnerabilities (to the initial hazard) decrease by response capacities; but increase of response capacities of some actors (subsystems) is achieved by transferring vulnerability to others.

What is probably the most important lesson from the Mexican case and from Davis's respective analysis and interpretation is that resilience cannot inherently be seen as good or bad. It is surely helpful to recovery of the actor or system who / which employs such an attitude but it may be harmful to the recovery and long term vulnerability of others.

8. Opportunities and challenges in integrating vulnerability aspects

The objective of this section is to explore the ways in which physical and systemic, also systemic, institutional, social, economic and territorial vulnerabilities have been integrated to date, and how they might be in future. Integration of the several versions of vulnerability into a comprehensive model pre-supposes full understanding and acknowledgement of the known or still unknown factors that intervene, mediate, activate or facilitate vulnerability successions or relationships.

The interactions between physical elements failures and technical systems functionality appeared to be the easiest vulnerability aspects to quantitatively integrate together. The consequences of failures of generating plants or distribution lines on the behaviour of the whole lifelines have been investigated in several studies, on different lifelines:

- Electricity (Dueñas-Osorio and Vemuru 2009, Eusgeld *et al.* 2009)
- Transport (Gleize 2005, Matisziw *et al.*, 2009, Kuwata and Takada 2004)
- Gas (Li and al. 2008, Chang and Song 2007)

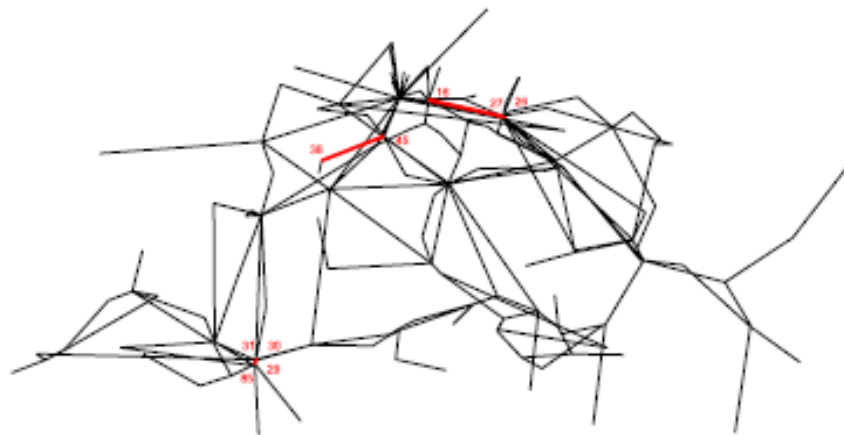


Fig. 5. The five most vulnerable lines according to the topological vulnerability evaluation.

Figure 44: Example of vulnerability assessment of an electric network. (Eusgeld *et al.* 2009)

Their approaches are based on graph theory concepts where distribution lines or roads are represented by edges and the plants (generating or transformers for electrical system; wells, storage tanks or treatments plants for water system or stations; crossroads or stations for transport networks) by vertices. The networks can then be described with mathematical terminologies, (mean connectivity, orders, diameters, ...) and the effects of failures of elements (either edges or vertices) on the general performance of the system can be assessed, with the removal or the reduction in capacity of the affected elements. However, this method requires a complete knowledge of the systems, but also, to be realistic, of the demands, to be able to assess the impact of the system dysfunction on the society (evaluation of the ratio supply/demand in the different zones).

Interactions with other technical, human and/or territorial systems have been less studied. Several methodologies have been introduced, mostly based on economical approaches:

- Agent-based models (Rinaldi *et al.*, 2001)
- Inoperability Input-Output Model (Santos, 2006; Jiang and Haines, 2004)
- Computable General Equilibrium (Chang *et al.*, 2000)
- Holographic hierarchical models (Haines *et al.* 2002)

However, even if these methodologies allow estimations of the indirect costs and impacts on society from physical damages and systems dysfunctions, these methods cannot picture the impacts of the socio-economic, institutional or territorial vulnerabilities on physical and systemic aspects. Indeed, most of the studies focus on the physical causes to socio-economic consequences relationships.

In order to take into account these retro-actions, indicators have been developed (Cardona, 2005). These indicators quantify the four main aspects of vulnerability at national scales, (but a similar method exists for the local level, Carreno *et al.*, 2007):

- Disaster deficit index, from a macroeconomic and financial perspective (estimation of critical impacts and financial ability to cope with the situation, ***economic vulnerability***)
- Local disaster index: empirical social and environmental risks resulting from more recurrent lower level events (***spatial vulnerability*** and ***exposure***)
- Prevalent vulnerability index: exposure, socioeconomic weaknesses and lack of social resilience in general (***exposure*** and ***socio-economic vulnerabilities***)
- Risk management index: organizational, development, capacity and institutional actions (***institutional vulnerability***)

Hence, the composite final indicator takes into account, not only the expected physical damage, victims and economic equivalent loss, but also social, organizational and institutional factors.

Another opportunity for integrating and measuring the total potential of vulnerability comes from the possibility of considering separately the stages of the disaster cycle wherein vulnerability and vulnerability relationships vary regarding their nature and accordingly determinant factors. More specifically:

- ▣ Prior to the disaster and during the disaster stage – at least in the case of extreme and abrupt events – vulnerability is a matter of exposures, all systemically connected exposures (exposure to stress and exposure to losses). While response capacity is partly built in pre-disaster terms up to the emergency period remains latent, inactive and dormant. Hence, the major concern in pre-disaster terms is exposures, except in the case of institutional vulnerability where the matter of concern is coping capacity of institutions. But exposures should be considered here in the widest possible sense; they are not only locations in the geographical space and distance from threat (hazard). Economic exposure is a matter of position in the economic ladder; human/cultural exposure is a matter of position in the knowledge

ladder (with respect to the threat) and technological exposure is a matter of position in the technological ladder. Exposure is a relational property and territorial exposure is the composite outcome of the position of the involved forms of capital in social, economic, institutional, technological and knowledge hierarchies.

- In the emergency / relief period technical systems (the lifelines) together with the institutions responsible for emergency operations formulate wider techno-institutional systems the vulnerability of which is a critical component of the vulnerability of the respective territorial systems in the same period (see Sections 4.2.a, 5.2.1). In the emergency/relief period the basic matter of concern for territorial vulnerability is interaction between response capacities and exposures: in particular – and in such periods – institutional response capacity is adversely affected by physical exposures and the first one deteriorates in turn exposures and response capacities of social and economic systems.
- In the recovery / reconstruction period vulnerability is fundamentally a matter of response (coping) capacity and hence a matter of accessibility to resources which are essential for recovery (physical, social, political, economic, cultural capital)(see Sections 6.b, 7.d).
- In the recovery / reconstruction period the upper hand is gained by “vulnerability actors” (a term closely related to the “response capacity” term) which are entities with “selection-making” and “decision-making” capabilities and powers (persons, households, businesses, institutions, techno-human systems, eco-human systems etc). These are the managers of vulnerability changes and relationships. In the context of actors’ struggle for resources, exposures (and vulnerabilities) may be transferred from certain territories to others, from powerful groups to powerless and so on; besides powerful groups and actors increase their coping capacity by neutralizing the coping capacity of the powerless (5.3.a, 7.b, 7.c, 7.d).
- In the recovery phase territorial vulnerability is closely connected to the total coping capacity of all the “vulnerability actors” involved in the territory. A territorial system’s response capacity in the recovery phase depends on the internal and external to the system accessible capital, i.e. pre-disaster capital after losses plus extraordinary forms of capital that are only generated or emerge after crisis situations:

$TeReCa = f(PreCa_{al} + PostC)$ where,

TeReCa: Total Territorial Coping or Response capacity

PreCa_{al}: Pre-disaster accessible Capital after losses

PostC: Post-disaster extraordinary (internal or external to the system) accessible capital

It is obvious that after disasters response capacity of some systems or “vulnerability actors” (social, economic, institutional, eco-actors) is superior to that of others; but in any case response capacity of a territory (and the involved system of actors) at a certain moment of the disaster cycle is equal to the sum of relevant capacities of the actors that make up the territorial system at this specific moment:

$$TeReCa = \sum_{act} AReCa$$

It is evident from all the above that consideration of territorial capital’s exposure, as well as its role in response capacity in pre- and post-disaster terms, opens windows for integrating vulnerability aspects and assessing fluctuations of vulnerability along the disaster management cycle.

8.1. Catalysts of vulnerability relationships

A catalyst is something that causes a change in something else i.e. it is a 'driver' of change. Therefore we need to understand the factors that intervene, mediate, activate or facilitate vulnerability relationships (i.e. the connections or linkages) or in successions (what makes one thing follow after another). So in other words we are asking what things cause other things to happen and to follow one another.

Our conceptualization is that:

- a) Relationships exist 'naturally' between different types of vulnerability, since these types are facets of the vulnerability which is a 'single' whole;
- b) a catalyst is then 'a driver of change' which forces movement along these natural channels of relationships causing a change to take place.

For example, a relationship will exist between the physical vulnerability of a house structure and the social vulnerability of those occupying the house. During periods of geological stability or say in between floods, the relationship will lie almost 'dormant' or will be stable. However, a catalyst (or as it is commonly called now in English language – 'a driver of change') will then 'activate' the relationship causing instability. This occurs when an earthquake or flood takes place, and the house structure is damaged leading to a sudden increase in the social vulnerability of the occupants. In the worse case occupants may be killed. Hence, during crisis (in the disaster phase) the basic catalyst is the stress and its characteristics (location, intensity etc). For instance an earthquake with its epicenter under the center of a metropolis will trigger off a chain of vulnerability relationships which is very different from the chain that would be activated if the earthquake had its epicenter at a location in the periphery of the Metropolis.

Many other catalysts can alter vulnerability. In pre-disaster terms particular changes in development patterns may alter the structure of vulnerability relationships and interactions: urban-rural migration, failure of food crops and increased food insecurity are conditions, which tend to set up vulnerabilities and cause change. Furthermore, urban redevelopment, social and economic regeneration initiatives, social welfare programmes and social justice programmes are examples of catalysts of change. Natural hazard mitigation programmes are also relevant examples of catalysts. Institutional vulnerabilities may be transferred to others (either institutional or social / economic actors). In general terms planning initiatives serving risk mitigation objectives (and not only) are the major catalysts of change in vulnerability hierarchies, distribution and relationships in pre-disaster terms.

Finally, in emergency, relief and recovery periods the major catalyst for vulnerability relationships to activate, especially such relationships as transformation of vulnerability to other hazards and transfer of vulnerability from one actor to another, one system to another etc., is Response/Coping Capacity and Resilience. Indeed the activation of Response Capacity and Resilience potential, which alters response capacities, facilitates vulnerability transfer and redistribution among actors, communities, territories and so on.

9. Conclusions

The theoretical discussion at the beginning of the chapter and the case studies that followed (Chapters 4-8) shed light to the meaning and semantic implications of basic terms that have been extensively used and lie at the core of the ENSURE project, such as systemic vulnerability, external and internal systemic vulnerability, vulnerability to stress and to losses, exposure, coping or response capacity, resilience etc. Besides the material quoted in this chapter revealed the spatial-temporal coordinates of the above attributes or properties, i.e. when and where these are produced and manifested why and under which conditions. More specifically, relevant meaningful conclusions are:

- ▣ Systemic vulnerability has been considered and defined in two ways: (a) as vulnerability of a system, i.e. a system's susceptibility to loss and its capacity to recover, and (b) as the outcome of interaction between vulnerabilities, i.e. as the potential of an entity for a mixture of losses (physical, social, economic etc) or as the form of vulnerability that arises out of the linkages between the other forms. In essence the pursued relationships between vulnerabilities the always present systemic character of vulnerability.
- ▣ Each system - let it be ecological, social, institutional, economic, technical - can carry vulnerability due to its internal features and structure (internal systemic vulnerability) and additional vulnerability owing to external factors and other systems (external systemic vulnerability). Each technical system for instance is interconnected to others (technical, institutional, social etc), hence internal systemic vulnerabilities are affected by external ones. External and internal systemic vulnerability depend on system's definitions, i.e. when interrelated systems are considered as a supersystem, external vulnerability becomes internal and vice versa.
- ▣ Territorial vulnerability can be defined as the vulnerability of a territory (a territorial system), i.e. its susceptibility to mixture of losses (social, institutional, physical) and its capacity to recover; it is related to the aggregate vulnerability of all forms of capital which are involved. Alternatively, the unique assemblage of physical, social, economic, institutional etc vulnerability in the case of a specific place can be expressed as territorial vulnerability.
- ▣ Eco-human entities or systems are very close to territorial ones and eco-human vulnerability is very close to the meaning and content of "Territorial Vulnerability" (see Sections 6.a, 6.b)
- ▣ Institutional vulnerability may be conceptualized in two ways (Sections 5.2.1, 6.b, 7.a): (a) as the vulnerability of an institutional system, i.e. its susceptibility to loss and consequent capacity to own recovery, (b) as its incapability to release risk mitigation policies and measures, increasing thus other systems' vulnerability (social, economic, territorial). Institutional vulnerability is crucial for exposure and vulnerability of all the other systems and therefore territorial too.
- ▣ Vulnerability of a system is reflected to losses once the hazard (stress) is manifested; however a system can undergo losses and impacts due to the losses of another interconnected system. Consequently a system can carry Vulnerability to Stress and Vulnerability to Loss (see Sections 3.2, 4.1, 6.a, 6.b, 7.d).
- ▣ Vulnerability to Stress is a function of the characteristics of the stress (intensity, location, spatial extent etc) while Vulnerability to Loss is a function of certain thresholds of losses (see Sections 6.a, 6.b, 6.1)

- Vulnerability of a system also depends on its Response or Coping Capacity. Response or Coping Capacity refers to the capability to respond and minimize losses. It is basically a property referring to systems and "vulnerability actors" with decision-making or adjustment capabilities. Knowledge and "skills" are crucial elements of Coping Capacity.
- Ecological Vulnerability results from interaction between social and ecological systems. Accomodating the needs and risks of developing social and economic systems turns to accumulation of ecological exposures and vulnerabilities. The latter turn into new threats for socio-economic systems. This is actually a cycle of vulnerability transfers through constant alteration of the environment.
- Exposure is a function of location/position in the geographical, social, economic, political, knowledge, psychological and technological space in relation to stress or potential losses (and their intensity): $E=f(L_g, L_s, L_e, L_p, L_{kn}, L_t)$.
- Response Capacities and Exposures interact. In the emergency period for instance exposure to loss of means and equipment of the agencies responsible for emergency operation may counteract their Response Capacity and the latter in turn may cause new Exposures of populations to new and other hazards (i.e. physical or a techno-system's exposure to stress → cancellation of response capacity of institutions → physical or social exposure to the initial and new hazards) (see Sections 4.1, 5.3.1.a, 6.b, 7.c)
- Vulnerability changes occur due to interaction between exposures and coping/response capacities and the catalytic action of Resilience which alters response capacities.
- Resilience is an attitude that affects positively coping capacity of the system that exhibits such an attitude; expressing it in another way resilience is the ability to increase response/coping capacity.
- Resilience conceptualised in operational terms is the ability of a system (a) to develop inherent resources and means usable to response and recovery and / or (b) to extract from the social, economic and ecological environment means and resources to engage and commit them consequently for the purpose of own response and recovery or improving own position.
- Resilience, especially in the relief / recovery period is a catalyst for vulnerability change, transfer and transformation but such attitudes and processes entail uneven distribution of exposures and response capacities and hence vulnerabilities in the geographical, social, economic, political space.
- Systemic (or functional) vulnerability of technical systems (lifelines) is a matter of their design and structure (e.g. mono-centric are disadvantageous compared to poly-centric systems) and it is related to thresholds of losses at key nodal points or losses (vertices and edges)(see Section 4.1).
- In general terms all types of centralized and mono-centric systems (technical, institutional etc) are vulnerable to losses of the center, which the function of the whole system depends on. Once this center is exposed to hazards the whole system is at risk and vulnerable. This implies that vulnerability to losses of such a centralized system is a function of exposure to stress of its center (see Sections 4.1, 7.d).
- Vulnerability of techno-institutional systems in the emergency and relief periods depends on (a) functional vulnerability of the interconnected with the institutions technical subsystems, (b) the indispensability of the above connections (lack of redundancy) and (c) some forms of capital supporting the coping capacity of the

above institution (i.e. physical capital for resourcefulness, human capital such as knowledge, experience, innovation and political capital to vouch for self-organization and autonomy, pre-disaster planning etc) (see Sections 4.2.a, 5.2.1, 5.3.1.a).

- In the cases of eco-human and territorial systems their vulnerability in the pre-disaster up to the disaster phase might be correlated with the composite level of exposures of the involved forms of capital (social, economic, human, physical etc); these exposures are determined by position in the respective ladders.
- In the cases of eco-human and territorial systems and in the course of the recovery process vulnerability may be transferred (with the help of resilience) by some systems to others; this is achieved by the first through depriving the second of the needed recovery resources. Transferences and transformations of vulnerability during the relief and reconstruction phase causes vulnerability redistribution among sub-systems and forms of capital and radical change in overall territorial vulnerability.
- In the cases of eco-human and territorial systems pre-disaster systemic relationships between the eco-environment and social/economic sub-systems or between institutional and other sub-systems is possible to break down in the recovery/relief period in an attempt of these sub-systems to search for external resources and support by appealing to other systems and by building new systemic relationships (spatial and temporal scale interactions) (see Sections 6.a, 6.b).
- In the relief/recovery phase, a territorial system's response capacity can be equalized to the forms and quantities of the internal and external to the system accessible capital, which is then committed to relief/recovery.

It is evident that the above remarks open windows for systematic assessment of territorial and other integrated forms of vulnerability per stage of the disaster cycle.

10. References

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