



## **ENSURE PROJECT**

*Contract n° 212045*

# **ENSURE E-LERNING TOOL**

## **F38**

### **Structuring the relations between physical, social and economic vulnerabilities**

### **Application to different case studies**



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#### **Reference reports:**

Del. 2.1.3: Relation between social, economic and physical vulnerability (chap 4 to 9)

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# 1. Droughts<sup>1</sup>

## 1.1 *Agricultural practices in the Negev*

Two types of populations reside in the Negev, a Jewish and a semi-nomadic Arab (Bedouin) population. Both populations exploit the land, whether directly by cultivation or grazing or indirectly by feeding sheep or goats on hay and grains produced in the fields. While the Jewish sector cultivates the land in a very systematic, organized and sophisticated manner, the Bedouins, although using for the most part machinery, cultivate their land in a more traditional manner. While cattle and sheep are grown in enclosures in the Jewish sector, the traditional practice of open land grazing of sheep and goats is common in the Bedouin sector. These differences may largely stem from fundamentally different social structures.

### ***Factors***

The Jewish and Bedouin populations differ markedly in their social structure. On the Jewish side there are, Kibbutzim, a closed community advocating equality and the sharing of community resources in a more or less egalitarian manner, and Moshavim, a slightly more open community where only some of the revenue from resources is shared. On the Bedouin side, then, the population is either scattered or resides in towns. Most of the scattered part of the community reside either on disputed land, illegally on state-owned open areas, or in small towns - some of which were established spontaneously without legal foundations and therefore without infrastructure. Others however reside in one of the seven pre-planned towns where government provides the infrastructure and the municipal facilities.

Tradition plays a cardinal role in shaping the lifestyle of the Bedouin community.

Yet, during recent years the traditional family and tribal tradition has undergone some fundamental changes, not necessarily positive ones. Rich individuals who became wealthy through illegal means, such as drug dealers and other criminals, are now replacing the elderly as the new tribal authority. Conflict and violence between families of different tribes are common and the necessity of creating a 'strong' family may explain, at least partially, the high birth rate in the Bedouin community.

The birth rate within the Bedouin community is the highest in the world and the Bedouin population is doubling every 13.5 years. Polygamy is the rule rather than the exception, relying on the Koran that permits marriage to four wives simultaneously. Yet, since the Shari'a (Islam's code of laws that is in use in Israel's Moslem communities), permits facile divorce. Very good medical facilities and government programs providing monthly income to families in accordance with their number of children contribute to a high birth rate (average birth rate of a Bedouin woman is  $\pm 10$  children).

As a consequence of high birth rates and the resulting economical burden imposed on the family, children often do not receive a full education (despite being mandatory up to 18 years) and enter the labor market when still teenagers. Poverty and crime is consequently very high. On the other hand, modernity and increased exposure to the more western-Israeli culture weakened solidarity, once high in the Bedouin sector.

Overall, while the education level and solidarity are very high in the Jewish sector, both are low in the Bedouin sector. Whereas commonly both parents work in the Jewish section, only one salary is available for a typical Bedouin family. Therefore, when an external hazard such as a meteorological drought hits the Northern Negev, the capability of both populations to deal with the subsequent agricultural drought is very different.

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<sup>1</sup> Case material provided by TAU, Israel

## Vulnerabilities

If defining drought as a mainly socio-economic phenomenon resulting in "a substantial reduction in crop yield" (*cf.* Swearingen, 1992; Dalezios *et al.*, 2000, Roberts, 2002; Tsakiris *et al.*, 2007), any measure taken in order to increase crop yield may thus influence the physical and socio-economic vulnerability stemming from drought. Social factors such as solidarity or education may play a pivotal role along with economic factors. As a possible link between political and economic factors cannot be ignored, one may assume that social vulnerability may determine, to a large extent, the economic vulnerability. This is the case in many countries throughout the Mediterranean such as Greece (Katsoulis and Tsangaris, 1994), Italy (Piccarreta *et al.*, 2004), Spain (Roberts, 2002; Fornés *et al.*, 2005) and Morocco (Swearingen, 1992). Israel is no exception, as evidenced in the Northern Negev, where droughts, stemming from a substantial decrease in precipitation, may occur regularly once every few years.

## Stage II: Implementation

### Public Intervention

Public intervention in Israel is high. Owing to the high solidarity under which the state was created and owing to socialist views that were dominant during most of the 20<sup>th</sup> century national programs and numerous local enterprises for drought mitigation were set up. In what follows, and also described in Table 3, some of these enterprises will be discussed:

- a. The demarcation of a '**drought line**' was undertaken in 1964 in order to provide a viable solution for farmers who lost not only their possible revenue but also their investment after a drought. The area demarcated includes the Northern Negev between the rain isohyets of ~250 to 450 mm. Being prone to droughts at a relatively low frequency of occurrence of once in a few years, the government passed 'The Drought Law' that guaranteed the reimbursement of the farmer's expenses during drought years. A joint committee of the government in collaboration with the Association of Farmers declares drought years following a meteorological drought during which precipitation was too low to allow for any meaningful crop yield. Once a drought year is declared, the committee samples the yield from different areas and based on their result and the revenue expected. The government then pays the farmers the difference between the expenses and the revenue obtained. In this way, the farmer's and settlements' financial collapse is prevented and field abandonment is avoided. For several years, some compensation to farmers with fields below 250 mm isohyets was also provided.
- b. Aiming to provide drinking water to all inhabitants and for the same price, **the National Water Carrier** was designed in the early 1960s. It connects the relatively wet part of the country in the north (the Sea of Galilee) to the Northern Negev Desert. From the 1960s until the late 1980s some of the water was also used for agriculture. Yet, with the growing population and the higher frequencies of droughts, this water is now almost solely used for drinking purposes.
- c. An example of **water purification** is the water purification plant of the metropolis of Tel Aviv (The Shafdan). The level of purification is one of the highest in the world and the water is safe for occasional drinking. All crops including green leaves such as parsley can be irrigated with this water. It reaches over 80% of all settlements in the Northern Negev. Other examples are local purification installations whether large, such as the sewage of cities of Jerusalem and Beer Sheva, or small, such as the sewage of the Kibbutzim and Moshavim. During the last three years, all water is purified to a high level that facilitates irrigation of vegetables such as potatoes and carrots.
- d. The construction of **water reservoirs** aiming to catch runoff water that enters wadis (arroyos) such as Shikma, Gerar, Lachish and Nizzana. The water caught is used for irrigation. The Jewish National Fund (JNF) is highly involved in reservoir construction.
- e. An infrastructure of **professional services** including agronomists and researchers as well as laboratory facilities was set up. Associated with the Ministry of Agriculture, these professionals are involved in providing free advice (the agronomists) or low-cost services (laboratories) in order to improve production. The Ministry of Agriculture is also involved in providing food for the Bedouin herds,

e.g. during droughts. The Ministry is looking for grazing permits in Kibbutzim and Moshavim and in army firing zones that are usually closed to the public. In addition, the JNF provides free access to its forests in the south and central parts of the country. Bedouins are allowed to enter the forests, each herd owner to a specific area, following a contract agreement according to which the herd owners are committed to follow strict behavior codes in order to minimize damage to the forests. Access to the JNF forests is provided regardless of droughts. The payment requested by the Bedouins is about 0.5 euro for each sheep for the entire grazing period of approximately three months and thus rather symbolic.

Type of Intervention	Extent	Description and Remarks
The Drought Law	National/Regional	Aiming to prevent land abundance
The Water Carrier	National	Aiming to facilitate countrywide settlement
Sewage purification: Shafdan	National	Aiming to switch the drinkable water for agriculture with purified sewage water
Sewage purification	National/Regional	
Water Reservoirs	Regional	
Utilization of Ancient Saline Aquifer	Regional	
Agricultural Infrastructure	National	Aiming to spread new techniques of water irrigation, cultivation, seed varieties, de-ceases etc.
Sea Water Desalinization	National	Aiming to increase

*Table 1: Public Intervention Dealing with Physical Vulnerability*

In this regard, it is interesting to note that while a large scope of measures were taken in Israel much fewer measures were taken by European countries, as can be seen in Annex II: A comparison between Israeli and Spanish water use categories.

### ***Private Intervention***

The private sector is highly involved in the attempts to ameliorate production. Several industries exist that specialize in the production of irrigation equipment. One of them is Netafim. It is located in the Northern Negev and developed the drip irrigation system that is gaining more and more popularity in the world. This is due to the high proportion of water saved, the capability of using the system for concomitant fertilization and its advantage in minimizing soil salinity and plant decease. Recently, a new generation of subsurface drip irrigation was developed. Buried at 7 to 30 cm below the surface, it minimizes evaporation while still permitting the use of machinery (Tal, 2006). Certain companies have produced sophisticated data loggers to control irrigation while other companies have developed sensors, attached to trees that monitor the water status of the tree and automatically control its irrigation. Other companies have developed specific machinery aiming to improve the water storage of the soil (used in Kibbutz Ruhama) while others have produced sensors, attached to cattle, aiming to improve milk production.

### ***Civil Society Intervention***

A constant and ongoing effort to combat droughts is taking place in the Jewish sector. For this purpose, some Kibbutzim combine their means of production in order to reduce expenses. This is the case with Bet Kama and Mishmar HaNegev. All heavy machinery is jointly purchased and one Kibbutz member is in charge of all field production. Following research done by the Ministry of Agriculture and following results that showed that no-tillage cultivation may save on water and thus increase crop production, special machinery was purchased in order to facilitate seed insertion into the non-tilled soil. The cost of this machinery was twice as high as conventional machinery. Yet, by trial and

error, specific changes were necessary and consequently executed in order to adapt the machinery to the local soil conditions. Furthermore, both Kibbutzim joined hands and decided to utilize the sewage water of the nearby Bedouin town of Rahat. While the sewage water is free, the condition of acquiring the water necessitated both Kibbutzim to build the infrastructure for storing and distributing the water in accordance with the crop need.

Similarly, all 34 Moshavim in the Negev decided to jointly cultivate some of their fields. This includes crops that are better cultivated in large fields such as wheat, potatoes, carrots and sunflowers, as well as citrus orchards. The individual Moshav farmer will mainly focus on cultivation in greenhouses located near his home while a private firm will jointly cultivate the majority of the fields, which are at a distance from the residential area.

Kibbutzim and especially Moshavim invested in greenhouse construction. As individual farmers need a steady income in order to receive loans for greenhouse construction, it is easier to cooperate to jointly obtain the required guarantees. It is thus the community that jointly works towards better conditions and easier access to the necessary capital.

Whereas the use of purified sewage water facilitates irrigation also during severe droughts and thus allows for good crop yield, crop yield per cubic meter of water is most efficient in greenhouses. Both measures enable a successful drought management, facilitating drought mitigation and even drought 'avoidance'.

Non-profit organizations are involved in trying to improve crop yield and consequently to successfully combat droughts. One of the most powerful organizations is the Association of Farmers. It is not only involved in the receipt of the 'drought law' and in the decisions regarding money compensation for farmers during droughts, but also in other projects aiming to expand research and hence knowledge regarding agriculture under conditions of high water stress and low predictability. One of the projects that they are involved in, entitled 'Punctual Agriculture', entails the receipt of six to ten remote sensing images of crops in the Negev Desert during a single growing season. These images are analyzed to a resolution of a tenth of a hectare in order to detect areas short of water or nutrition and thus offer immediate remedies for these fields.

### ***Stage III: Evaluation***

#### ***Key Factors***

Although both sectors, the Jewish and the Bedouin, have free access to agricultural agronomists, provided by the Ministry of Agriculture, the Bedouin sector is taking far less advantage of this service. Consequently, basic guidelines, such as cultivation in accordance with topographical contours are not always followed, bringing about not only erosion but also water loss due to runoff. No-tillage agriculture is not implemented while only limited adjustments are made for use of more efficient water-consuming crops, such as barley, instead of the traditional wheat. Machinery that promotes the increase of surface storage is also not used in this sector.

Only few Bedouin farmers abandoned the traditional practice of growing sheep and goats via open-field grazing. Apart from heavily relying on nature for adequate food supply, this traditional practice has additional drawbacks, as it highly complicates the use of sheep or goats for dairy production and thus substantially reduces the revenue obtained from the herds. Recently, herd owners face an additional problem as their children attend school and refuse to wander with the herds. While only few adopted the modern method of growing the herds in enclosures, others abandoned this profession altogether and moved to towns.

Field cultivation by Jews not only has positive consequences such as drought 'avoidance' or drought mitigation, but may occasionally have negative consequences. The use of heavy machinery may trigger soil compaction resulting in runoff and soil erosion. Runoff production reflects a net loss of water within the soil column, intensifying the consequences of the drought. Furthermore, the attempt to grow industrial plants such as cotton, which require large amounts of water, was unsuccessful when the water used was of low quality. Thus, in Kibbutzim like Kefar Aza, relatively saline water from a Pleistocene aquifer was used. Although suitable for cotton growth, the high input of salt caused

huge structural damage to the soil and to future crops. Not having better quality water on hand, this was one of the reasons that led to the cessation of cotton growth in the area.

## ***Blind Spots***

Weakened communal bonds and low income per capita tremendously lower the coping capacity of the Bedouin sector. Pan-Arab nationalism and ethnic pride within the Bedouin community make Jewish intervention problematic and thus assistance, to say the least, is not always welcome. The Bedouins do not assemble in civil associations and do not provide the initial capital needed for new enterprises. Heavy machinery that may be too costly for the individual but can be purchased by joint entrepreneurial efforts is not purchased due to the lack of solidarity and/or capital. Thus far, our research did not point to any 'real' and specific measure taken by this sector in order to better cope with the drought hazard. However the Bedouins do benefit from some measures taken by the state and by the private sector. Thus, those of them who have irrigated fields benefit from some of the water facilities and techniques and the development of new varieties of crops that are better adapted to dry conditions.

## **2. Earthquakes<sup>2</sup>**

### ***2.1 Socio-economic factors affecting physical vulnerability<sup>3</sup>***

#### ***Stage I: Initiation***

In the literature and in evaluations of several past disastrous events, impacts of infrastructural failures on the socio-economic structure of affected areas have been broadly studied. The scale of those impacts can be evaluated according to the number of affected infrastructural systems and the recovery period. For instance, when the impacts are minor, a short-term disturbance in social environment and limited negative impacts on certain business units can be revealed. On the other hand, in large-scale events, these impacts go through inconvenience with associated stress and conflict in community and economic tension at regional or national scale (Centre for Advanced Engineering, 1997). Concerning the physical environment or built-up environment, which is a product of socio-economic milieu, it is possible to find some traces on this mutual relationship which either increase or decrease vulnerability. Socio-economic structure of a region or a country comprises population size and distribution, demography, migrants, fiscal power, dependency/independency of the system, income distribution, national economic indicators etc. These invisible components become visible in the form of built-up environment. The socio-economic system shapes the quality of the physical environment, such as the redundancy of critical facilities and the response and recovery processes after crises. Consequently, if a socio-economic structure has vulnerable spots embedded, there will be some reflections on the physical system as well. On the other hand, the links of physical vulnerability and socio-economic vulnerability refer to a connection through functional efficiency of exposed elements on socio-economic life (Figure 4). To clarify the links between socio-economic parameters and physical vulnerability, we will refer to systemic vulnerability components (mostly infrastructural systems) with their possible impacts on the socio-economic environment. With this knowledge we will focus on the deficits of socio-economic structures which lead to failures in the physical environment. In other words, in order to reveal the impacts of socio-economic factors on physical vulnerability a case-study based approach will be followed. The starting point will be the possible impact of infrastructural damages on the socio-economic assets of a given region. Subsequently attention is given to the inherent vulnerability of socio-economic systems that may enhance infrastructural vulnerability.

<sup>2</sup> Case material provided by T6 and POLIMI, Italy and HUA, Greece

<sup>3</sup> Contribution by POLIMI

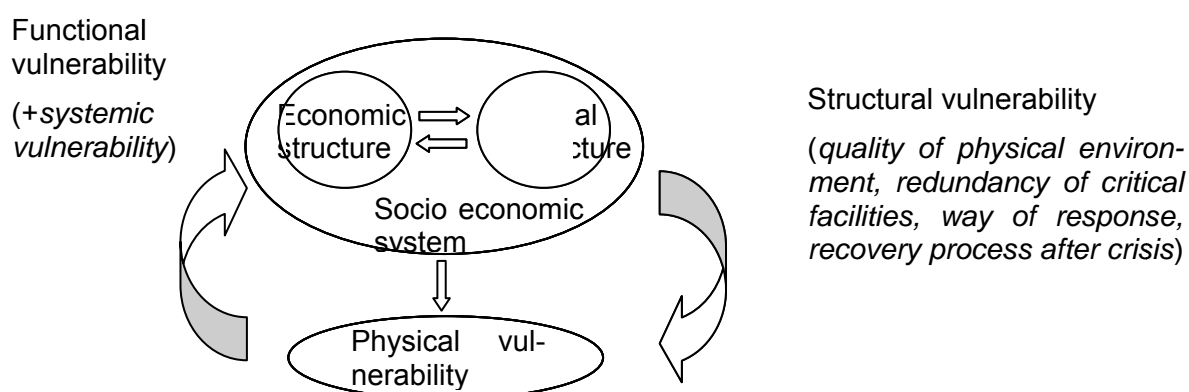
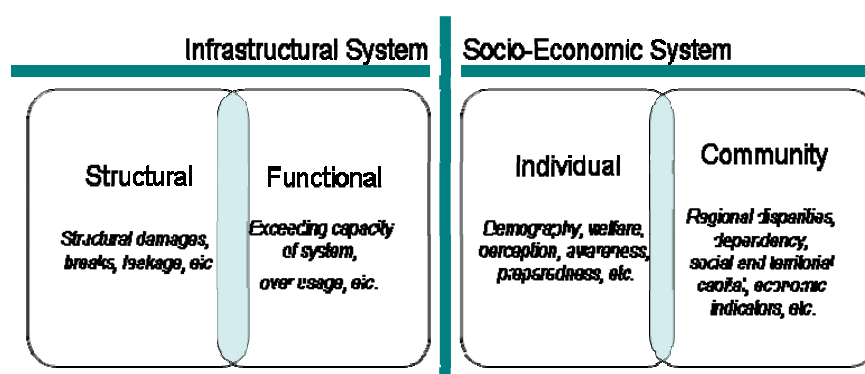


Figure 1: Relationship between Socio-Economic Vulnerability and Physical Vulnerability



The relations between socio-economic vulnerability and infrastructural vulnerability can be both direct and/or indirect. Considering the impacts of infrastructural vulnerabilities upon socio-economic vulnerability, they are not directly connected with infrastructural physical failures. However, the socio-economic environment may suffer because of the interruption of services which can be called functional failures. Here, infrastructural and socio-economic vulnerabilities are examined in two sub-components each: (1) infrastructural system with (a) structural and (b) functional aspects and (2) socio-economic system at (a) individual and (b) community level (Figure 5). The reason of this categorization is that some social aspects at individual level (such as age, gender, ethnicity etc.) are not relevant with regard to infrastructural failures. However, when considering all these individuals as community, it would be easier to find out some effects of the socio-economic environment on the infrastructural system. As can be seen in the Figure, even though sub-components of groups are identified, the intersections in both Venn diagrams illustrate that no strict distinction can be made. For instance, due to a natural event, an infrastructural system is damaged which affects the running capacity of the system. Moreover, in the socio-economic environment, individual welfare is strongly related to national economy and/or territorial capital.

## ***Stage II: Implementation***

The Northridge earthquake, of January 17, 1994, has been noted as the most costly disaster in U.S. history before hurricane Katrina hit New Orleans in 2005. The most remarkable impact of the earthquake was partial or entire collapses of highways which were major routes for daily commuting for many people. Fortunately redundancy of the transportation system in Los Angeles supported by several roads decreased the long-term impacts of transportation failures. Nevertheless, in the aftermath of the earthquake, several business units reported that both their employees had difficulties to reach their working places and they experienced difficulties in delivery of goods and services (Tierney, 1997). Except large scale collapses in certain parts of highways, the majority of reconstruction or rehabilitation of roads took no more than a few weeks (ASCE, 1995).

Similar transportation failures were experienced in Kobe earthquake exactly one year later on January 17, 1995. The collapse of Hanshin Expressway caused severe interruptions in both the operation of rescue activities and the further evacuation. However, as the city of Kobe has developed on a line between the Rocco Mountains and the Pacific Ocean, the low redundancy in transportation caused long-term impacts on the affected region. Moreover, the connection between the main land, Port Island and Rocco Island was interrupted. It took 20 months to reconstruct Hanshin expressway, eight months for the Osaka Bay route and three months for the Shinkansen rapid train route (The City of Kobe, 2008). Reconstruction cost and monetary losses by interruption of traffic flows caused great deficits in Kobe and Hyogo's economies as well as Japanese economic growth. Sichuan (China) Earthquake on the 12<sup>th</sup> of May 2008 caused wide range of destruction. The rescue efforts were especially complicated by interrupted transportation flows due to structural damages, falling rocks or landslides.

When comparing Northridge and Kobe earthquakes, there are big differences in response and recovery processes after the events. To identify these differences it is crucial to understand linkages between physical and socio-economic vulnerability. After the Northridge earthquake, the recovery process of physical structure was quicker than it was in Kobe. As both cities are situated in developed and pioneering countries, this difference cannot be explained by economic power. First, the impact of Kobe earthquake was greater than the impact of Northridge earthquake. Second, it is likely that the different recovery processes depend on the different institutional systems of both countries. These three examples, and many others, are evidence of how infrastructural vulnerability, when considering accessibility, affects every level of socio-economic structure of communities.

Another crucial infrastructural system is the electricity network which is very important to business continuity on one hand and public safety (i.e. traffic signals, street lights, safety alarms etc.) on the other hand. The Northridge earthquake hit business activities and production of high-tech industries in the Los Angeles Basin (Suarez-Villa and Walrod, 1999). In her case study Tierney (1997) found out that more than 50% of businesses were not able to continue to run their activities because of black-out. In another survey conducted by Tierney and Dahlhamer (1998), respondents declared that in order to continue their business electricity is very important (82,1%) and without having this service they could operate their business with a median value of 0 (zero) hours.

Even though natural gas has a history for more than a century, the domestic usage has expanded only in the last decades of the 20<sup>th</sup> century. Today, natural gas is widely used in many countries for several purposes. The first major failure of a natural gas system occurred during Kobe earthquake in 1995. Since Osaka Gas Company was too late and slow in shutting down the valves, fires caused by ignition of natural gas from the breaks of pipes widened and caused further destruction and loss of lives in Kobe.

Communication systems changed not only personal habits to communicate but also the way to act during an emergency. In fact they play a key role during an earthquake and in the immediate aftermath. In the early 20<sup>th</sup> century, transferring information on what had happened in the disaster area, as illustrated by Messina (1908) and Avezzano (1915) earthquakes, was difficult, also because of the condition of communication networks. Nowadays, communication networks are more sophisticated

and they permit to transfer information on the severity of damage related to disasters. But even if the standards of the communication systems were to be further improved, they are not immune to damages. As described by Chang and Nojima (1998) for the Kobe earthquake, the breaking down of electric lines caused the failure of the Satellite Communication Network, installed at the Prefecture of Hyogo, civil protection organization for the city of Kobe. In the Sichuan earthquake (China, 2008), the mountainous areas in northern Sichuan were completely isolated and the Chinese government had to send paratroopers to get information about the situation. Moreover, communication networks tend to be highly congested after an earthquake, both because of damage to facilities and high usage. In Italy, the solution adopted in case of local congestion, linked to several issues, is the call gaping. This means that the system assures that every call that exceeds the net capacity will be locked, and that the system will ask the customers to call again later. The system which has been used in California, enables priority access to telephone lines for critical facilities such as hospitals and firemen (Menoni, 2001). Such organizational mitigation measures can ease the future post-disaster management.

### ***Stage III: Evaluation***

Table 4 gives a general summary from past earthquakes on how physical failures affected and may affect socio-economic structure. Failures in infrastructures have direct impacts on human live and safety at individual level, and at a higher level the reconstruction process charges the national budget. After disastrous events, poorer countries may have to loan from other countries for recovery purposes. Depending on both, intensity and location of the event, collateral hazards (most evident for na-techs) may occur. As a chain reaction toxic materials are released into air, water and soil and indirectly affect human health and the quality of life in the medium or long term. Functional infrastructural failures, on the other hand, refer short and medium term after disasters. The most critical issue following disasters is to get accurate information about spatial distribution of damages in order to organize search and rescue activities. Thus, a working communication network and accessibility is vital in managing the situation. Business activities are mostly vulnerable to blackouts and transportation system failures that hinder production and impede the delivery of goods and equipment. When looking at previous natural disasters (i.e. Northridge earthquake, Kobe earthquake and Kocaeli earthquake), the economic losses in businesses caused by such failures are called 'indirect losses' which are not easy to estimate or to calculate because of the complex structure formed by linkages among business activities.

Blaikie *et al.* (1994) define the progression of vulnerability with certain indicators related to the socio-economic environment at community scale, as previously mentioned. In Table 5, relevant socio-economic indicators which are likely to affect infrastructural vulnerability are listed. Structural vulnerability depends on fiscal asset, awareness and willingness of the community. Even though a community has a good assessment of the situation, it may not be able to afford taking relevant measures. Even if a community has fiscal power, there may be other priorities besides mitigation of hazards with long return periods.

At the individual scale, functional vulnerability of infrastructural systems turns out to be important. In several past earthquakes, communication and transportation lines were blocked because of overloading. As part of family disaster preparedness programs, specialists suggest people to use telephones only for emergencies and not to use their cars in order to avoid traffic congestion. For instance, after the Kocaeli earthquake, several people either drove through the area or made calls several times as they were not officially informed well about their relatives.

Socio Economic Infrastructure	Individual		Community	
	Individual		Community	
Structural	<ul style="list-style-type: none"> <li>Low accessibility or no accessibility to services.</li> <li>Collateral hazards</li> </ul>		<ul style="list-style-type: none"> <li>Medium to long term economic impacts</li> <li>Reinstatement costs</li> <li>Ecological impacts</li> <li>Impacts on human health</li> </ul>	
Functional	<ul style="list-style-type: none"> <li>Limited information and limited services</li> <li>Misleading operational services (e.i. search and rescue)</li> </ul>		<ul style="list-style-type: none"> <li>Decrease in administrative services</li> <li>Decrease in production and interruption of business activities</li> <li>Problems in delivering goods</li> </ul>	

Table 2: Effects of Infrastructural Failures on Socio-Economic Structure

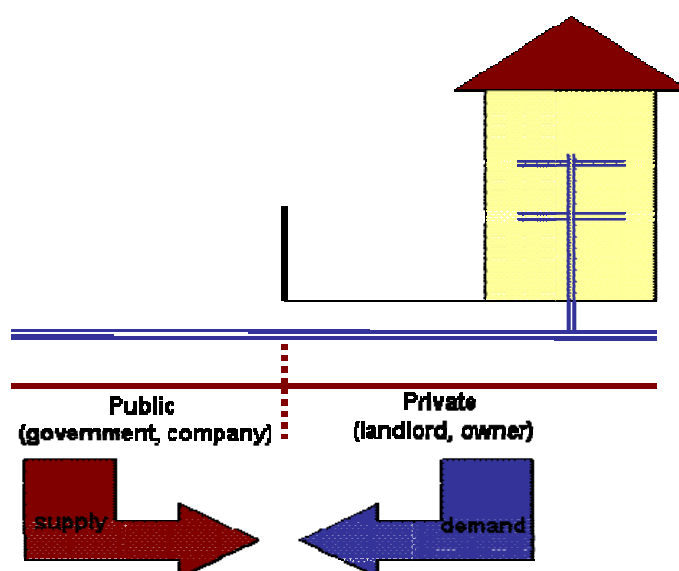
Table 3: Effects of Socio-Economic Structure on Infra-structural System

Population growth and increasing population density in already built-up areas are important indicators to allocate resources. In many metropolitan cities in the world, the growth has been followed by agglomerations and cities expanded in an un-manageable way. In some cases, such as Turkey, the planning process lags behind the acceleration of urbanism. In many big cities regeneration and development plans are only partially applied. These kind of patchwork infrastructural investments are usually not analyzed in a systematic approach that would enable a better understanding of the entire framework. Nevertheless, planning is used as a tool for economic development of certain places and regions. During the decision process on this type of investments the efficiency and cost-benefit relations have a strong impact on the final decision. However, as experienced in Kocaeli earthquake, when choosing a location not only economic considerations should play a role but natural hazards should also be taken into account in order to avoid disasters. In line with what has been said above, a disaster prone area should be used as disincentive and/or discouragement to new development, both in normal period and in the aftermath (Pelling *et al.*, 2002). On the other hand, in less developed economies, decision makers may always prefer a disaster prone location to no location at all to further economic development. To clarify, as affirmed by Coburn (1995), hazards are known to have direct effects on land price and so they possibly change the character of urban areas in the long term. Information on hazards such as micro-zoning maps can decrease the land value and its attraction, so "an educated real estate market can make decisions that protect itself against hazards" (Coburn, 1995). Increasing population density, as well, has a crucial impact on the infrastructural system by the means of carrying capacity of the system. In other words, systems running with over-capacity in 'peace' periods are more vulnerable during and after disasters.

Risk transfer and the insurance system are key components of risk management. From a structural perspective this system is not directly related with infrastructural vulnerability. However, in the context of functionality, insurance systems and substitutes of infrastructural systems play important roles for the continuity of business activities. Moreover, the insurance system could be a way to increase the quality of preventive structures by ensuring the implementation of and adherence to safety regulations. In the Memphis and Shelby case studies by Tierney and Dahlhamer (1998), it has been noted that larger businesses pay more attention to insurance and preparedness activities than small businesses do. Small businesses are more vulnerable because they have limited financial and personnel resources. On the other hand, ownership is a crucial indicator to understand human behaviours. Homeowners and business owners are "better prepared than renters because they see themselves as having more to lose in the event of a disaster" (Tierney and Dahlhamer, 1998).

The case studies and examples given to discuss impacts of natural disasters on infrastructural system and consequently on socio-economic structure of affected regions show that there are strong linkages between systems which can be called causal. In many events, socio-economic impacts and failure are evaluated as consequences of physical environmental deficits. However, when looking from another perspective, the physical environment is shaped according to a community's demand and its financial capacity. Decisions taken by city managers (elected by citizens) influence urban and regional conditions in a positive or negative way. This mutual relationship sometimes leaves scientific facts on natural hazards with long return periods aside (i.e. the probability of a natural hazard in the next 100 years). Considering short life expectancy in politics and little longer human life expectancy, it is obvious that lay people and scientists/professionals do not perceive phenomena in the same way. Therefore, reinforcement, rehabilitation or reconstruction of the physical environment is not on the agenda unless a massive shock occurs.

Corruption is strongly connected to the physical environment. It is mainly caused by a wide-ranging economy, which includes construction of national infrastructures and the construction of network systems for individual homes. In fact, corruption is found at every phase in construction projects: during planning and design, in the awarding of contracts, during the construction process, and during the operation and maintenance of projects after construction is finished (Escaleras *et al.*, 2007). As demonstrated by the Marmara earthquakes in Turkey, the problem was not due to a lacking understanding of seismically sensitive engineering or appropriate construction standards, but rather due to unscrupulous and often inappropriately trained contractors who ignored the country's building codes with the consent of government inspectors (Lewis, 2005; Bohlen, 1999; Kinzer, 1999). Jorge Diaz Padilla, president of the International Federation of Consulting Engineers (FIDIC), affirmed that most consulting firms are doing their best to define and implement anti-corruption policies. Such approaches tend to be piecemeal, however. What is missing is an integrity baseline that can connect and transform isolated acts of integrity assurance (Stansbury, 2005). In the case of Turkey, the collapse of several buildings that should have officially been built in accordance with the 1975 building code led to the examination of the inherent deficiency of the construction system. Additionally, building consultancy has been integrated in the construction process immediately after the earthquakes occurred in 1999.

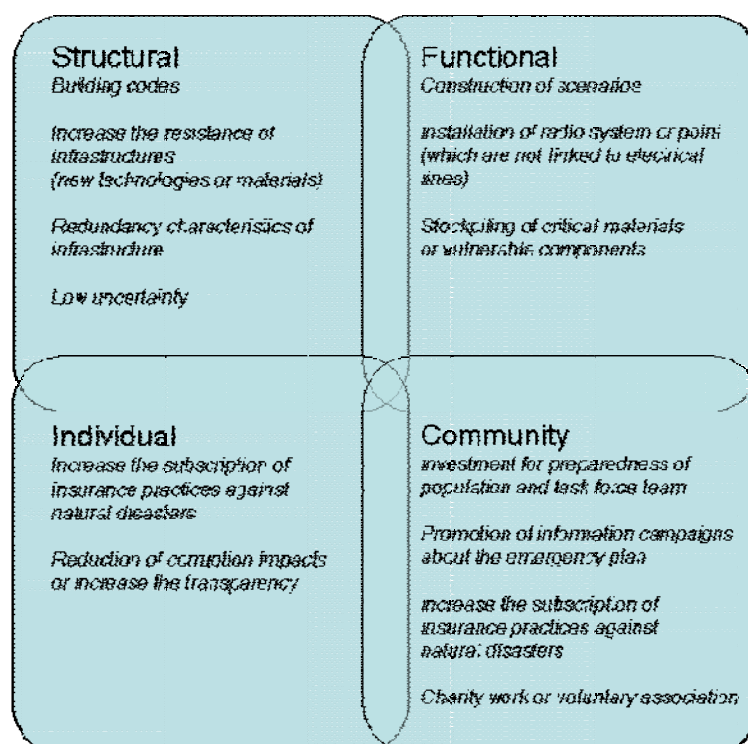


### Relations among Factors

As seen in Table 5, the cell of intersection on 'individual to structural' remains empty. Considering an infrastructural system which is a huge network covering settlements, an individual cannot have direct impacts on it. However, when these systems (or services) reach the end users, a modification by contractor, constructor or owner is always possible. In the Figure 6, the limits of individual interven-

tions in the infrastructural system are shown as a sketch of a building plot. In this demand and supply circle, despite there are regulations on how to connect these services for domestic uses, after the first installation, the initiative belongs to users. In daily life, there are numerous examples for domestic and business accidents which are caused by poor maintenance and wrong modifications. Especially in developing and less developed countries, low qualified professionals, scarcity of financial resources and lack of awareness lead to insufficient safety standards.

To sum up then, it is worth to note once more that the physical environment is a product of the socio-economic environment. In the previous paragraphs, this relationship was described using recent case studies from different countries with different socio-economic levels. Defining vulnerability enables us on the one hand to get necessary measures for mitigation and on the other hand to define resilience parameters. In Figure 7, a brief evaluation on resilience regarding socio-economic structure is given. The sub-components of each box are strongly connected to each other in a network. From a structural perspective, resiliency depends on the implementation of building codes, redundancy and engineering approaches to improve new technologies and decrease uncertainties. Functional resilience is related to how people receive necessary services and the infrastructural organization supporting the system. Individuals on the other hand have their own responsibilities in reducing their risks in their business places and living places. Moreover, they can play an important role in improving the functioning of construction systems. Finally, the community is essential to increase resilience and to decrease vulnerability of settlements. Awareness, risk perception and acceptable risk level of each community depend on how much information they can get. Therefore, dissemination activities on disaster mitigation are very important to decrease socio-economic vulnerability that may have direct and/or indirect effects on other components of vulnerability.



## 2.2 Earthquakes, case of three Islands in Aegean Sea<sup>4</sup>

Taking an insular setting as a distinct risk environment, an effort is made to identify core issues relating physical vulnerability to social and economic features of such a context and to social and economic earthquake vulnerability. Three islands from the Aegean Archipelagos in Greece—Chios, Kos and Nissyros— serve as case study areas (Figure A.1 in Appendix II.A). Each island has a different

<sup>4</sup> Contribution by POLIMI

profile as regards its administrative level, demographic composition, human geography, building stock and settlement structure, accessibility and transport conditions as well as emergency institutions (Table A.1 in Appendix II.A).

### ***Stage I: Initiation***

This contribution is based on previous research attempting to develop a methodology to pinpoint central issues related to earthquake risk and disaster protection policy, adjusted to the specificities of the insular setting (Delladetsima *et al.*, 2006).

### ***Factors and Vulnerabilities***

Based on the aforementioned research project an attempt was made to connect key social and economic features of the case study areas with physical and social vulnerability, both seen as susceptibility to loss and capacity to recover (Tables B.1 and B.2 in Appendix II.B).

The impact of these social and economic factors on earthquake vulnerability can be straight forward, but in many cases is indirect and depends also on a range of other factors as well as on the policies applied before and after the disaster. All in all, the possible impact of the social and economic factors on physical and social vulnerability can be disputed. It is case-specific, depending on context, time and territory. However, some relationships seem to hold more generally as demonstrated by previous experiences and related literature. These are put forward in the following section that summarizes the situation as presented in Table A.1 and Figure A.1 in Appendix II.A.

### ***Stage II: Implementation***

Aged population in an area is connected with less dynamism and less potential for change, lower building stock renewal rates and less building maintenance, thus higher physical vulnerability. What is more, older people are more vulnerable in case of an earthquake because of mobility difficulties and health fragility. Elder households are more reluctant to use financial support offered (loans, subsidy, and aid) in order to retrofit or repair/reinforce the damaged buildings, tend to stay longer to temporary housing and have less willingness to move on after the disaster. Based on lessons learnt from the 1995 Kozani-Grevena earthquake, pre- and post earthquake interventions to deal with physical vulnerability are more effective when they do not put the associated economic and managerial burden on the elder households (Mousteraki *et al.*, 2009).

### ***Public Intervention***

Acute income inequalities in the case study areas are connected mainly with on the one hand structural features of agriculture, low pensions for farmers as well as incoming legal and illegal migration and on the other hand fast economic growth through tourism. Low-income households spend less on seismic safety as they are forced to cope with everyday difficulties and tend to use (buy or rent) low market housing that can be older or of lower quality (possibly more vulnerable) or poorly located. Seismic retrofitting or repair/ reinforcement of earthquake damaged buildings normally results in an increase of housing prices and pushes low income households out of upgraded buildings and areas to old and vulnerable building stock. Research concerning temporary housing after earthquakes demonstrated that low-income households and renters tended to stay longer in temporary housing and that income loss because of the disaster affected their capacity to recover and rehabilitate permanent building stock (Dandoulaki, 1995).

Seasonal variation of the population associates with a temporal use of the building stock; this results in less exposure but also in less concern for seismic interventions and building maintenance. Population increase in the summer relates mainly, although not exclusively, to tourism. Tourism presses for more construction and it even guides development towards unsafe soil such as the seaside and steep slopes with a view. Tourism also leads to a reuse of old buildings stock, especially historic buildings and settlements. However, seismic safety is marginal in the institutional framework for tourism and a low priority for the tourist sector that is focused on promoting the positive sides of the place. As a rule, tourists have little awareness and low risk perception as regards earthquakes thus seismic safety is not marketable. All this affects physical vulnerability but the relationships are not straightfor-

ward and need to be examined case by case. Moreover, dependency on tourism makes the economy vulnerable in case of a disaster, or even in case of mere seismic activity, and can drastically limit the available means and resources for recovery. Such an activity raises the risk awareness of tourists and leads them to choose another holiday destination, possibly reducing the sector's income for several years.

The issue of vulnerability of historic buildings and settlements is a significant and multifold one. Interventions normally target upgrading the seismic safety of buildings according to the National Seismic Safety Code. Nonetheless the National Code does not always apply to the vast variety of local construction systems each posing a different set of problems as regards maintaining a balance between preservation and seismic upgrading (Dandoulaki and Delladetsima, 2003). To successfully intervene at the building level, policies must employ research, guidelines, codes, technical support, education and training, incentives and rising awareness in order to respond to the specificities of local construction systems. More challenging, still, is the task of putting policies dealing with physical vulnerability on the level of settlements into practice. This is so as it has to be done in a comprehensive manner, that takes preservation, seismic safety and development into account.

Building stock renewal rate seems a crucial factor for the selection of interventions to deal with physical vulnerability. While interventions targeting seismic safety of new buildings are well established, interventions on existing buildings are far more challenging posing technical, legal, economic, psychological, social, urban planning, managerial and administrative difficulties. Table 6 depicts the spectrum of earthquake interventions for areas of high and low building stock renewal rate.

Earthquakes

Interventions	High renewal rate of building stock	Low renewal rate of building stock
<b>Physical structures</b>		
<b>Regulation</b>		
Planning (land use, urban)		
Building codes		
Building permissions		
Building inspections		
Other regulation		
<b>Standardization and quality control</b>		
<b>Insurance / Risk sharing</b>		
<b>Economic incentives</b>		
<b>Private initiatives</b> (BCP, Corporate Social Responsibility etc.)		
<b>Real estate, market and marketing</b>		
<b>Civil society initiatives</b>		
<b>Partnerships and networking</b>		
<b>Education, information &amp; awareness</b>		
<b>Prevention and safety culture</b>		
<b>Emergency planning and management</b>		
<b>R and D</b>		

	<b>Indispensable</b>
	<b>Very important</b>
	<b>Important</b>
	<b>Useful</b>
	<b>Irrelevant</b>

Table 4: Interventions to Deal with Physical Seismic Vulnerability

Uneven distribution of population and regional disparities are apparent on some islands. These associate with different rates of renewal of the building stock, uneven availability of means and resources for pre- and post-earthquake interventions, uneven distribution of infrastructure, facilities and services. In many cases physical vulnerability is high in areas of low exposure such as fading small settlements and low in areas of high population and building densities. This challenges decision-making as regards the geographical prioritization of interventions and the reconstruction strategy especially with remote and fading areas having little access to decision making.

Isolation of the islands and the accessibility conditions connect with the situation in the construction sector in terms of cost of materials and construction, regulation enforcement and know-how. Although it is difficult to identify a straightforward relationship between physical vulnerability and accessibility conditions, interventions should respond to these difficulties. For instance lower transport costs for construction materials may be required in order to promote seismic safety especially on small islands.

Connected to the isolation of islands are the administrative structure and decision-making procedures. Access to decision-making varies for each island depending on its administrative level. A key issue for some islands is that pre- and post-earthquake interventions to deal with physical vulnerability take place locally using mainly local potential and resources while decision-making takes places elsewhere and the competent authorities are based on another island.

### ***Stage III: Evaluation***

#### ***Key Factors***

Summing up, the case study supports the idea that physical vulnerability is not primarily or even mainly a technical and engineering problem but that it is correlated with social and economic factors. Factors of social vulnerability, in the broader sense of the term, such as ageing population and income inequalities, have an impact on physical seismic vulnerability as well as on social seismic vulnerability each seen as susceptibility to loss and capacity to recover. Relationships between physical, social and economic vulnerability on the one and hazards and loss on the other side seem even more difficult to conceive. It should be stated though that the aforementioned relationships may be debatable if examined in another context and that generalizations can be misleading. Still, considering the social and economic profile of an area is of outmost importance, if one is to intervene successfully before or after a disaster.

### ***2.3 Earthquakes, case of Abruzzo<sup>5</sup>***

In the night of the 6<sup>th</sup> of April 2009, a 27 seconds earthquake occurred in Abruzzo region, in the central part of Italy. It caused the death of 298 people, the injury of 1600 people (La Repubblica, 6<sup>th</sup> May 2009) and the destruction of the historical centre of L'Aquila, the main city of the region, with some neighborhood completely destroyed (e.g. Onna center).

<sup>5</sup> Contribution by T6

Straight after the earthquake, a comprehensible research for responsibilities arose. This was partly due to the great number of victims that does not match well with the magnitude of the event, which was 5.8 on the Richter scale according to the AMRA centre. Such investigation was focussed on two main aspects, both related to intervention mechanisms:

1. The need or, at least, the opportunity of alerting population, taking into account that significant earth shaking had been occurring in the area since the previous December;
2. The compliance of the building characteristics with seismic building codes.

## ***Stage I: Initiation***

An intense debate followed with respect to the first point. Once again, it has been remarked that it is not possible to predict earthquakes in the understanding of establishing exactly when, where and with which magnitude a given event will occur. At the same time, it has been confirmed that it is possible to make probabilistic forecasts.

In the area concerned, the seismic activity had been recorded for the previous five to six months. One day after the persistence of tremors and the last shake of magnitude 4.0 on the 30<sup>th</sup> of March, the Chief of the Department of Civil Protection<sup>6</sup> convoked a commission devoted to the analysis of major phenomena causing disasters (*Commissione Nazionale per la Prevenzione e Previsione dei Grandi Rischi*). During the meeting, the absence of a direct and unambiguous relationship between the presence of seismic activity and the occurrence of an event of major severity has been highlighted. At the same time, such a possibility should have not been excluded due to the seismicity of the area and the existence of cases in which a shake with a magnitude of more than 5.5 (moderate intensity) was anticipated due to prior seismic activity (Commission minutes published by "L'Espresso").

Nevertheless, in the absence of a deterministic correlation between data, the Commission, responsible for awareness activities, decided to avoid any measure alerting the local population. On the following day, the Mayor of L'Aquila sent a telegram to the Department of Civil Protection, to the Region's governor, to the Prefecture and to the regional councilor of the Civil Protection, asking for the declaration of the 'emergency state'<sup>7</sup>. In detail, he asked for a proper and urgent expenditure for structural interventions as a consequence of the continuous shaking since January (La Repubblica, 18<sup>th</sup> April 2009). Even though this sounds as if serious actions were taken, the Civil Protection received no instructions from the Major.. Referring to an evacuation order, it is plausible that considerations about the socio-economic consequences following a false alarm have had the upper hand here.

In the light of what happened one week later, such decisions appear highly debatable. However, the huge socio-economic consequences caused by false alarms, as well as the negative effects false alarms have on the trust of the population in local authorities, are factors that should not be underestimated. With all the given uncertainties, an evacuation operation apparently was too expensive.

## ***Stage II: Implementation***

Apparently, at institutional level, something didn't work. The tendency to leave aside any possibility of the occurrence of the earthquake broadly prevailed and in some cases a sense of reassurance was spread. In this respect, a lodging house for students (*Casa dello Studente*) provides the most significant example. Located in the centre of L'Aquila city eight students died under rubble (Corriere della Sera, 15<sup>th</sup> April 2009). At this moment, no official sources reporting the declarations of the surviving students can be found. Chronicle news report that, following the 4.0 magnitude tremor of the 30<sup>th</sup> of March, many of the students, were worried about lesions in the structure provoked by the 400

<sup>6</sup> In Italy the coordination of the National Service of Civil Protection is a competence of the Department of Civil Protection that is part of Presidency of Ministers Council.

<sup>7</sup> In this respect, it should be not disregarded the abuse of the "emergency state" requests by municipalities that induce to disguise those cases of real demand.

shakes of the previous months. They thus requested the Technical Service of the building<sup>8</sup> to verify the safety conditions. The inspection took place and ended with a positive assessment as regards the safety of the building. As a consequence, the students were reassured and invited to come back into the building.

The first controls of buildings have highlighted a widespread application of bad constructions practices. This topic opens a wider discussion involving legal aspects and building codes. The new Italian building codes have come in force only on the 30<sup>th</sup> of June 2009; hence, after the disaster. It is not an isolated case in that a disaster occurrence often provides the opportunity to review existing codes and plans (e.g. building codes in housing construction were enforced after the 1999 earthquake by the Turkish government; the approval of the Sarno decree 180/98 by the Italian Government after Sarno mudflows).

Anyway, in Appendix III, the last steps followed by the evolution of Italian building codes with respect to seismic risk are reported. The building codes should have been passed earlier but were delayed. This was due to the overlap of regulatory initiatives taken by two different entities (Civil Protection and the Ministry of Infrastructure) and to a lacking alignment with European measures (Eurocode 8). As shown, the approval and entering into force of seismic building codes has been subjected to an extension procedure since 2003 with an announced further extension to June 2010.

After the Abruzzo earthquake, this last extension comes into the fore as a shameful measure. Nevertheless, it is useful to highlight the reasons for this temporal shift since they shed light on some blind spots existing between socio-economic aspects that affect intervention mechanisms.

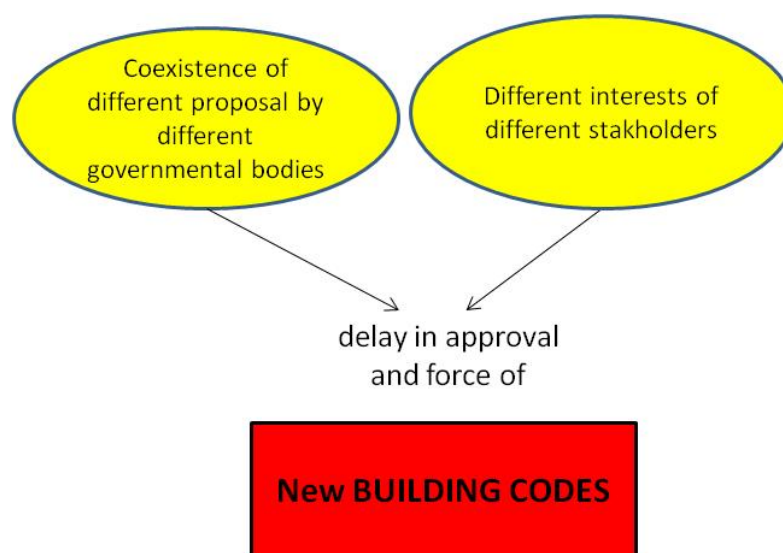
In the case at issue, the official declaration provided by the senator promoting such amendment has referred to the "requests of much time, by engineers and constructors, to comply with new rules" (La Repubblica, 10<sup>th</sup> April, 2009). Eminent representatives<sup>9</sup> of the first category refuse the explanation imputed to them: due to the long extension process, engineers have had enough time to get used to new codes. On the contrary, the influence on institutional decisions by the constructors' pressure appears a more reliable reason. In fact, a rise of prices to build (especially in terms of quantity and quality of used materials requested to satisfy security conditions) should have resulted in the application of the new building codes, according to a no saving economy criterion. This is an interesting demonstration of how 'hidden' socio-economic factors can influence, in a negative manner, some intervention mechanisms, in turn affecting physical vulnerability.

To sum up, the dynamics responsible for the delay in approval and force of NTC 2008 (Italian building codes) can be synthesized as shown in Figure 8.

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<sup>8</sup> The "Casa dello Studente" building was managed by ADSU, an entity for student's right but was a property of Abruzzo Region.

<sup>9</sup> Interview to Eng. Martelli, responsible for the section Prevention natural Risks of ENEA (La Repubblica, 9<sup>th</sup> April, 2009)



*Figure 5: Main Factors Determining Delay in Approval and Coming into Force of New Italian Building Codes*

Nevertheless, there is no doubt that a faster procedure of approval would have had not influence on the damage. In fact, the new building codes shall apply to the construction of new buildings and not to the existing built environment, which, as a consequence, is characterized by a major level of vulnerability in face of an earthquake<sup>10</sup>. Hence, other kinds of initiatives, in terms of retrofit and strengthening solutions, are required to deal with the different categories of buildings built in previous ages, including both masonry and reinforced concrete typologies due to deterioration and aging processes. Such initiatives fall into the category of prevention and mitigation measures, but their implementation is strongly influenced by cultural and economic factors. In the latter respect, the main deterrent is represented by the fact that such initiatives require a large amount of investment without immediate feedback. Nevertheless, with respect to the seismic hazard, the compliance of strategic structures with criteria recognized within the seismic culture, have to be warranted, especially in earthquake prone areas.

In this respect, the Abruzzo earthquake provides other topics of discussion. In fact, many public structures (the Court of law, the Cadastre, the Prison, the Regional Council, the University) have suffered severe structural damages and have partly collapsed. More alarming is the fact that during the emergency phase two structures have missed their strategic role. First, the main hospital of the city (San Salvatore hospital) had to be declared 'unfit for use' a few hours after the earthquake<sup>11</sup>, and consequently needed to be evacuated. Second, the Prefecture (*Palazzo del Governo*), a symbol of L'Aquila city was completely destroyed, although it was restructured in the nineties (La Repubblica, 9<sup>th</sup> April, 2009).

While the strategic importance of a hospital in an emergency phase is rather obvious, the importance of the Prefecture is shortly explained. According to Law 225/92, the Prefect, at the occurrence of a natural disaster becomes the chief of the comprehensive management of the emergency services and has the responsibility of coordinating the emergency activities among the involved institutions (Province, Civil Protection, Municipalities) making use of the prefecture structure. That it was impossible in L'Aquila to follow up on this law can be seen in Figure 9.

<sup>10</sup> As an example, obsolete design principles include the use of plain round bar instead of deformed bars characterized by a better adherence with the concrete or the absence of stirrups inside the joint region in the columns.

<sup>11</sup> The hospital was inaugurated in 2000 and as a consequence, it was supposed to adequately react to an earthquake. Its evacuation has forced the Civil Protection to create a provisional medical service in the square in front of the San Salvatore structure and to move patients to other hospitals, even in other regions.



Figure 6: The Prefecture Structure of L'Aquila City after the Earthquake (source: Civil Protection)

Not surprisingly, the Public Prosecutor's Office (*Procura della Repubblica*) has opened an inquest to ascertain potential penal responsibilities related to the construction of buildings according to the Law 64/74, related to specific rules for building construction in seismic areas. The Public Work Office (*Genio Civile*), where documents related to the design of buildings and to construction companies are stored, has been seized for precautionary reasons in order to verify intentional responsibilities (Corriere della Sera, 18<sup>th</sup> April 2009). Presumably, the first inspections will be made on tenders for contracts won by the 'max *ribasso*' criterion, or in other words, the bigger discount on the initial amount requested to realize the work. Not rarely, such a discount has ranged between 20 and 40% with a clear subsequent difficulty by constructors to respect what the plans, in terms of specifications, established<sup>12</sup>. This fact gains further validity in case of tenders won through corruption practices. Public constructions are highly susceptible to collusion between levels of administration, elected officials, bureaucrats and private contractors with respect to other sectors (Bosher *et al.*, 2008). Anyway, the lacking compliance with the building quality turns into a lack of security, especially when facing an earthquake.

Such considerations extend the role of intervention mechanisms with respect to physical vulnerability. The 'max *ribasso*' criterion is a legal practice, admitted also in the last Italian Public Contracts code (D. Lgs 163/2006). The intrinsic risk is about accepting a saving at the cost of compliance with the plans, and as a consequence compliance with safety conditions.



Figure 7: Need of a Comparison between the "Theoretical" Specifications of Building Codes and Criteria for Awarding a Public Contract as Recognized by Law

Hence, even the procedures by which tenders are assigned have to be included among those intervention mechanisms affecting physical vulnerability. Obviously, it should be sufficient to realize controls and supervision during the period of construction and to pay particular attention to the stage of the final test. Taking an institutional perspective, it is worth mentioning another 'tool' abused by some governments. That is legalizing something that previously was not authorized, namely the building condone. Conversely, illegally constructed dwellings should be demolished both as warning against such practices and for safety reasons. Not surprisingly, illegal buildings are built in risk-prone areas and any kind of inspections are avoided.

<sup>12</sup> As an example, the steel requested for the framework is paid according to the weight. To save money can mean to diminish number of elements, to reduce the diameter of bars or to advocate the expedient of variation within the progress of the work, at the expense of security conditions.

### **Stage III: Evaluation**

To sum up, the Abruzzo earthquake is significant for the ENSURE project because it sheds light on some deficiencies with respect to intervention mechanisms that strongly affect physical vulnerability and provide suggestions to better understand the inter-linkages among different kinds of vulnerabilities. In detail, it has been highlighted how the socio-economic factors have influenced the approval and implementation of Italian building codes and how economic criteria can influence the construction of a building, apart from the quality of the drawings and its accordance with seismic codes. Hence, the existence of building codes particularly advanced in knowledge is a prerequisite for the spread of a seismic culture but it is not sufficient.

With respect to new buildings, further steps are matching the seismic codes with the wider contractual systems, avoiding subcontractor practices, condone and other tools (e.g. max *ribasso*) oriented towards saving at the expense of safety, and to implement a severe control systems during all the construction stages, that is from authorizations to final test.

With respect to the existing built environment, seismic retrofit and strengthening solutions have to be implemented, especially in earthquake prone areas. Delays in seismic adaptation have to be avoided, especially when it comes to strategic buildings (e.g. hospitals, structures of Civil Protection). A lack of these buildings would be a further source of vulnerability in a case of emergency..

Finally, in the Abruzzo earthquake, another intervention mechanism has that it lacks efficiency, namely the information and awareness system. Leaving aside the possibility of an evacuation due to the uncertain boundary conditions surrounding earthquake-forecasting, other preparedness-mechanisms have to be guaranteed,. In fact if 'false alarms' are dangerous, especially in terms of economic consequences, the spread of a sense of 'false safety' can be devastating.

It is worth reporting that at the time of writing this paper (end of June 2009); the Abruzzo region is still shaking.

## **2.4 The French West Indies case**

### **Initiation**

The French overseas territories located in the Western Indies, e.g. Guadeloupe and Martinique, are confronted to various natural hazards: moderate to strong earthquakes (e.g. Martinique, 1999, Les Saintes, 2004, Martinique, 2007), tropical storms and cyclones (Hugo, 1989; Marilyn, 1995; Lenny, 1999; Jeanne, 2004), causing landslides and floods, and finally volcanic activity in Guadeloupe (last eruption of La Soufrière in 1976).

Among the past disasters that hit these territories, the earthquakes of Martinique (Mag. 5.4, June 1999; Mag. 7.4, November, 2007) and 'Les Saintes' (Mag. 6.3, November 2004) provide good cases to illustrate the influence social and economic factors as well as institutional mechanisms have on physical vulnerability. This is so as post-seismic investigations have been carried through and analysed so as to provide local and national authorities with seismic risk prevention and mitigation plans. In addition, the second crisis provides an example of possible interlinkages of different events. The Guadeloupe archipelago was first struck by intensive rainfalls, causing historic floods and numerous landslides on the main Guadeloupe Island (Basse-Terre, Grande-Terre), before the earthquake occurred between Les Saintes and La Dominique only a few days later.

### **Factors**

From these surveys and the one also performed after the eruption of La Soufrière (1976), some main social and economic factors can be identified that may enhance the physical vulnerability in this region, in relation to unfavourable urban and land-use contexts.

An ancestral custom of mutual aid for individual construction (the so-called "*construction en coup de main*") is predominant in these departments: at the origin, it was developed in the colonial and post-slavery context, but it is perpetuated nowadays. It has even transformed into a generalized illegal

work activity, performed by unskilled workers, who neither know about nor follow the basic anti-seismic design rules.

Two main reasons for illegal housing can be identified. First, there is a chronic lack of social housings, which results in an anarchic development of settlements (sometimes lasting for generations now), generally in dangerous zones (e.g. steep and/or unstable slopes, liquefiable zones). Most damages observed in Les Saintes Island and Basse-Terre (Guadeloupe) after the 2004 crisis, were caused by ground instabilities. Second, illegal immigration from the neighbouring countries (Haiti, Dominican Republic) is a crucial problem, especially in Guadeloupe. As a consequence, excessive concentration of precarious settlements is found in large urban areas.

Most buildings have been built either before the date of mandatory application of anti-seismic regulations (1998) or following now controversial design rules (only 27% is correctly designed in Guadeloupe). From the conclusions of the GEMITIS study performed by BRGM in 1999 (GEMITIS, 1999) a large number of buildings, including public buildings useful for crisis management (hospitals, fire stations, schools, etc.), would be destroyed in case of a strong earthquake. According to this report, an earthquake comparable to the 1839 or 1843 ones would possibly cause thousands of deaths, this time period corresponding to a probable return period for such a major event. Furthermore, rescue infrastructures are often located in highly exposed areas (see Figure 11).



*Figure 8: Fire Engines after the Les Saintes Earthquake*

On a general level it can be observed that there is a high population density in highly exposed areas, with an average of 338 inhabitants per km<sup>2</sup> in Martinique and 248 inhabitants per km<sup>2</sup> in Guadeloupe.

On the local level surveys show that the risk perception and awareness of the local population and authorities is good regarding seasonal climatic events, as a consequence of their frequency of occurrence. The only problem may come from the unawareness of tourists (the only recent victim was an unwise tourist during Lenny in 1999). Hence, people are generally well prepared for such recurrent events (e.g. emergency kits kept in safe place in houses). Constructions also reflect this fact: in order to resist tropical storms and avoid consecutive effects, 'self-made' houses are preferably built on high grounds or on pilotis (out of reach of flooding), near slopes or cliffs (protection against strong winds), leading to higher physical vulnerability to earthquakes or landslides (see Figure 12).



Figure 9: Typical Housings in Guadeloupe

In contrast, seismic risk perception can be qualified as rather low, although the region has been struck by strong earthquakes in the past (e.g. Guadeloupe 1843: more than 3000 deaths, main city of Pointe-à-Pitre destroyed; Martinique 1839: at least 300 deaths, maybe around 3000 according to a reviewer, main city of Fort-de-France destroyed), and is still subject to regular tremors. The unawareness is partly due to the infrequency of occurrence of large seismic events, as evidenced by the surveys performed in Guadeloupe after the 2004 earthquake (e.g. CETE, 2005), which showed that a large public was not aware of being in a seismic zone. Respondents did not know what an aftershock was (about 25000 aftershocks occurred for one year after the main shock in November 2004) and thought that scientists knew the earthquake to be imminent.

The main pillars of the local economy are tourism and agriculture (e.g. agribusiness). For the Guadeloupe case, the last part of the road leading to the top of the Soufrière Volcano (located in the Guadeloupe National Park) is cut since 2004 and the main tourist parking is closed. Between 2002 and 2004 (before the crisis), the Region has also financed some large works to arrange and develop the tourist site of the second Carbet Waterfalls, but access is strictly forbidden since the 2004 earthquake, as it is classified as highly dangerous due to potential rockfalls and even cliff collapse. Lower incomes are found in these departments, compared to the other French continental ones, together with higher unemployment rates (around 22% for Martinique and Guadeloupe in 2008)

The communication and transportation networks (roads, etc.) are highly exposed to natural threats. For instance, in Guadeloupe, the only main road (RN1) between Pointe-à-Pitre and Basse-Terre, which is used daily by freight traffic, was totally cut for a few days after the 2004 intense rainfalls due to many landslides. Then, two tracks out of four have remained closed for six months after the November earthquake. Another small road exists in the North but it is difficult for trucks and takes much longer to reach the South end.

On the individual level, most people admit they are not prepared for earthquakes: 81% of investigated people had taken no specific dispositions before the Les Saintes event, and 85% admit having taken no new dispositions after it. Additionally, superstitions, mysticism (*'It is a magical phenomenon'*), religious (*'It is God's will'*) and fatalist beliefs (*'Nothing can be done against earthquakes'*, *'Part of the island will be engulfed'*, *'Earthquakes come with heat waves'*) are prevailing in the society, leading to passivity and wait-and-see attitudes.

There is also a predominant apology of self-resourcefulness, which may be a factor of resilience, but may also enhance physical vulnerability, as people do not understand the need to prepare. People either feel worried or suspicious about the official information: for instance, to the question "Do you think all the truth is said about the seismic threat?", only 22% of people answered "Yes" (social study after the Martinique earthquake, 1999). This might be because the media or supports used to communicate on the subject are not adapted to the social context. The surveys have shown that messages are not understood, because people find them too abstract or general, and not pragmatic enough. Moreover, the general public by far prefers television as information medium to radio and newspapers.

A last influencing factor identified here is the role of the insurance sector. Half of the housing in Guadeloupe and only 1% in Terre-de-Haut and Les Saintes Island are insured. This is so due to an

underestimation of potential consequences, insurance costs, suspicion and other priorities. Furthermore, Maaf insurance company broke many contracts after the Les Saintes crisis in 2004 and afterwards refused to take on new contracts arguing that the risk was too high.

## ***Implementation***

In Metropolitan France, the technical and legal acknowledgement of natural risks dates from 1982 with the allowance of financial compensations to victims from natural catastrophes, and from 1984 for the introduction of Risk Exposition Plans (called P.E.R in France) for various hazards (essentially earthquakes, landslides, floods). These Plans, established at municipality or intermunicipal scales, aimed at zoning areas exposed to predictable natural hazards. The Caribbean region, and more specifically Martinique and Guadeloupe departments, have been historically strongly exposed to various natural threats (seismic, cyclonic, volcanic, tsunami) and regarding seismic risks, both departments rank at the maximum risk level within the national classification (official decree in 1999); a level comparable to the one in Japan or California. Nevertheless, the French institutional recognition dates only from 1990, after the most destructive cyclone (Hugo) has struck Guadeloupe in November 1989.

Since 1995, P.E.R.s have been replaced by Risk Prevention Plans (called P.P.R. in France), with larger objectives: to ensure security for individuals, reduce if possible the physical vulnerability of exposed elements and reduce the costs of damages to the assets. The regulation is strict: new building is forbidden in zones classified with a high hazard level, if security of individuals is at stake. For existing buildings and properties located in dangerous areas, protection and safety measures can be made mandatory to private owners within five years at most. On the French West Indies, the first P.P.R. has been adopted in one municipality of Martinique (Prêcheur) only in 1999 (Leone, 2007).

In the framework of the International Decade for Prevention to Natural Catastrophes launched by the UNO (1990-1999), pilot studies have been initiated to assess the seismic physical vulnerability and to elaborate risk scenarios in the French West Indies (GEMITIS project in 1999). In addition, local strategies and initiatives for seismic risk prevention are implemented and tested since the Les Saintes crisis in 2004 in Martinique and Guadeloupe, within the framework of the National Seismic Plan (2005-2010) for the benefit of a large public (civil society, schools, workers, elected representatives, institutions, etc.). This shall reinforce or supplement the official efforts of the French State aiming at a greater implication of the local population and actors to their information and security concerning earthquakes (Mavoungou and Balandier, 2008). Within the National Seismic Plan framework, in 2006 Guadeloupe has launched a large program to assess the physical vulnerability of schools.

Moreover, an economic incentive is proposed by the Regional Council of Martinique since 2002 (it does not exist in Guadeloupe): an 'anti-seismic building prime' is given to private owners if they have their house built or controlled by specialists (architect, technical design or control office with required anti-seismic certifications). In 2006, this regional prime has been increased to 9000 € to cover most of the costs related to anti-seismic design/control, but it is still barely used, as conditions to obtain it are sometimes seen as too restrictive by some parts of the population (Mavoungou and Balandier, 2008).

## ***Evaluation***

The lack of regulation and control which has prevailed up to 1999 is greatly responsible for the anarchic development of housings in dangerous areas. Moreover, even when appropriate regulations exist, there is a general tendency among local representatives to be quite permissive essentially for electoral considerations. Another reason for this development is the crucial lack of building specialists adequately trained to anti-seismic design rules in Guadeloupe and Martinique, leading to design and execution mistakes (e.g. bad reinforcement, use of improper materials).

This can be explained by the fact that schools, universities and building professional courses of study are identical in these departments as in the Metropolitan ones, where there is no specific training on that matter. Martinique and Guadeloupe departments have recently begun to imply themselves in a true preventive dynamic, aiming at reducing the human and technical vulnerability to seismic risks: the 1999 earthquake in Martinique and later, the 2004 crisis in Guadeloupe can be considered as

catalysers for this collective awareness. In 2000, thanks to the initiative of some local representatives, associations, architects and engineers, a specific class has been created in Martinique, followed by trainings for various building workers categories. In Guadeloupe, development of such trainings has begun only in 2006.

In fact, although institutional efforts have started for a few decades now and amplified since the recent crises (essentially Les Saintes, 2004), resulting in the launching of a National Seismic Plan in 2005 (to end in 2010) by the French Ministry of Ecology, success is not as expected, due to a number of factors which appear in the post-seismic surveys (e.g. see Cartier and Colbeau-Justin, 2007; de Vanssay, 2007).

However, it can be said that in general the indirect aims are achieved: to make people aware and incite designers to follow the necessary trainings. Another unforeseen positive consequence of this policy is that the Regional Council is considered as a good resource partner for people willing to prepare to a catastrophic event or prevent it: medical workers, district associations, schools or any citizen come there to get technical or legal information, etc. Moreover, projects for cooperation with other Caribbean countries are under way to transfer competences of the specialists from Martinique.

Finally, regarding information dissemination and awareness mechanisms, the objectives and means of communication towards aware/unaware audiences have been elaborated by the local state representatives (e.g. the Regional Direction of Environment) thanks to the outcomes of post-seismic surveys, in order to fit the local social features and concerns. The main initiatives consist in specific awareness campaigns lasting over a few days or a week, such as the 'Sismik' and 'Réplik' days or weeks organized annually in Guadeloupe and Martinique respectively (e.g. see Intermedia Dom Immeuble, 2008). On these occasions information on various media are provided, depending on the target public: slogans, recurrent TV spots/clips and radio spots (method successful for cyclones), debates, videos, posters (e.g. on bus shelters), games (TV, board), memo-cards, magnets, conferences, earthquake simulator, etc. A national emergency exercise (the RICHTER National Exercise, 2008), was also organized in Guadeloupe at the end of the 2008 'Sismik' week.

## 3. Floods

### *3.1 Floods, Case of the Netherlands<sup>13</sup>*

In 1995, after 40 years of no major flooding, the provinces of Gelderland and Limburg (the Netherlands) had to deal with two flooding rivers, the Rhine and Meuse. The main characteristic of those floods was the smooth evacuation of 250.000 people. This case will show how this operation could run so smoothly and what the role of the decision-makers was. The case is an example of the policy cycle of our three stages. The Initiation stage of the 1995 Flood is actually the Evaluation Stage of the 1953 Flood.

#### *Stage I: Initiation*

After the large flooding in Zeeland in 1953, the emergency system had to be adapted. In 1953, there were no strong emergency plans available. Because of a hierarchy effect – officials turned to their hierarchical chief to take the decision – there was a lack of organised activities when the flood came. Due to the weather conditions, there was no communication possible between the different emergency organisations and they were not prepared and trained. During the hazard, competence conflicts and coordination problems occurred (Koppenjan and Hagelstein, 1995).

#### *Factors*

In the 1953 flood there was a lack of awareness at decision-making level. Organisations were not prepared and trained properly. No one knew at what level decisions should be taken. Competences were not clear and communication was not possible during the hazard. The role of management

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<sup>13</sup> Contribution by ITC

proves to be highly important during a hazard. Management interventions can reduce average damage by a factor 3 to 16. The effect of management can even be stronger than the effect of climate change (Tol *et al.*, 2003).

In 1995, local decision-makers managed the emergency. Regional Coordination Centers worked fast and effective. They spread information concerning the emergency to the media. Also, emergency plans were available (Koppenjan and Hagelstein, 1995).

### ***Vulnerabilities***

In 1953, physical vulnerability was increased due to dike breaks, high level of groundwater, damaged houses and infrastructure. In 1995, heavy rainfall and melting water that raised water levels in the rivers Meuse and Rhine increased the physical vulnerability (NEDIES, id 167). In the future, vulnerability of protected areas will increase more due to population growth (social factor) and economic development (economic factor) (Klijn *et al.*, 2004).

In 1995, the social vulnerability was influenced by unpreparedness of people. The process of flooding did not occur for a long time before 1995; people were not prepared and built houses in river winter beddings, which are vulnerable areas (NEDIES, id 167).

Economic vulnerability was influenced by damaged economy and material losses in 1953. In 1995 the economic loss was high, mostly due to the evacuation costs like transportation and absence of economic activities during the evacuation.

## ***Stage II: Implementation***

Almost 250.000 people got evacuated from the flooding areas in 1995 in Gelderland. The success of the Dutch evacuation was a mix of good policy and good luck (Koppenjan and Hagelstein, 1995).

### ***Public Intervention***

During the 90s, Regional Coordination Teams were set up. On national level, a National Water Board ('Rijkswaterstaat') was established. New regulations of The Hague on flood management, spatial planning and nature conservation came into practice. New initiatives came also from Brussels, on international flood management, water management and nature conservation (Tol *et al.*, 2003).

In the beginning of the nineties, the perspective on water management changed. The process of democratization took place; more stakeholders got involved. Water management was no longer only focused on the defence against the water; the focus was shifted towards "living" with water (Tol *et al.*, 2003). The Delta Plan for Large Rivers: *"a policy aimed at minimizing the potential damage, raising public awareness, improving international early-warning systems, and developing measures to increase flood safety levels, preferably in an international context"* was formulated (Van Stokkom *et al.*, 2005). The concept of living with water led to the creation of emergency flooding areas. When a flooding of a river was expected, the Dutch drained the water off to special flooding areas.

Policy shifted from the separation of land and water, towards a policy of accepting water inflow. Climate change increases the likelihood of floods and due to the increasing population and economic growth, the economic and social vulnerability to flood increases. In 2001, the Dutch government formed a new approach with the following guidelines: 1) Increase the awareness of citizens concerning the problems associated with water. The communication of the government on risks has to be improved, in order to get citizens involved in risk reduction. 2) The need for a Three-step-strategy. The three steps are retaining, storing and draining, and are based on anticipation to water and allocating more space to water. 3) Project More Room for the River; more space for water storage is needed. 4) Spatial planning; legislation should prevent the presence of housing and buildings in the floodplains. 5) The new water management approaches require more coordination and distribution of knowledge and education. 6) Clear distribution of responsibilities; different institutions are responsible for safety; an administrative agreement should be made to help division and cooperation between these institutions. 7) Investments; more investments should be made in order to support the developments. 8) International cooperation; intensify the international cooperation on flood protection and regional water management systems (Van Stokkom *et al.*, 2005).

### ***Private Intervention***

Before and during the evacuation of Gelderland, the media played an important informing role. It was the main link between citizens and decision-makers. Through the media, citizens became aware of the emergency and the actions taken by the government.

### ***Civil Society Intervention***

Following the news in the media, citizens did not wait for the official signal to evacuate. People saw on television that the floods came closer and that neighbour villages evacuated. Self-awareness of citizens led to this spontaneous self-evacuation.

## ***Stage III: Evaluation***

### ***Key factors***

The key factor in this case is the self-awareness of decision-makers (creating the policy) and of citizens (self-evacuation). The Netherlands have learned the following after the Rhine evacuation: 1) only clear and uniform information can pursue people to see the necessity of an evacuation. Communication between media and regional coordination centers are therefore important. 2) Preparations are important; the local governments have an important role in this process. 3) Individuals are hard to pursue to leave their homes. Therefore it is most important that people see the necessity. Otherwise it takes more time and effort to get people willing to evacuate. 4) All people have to be evacuated, hereby it is important to underline security measures to avoid theft and vandalism. People will leave their homes more willingly if they know that it will still be guarded. 5) A large number of people will reach safety zones on their own or organize the evacuation themselves. 6) Handicapped people, people requiring help and children need the most support. 7) The return does not have to be specifically organized (ICBR, 2002).

The success of the 1995 evacuation operation was owed to six elements. First the preparation, a specific emergency plan was formulated in 1993. The planning process was even more important, organizations were aware of the hazard and the possibilities to fight it. Secondly, the presence of a clear and a realistic threat. Images of flooding in the south of the Netherlands and Germany were shown in the media. Third, the time factor, people had time to prepare themselves for an evacuation. The possibility of an evacuation was announced on forehand. Fourth, communication to the citizens was done in three phases. Phase 1 was to prepare the people for a possible evacuation. Phase 2 was an urgent request to evacuate before a given deadline. Phase 3 was an ultimatum. 75% of the people were already evacuated before phase 3. Fifth, the role of the media; the media was used to communicate from the authorities to the citizens. Especially local and regional media played an important role. Last, the independence of people. Not the estimated 25%, but only 5% used public transportation to evacuate. People moved to friends or family outside the risk zone and did not use the crisis centre (Bezuyen *et al.*, 1995).

### ***Blind spots***

After the 1995 floods, political discussions arose concerning technical measures, like strengthening and heightening dikes around the Rhine river and broaden and deepen the Meuse bedding. Again, the importance of not allowing buildings in winter bedding areas was underlined (NEDIES, id 167). Another political discussion concerned the analysis of the decision-making during the hazard. It showed the need of (more) strategic thinking, political courage, individual sacrifice for the public good and the integration of land-use planning and water management (Tol *et al.*, 2003).

## 3.2 Case of Germany<sup>14</sup>

In this section a look is taken at the floods that hit middle-Europe in August 2002. While several regions in Germany as well as in the Czech Republic were involved, the region of Dresden will serve as example.

In mid-August heavy rainfalls, which were rare in terms of intensity, duration and spatial dimension, hit southeast Germany as well as the Czech Republic. As the soil mostly was already saturated due to earlier rainfalls, these heavy ones rapidly led to a flooding of several rivers, among which the Weißeritz and the Elbe were the most important ones for the Dresden region. Even though for each river individually the intensity of the floods was not too rare, the simultaneous occurrence among all rivers is what made this flood especially severe (return period >150 years).

### **Stage I: Initiation**

#### **Factors**

As with all natural hazards, human activities are not the cause of the catastrophe but have severe impacts on the effects such an event may have. In the case of the Dresden region such activities having a negative influence on the region's coping capacity were only initiated a few years before the severe flood occurred. This was so as the last major flood took place in the 1940s and the flood experience of the population thus has faded. In a survey Kreibich and Thieken (2007) found out that among respondents the last flood was on average experienced 28 years ago. Due to the lacking risk awareness, flood adaptation measures were no main priority. When Germany was reunited, eastern-Germany experienced a major pressure towards economic development in order to catch up with 'the West'. To further these objectives, ecological concerns were disregarded. Industrial areas were constructed in the floodplains, riverbeds were only badly maintained and also human settlements were built in the floodplains and in the inundation channels of the city of Dresden (*cf.* Kreibich and Thieken, 2007). These human activities apparently reduced the flood discharge capacity in the municipal area of Dresden (Grünwald, 2003 as cited in DKKV, 2003).

#### **Vulnerabilities**

The main social factor identified in the literature is the one of lacking experience and thus lacking risk awareness (e.g. Kreibich and Thieken, 2007; Thieken *et al.*, 2007). This is influencing all three vulnerability types as outlined above. Social vulnerability is enhanced, as no precautionary measures are taken when knowledge about the possibilities of severe floods is missing. Physical and economic vulnerability is clearly increased through the establishment of buildings in the floodplains.

Another important factor influencing vulnerabilities is the matter of ownership. As Thieken *et al.* (2007: 1026) found out in the region of the Elbe tributaries, where also Dresden is situated, ownership "was important for flood-proofing of the building". As house owners think more about safety and the value of their property as compared to tenants, ownership apparently decreases vulnerability. A link back to awareness can be easily established here as house owners inform themselves about the area in which their house stands and thus are aware of the hazards to which it is subject.

### **Stage II: Implementation**

#### **Public Intervention**

Land use planning mechanisms are important tools for limiting the vulnerabilities of designated areas. If a decision on the prohibition of building projects is taken in a given region, this prohibition is the most effective means of avoiding an increase of physical and economic vulnerabilities. In the case of Dresden, the local authority is in the key position concerning decisions on land utilization. The authority enjoys a great discretion in this regard, as nation-wide binding frameworks concerning flood protection are missing. Formally, there have been regulations in place in Saxony, according to

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<sup>14</sup> Contribution by ITC

which some of the destroyed buildings should have not been built in the first place. But as they exist, there is apparently enough leeway to maneuver around disliked provisions (cf. DKKV, 2003).

A further public instrument is the one of technical flood precautions through retention ponds, polders, dams etc. Generally, the existing technical flood protection mechanisms were fully available in Saxony. This means that 121 million m<sup>3</sup> of water could be detained in dams and retention ponds. Nonetheless, this capacity was not sufficient for the events of 2002, hinting again to the exceptional severity of the flood. But overall, the technical instruments contributed positively to the situation by ensuring drinking water provision and allowing for extra time before the peak water level was reached.

Money was made available quickly during the events of 2002. The federal government of Germany made 7,1 billion euro available through the emergency fund for reconstruction (*Sonderfond Aufbauhilfe*). And also the European level was involved in providing monetary aid. Through the structural and solidarity funds of the EU, further 444 million euro were available for a rapid recovery.

### ***Private Intervention***

According to the DKKV, private precautionary measures are comprised of building precaution, behavioral precaution and insurance-supported risk precaution (DKKV, 2003: 124).

In Germany private households and industry have the possibility to insure themselves against flood damage and other natural hazards in line with the so-called extended natural hazard insurance. Insurance coverage was indeed quite high in the Dresden area, compared to overall German coverage. This has foremost historical reasons as the GDR offered its citizens an insurance scheme which included flood damage, which was then also included in successor products. It is thus estimated that in Saxony and Saxony-Anhalt about 50% of the affected households were insured (DKKV, 2003).

A clear lack of behavioral precaution prior to the flood is identifiable. Inhabitants did not necessarily know whether their neighborhood will be flooded and if so, when. Due to this lack of information, people did not know how to respond to the situation. Furthermore a basic knowledge about how to behave in such emergency situations was lacking. This situation is again evidencing the lacking risk awareness of both the general public as well as the public authorities that would have been responsible for the dissemination of appropriate information.

The usage of precautionary measures in building adaptation is a purely voluntary undertaking. Once a building permit is granted, it is up to the owners to decide if and how to protect the building against floods. The DKKV survey showed that there was a rather low willingness of owners to adapt their property in any way to the possibility of flooding. Kreibich and Thieken (2007) state that only 13% of the households had taken building precautionary measures.

### ***Civil Society Intervention***

The 2002 floods were accompanied by huge solidarity through voluntary disaster operation and millions of donations. Relief organizations were able to collect 264 million euro in donations. Non-monetary help was not used to its full potential, as the organizations were logistically overstrained.

## ***Stage III: Evaluation***

### ***Key Factors***

In most of the studies on the impact of the 2002 flood in Dresden, risk awareness emerges as the key factor for other actions. This awareness is clearly dependent upon the experience of citizens with regard to natural hazards. And as a consequence of awareness, preparedness is hypothesized to rise. It can thus be stated, that a flood experience raises the risk awareness, raises the preparedness on public, private and civil societal level.

Before the 2002 flood, 65% of the inquired households in Dresden thought that private precautionary measures were effective. However, only a small minority of households did indeed take such measures, being an indicator of the low risk preparedness of the city. Preparedness did not only play an important role during the event, but also in the aftermath through enabling a fast recovery

(Thieken *et al.*, 2007). So, Kreibich and Thieken (2007) conclude that “much damage can be avoided by the means of private precautionary measures”, the effective usage of which depends on the risk awareness.

### ***Blind Spots***

A clear weakness during the 2002 floods was the dissemination of flood warnings. Thieken *et al.* (2007) found that in the Elbe tributaries 42% of their respondents received no flood warnings at all and were thus not able to react properly. Even if warnings were received, the lead-time was often rather short, precluding effective building protection. Furthermore, the warnings were concerned mostly with evacuation information instead of information about the flood (e.g. maximum water level, time-to-peak water level) or information about damage mitigation. As emergency measures are the more successful the more time and people are available to take action, earlier and more detailed information is called for.

### ***Policy Changes***

Already in September 2002 possible policy changes were negotiated on the federal level. The result was the ‘Five-Point-Program for the improvement of preventive flood protection’. It aims at a better coordination of international, federal and *Länder* programs to reach the common aims of giving more room to the rivers, to establish decentralized flood control measures and to use the management tools offered by spatial planning in order to minimize vulnerabilities. Also the further development of rivers needs to be closely examined in order to ensure an ecologically friendly usage of rivers as transportation routes. Furthermore emergency actions need to be better coordinated and self-help mechanisms shall be improved through the dissemination of information brochures (Bundesregierung, 2006)

In 2005 the Flood Control Act entered into force, which implemented many of the points raised in the above-mentioned plan. The new law puts a clear focus on preventive measures and on the introduction of uniform requirements for all *Länder*. Floodplains and flood-prone areas shall be managed better through risk identification and clear-cut definition of such zones and the incorporation of the possibility that technical flood protection measures fail in this calculation. The law is still not fully implemented. In this regard, Petrow *et al.* (2006: 727) criticize that “there are no regulations to ensure the appropriate implementation of flood precautionary measures”.

On the regional level, the *Land* Saxony adopted the Swiss flood hazard mapping scheme (Petrow *et al.*, 2006). According to this scheme, four zones and different severity scenarios are devised, making the publication of a flood hazard atlas for all major rivers in Saxony possible. Also *Länder* that were not directly affected by the floods in 2002 now intensified their programs concerning flood protection.

## ***3.3 Cases of England and Malaysia<sup>15</sup>***

### ***Stage I: Initiation***

The loss of traditional flood adaptation knowledge causes an increase in physical vulnerability. Increased social vulnerability or increasing welfare culture dependence contribute to this development: cases from Peninsular Malaysia and London.

### ***Vulnerabilities***

Physical vulnerability of buildings to floods is likely to increase when knowledge about largely successful, traditional flood adaptations is lost. This may be either because of major, and usually rapid, social and economic transformation which weakens the social capital of communities, or because other factors lead to a progressive erosion and loss of construction know-how. This is a case of eco-

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<sup>15</sup> Contribution by MDX

conomic and social change impacting negatively on social **vulnerability** which in turn leads to increasing physical **vulnerability** to floods (see Figure 13).

*Figure 10: Traditional Adaptation Knowledge*

Traditional Malay culture and rural ways of life are closely intertwined with the use of flood plains for padi planting, fishing and 'kampung' (i.e. traditional Malay villages). The use of stilts to raise houses is a traditional characteristic of vernacular 'kampung' architecture and almost certainly evolved to allow people to inhabit swampy and unusually wet environments. Other adaptations, such as attuning padi varieties and planting to floods, are also used.



*A 'Stilted' Kampung House, Peninsular Malaysia (from Parker, 2000)*

However, with increasing urban-rural migration and the penetration of kampung life by Malaysia's rapidly modernizing consumer society, and with the Government's social restructuring policies, traditional architectural styles and flood adaptations are gradually being extinguished altering physical vulnerability. At the same time, rural-urban migration, which it is hoped by most migrants will lead to increasing financial resilience, has weakened the strong kinship ties present among kampung communities reducing their social resilience (and increasing social vulnerability) and contributing significantly to the breakdown of the process of inter-generational communication of local knowledge. State policies advocating low-cost terraced housing, institutional influences including housing legislation, and a tendency for the young to build houses without stilts, have combined to make stilt houses much less common particularly in western Peninsular Malaysia (Chan and Parker, 1996). Along with these changes has come increased physical vulnerability to floods, partly because houses are less resilient to floods (though they are more resilient to wind and torrential rainfall) and partly because urbanisation has increased both the magnitude and frequency of flooding. Similar traditional house design features, or finely-attuned designs, have been found in many part of the world including throughout South-East Asia, in The Netherlands, in Venice and in Bangladesh. Such construction techniques are now being 'rediscovered' by European policy-makers wishing to promote 'flood proofing' and 'flood resilience' measures in new building projects. Houses constructed on high pilings which raise them above river levels and tides, have also been found in other traditional cultures, including in the eighteenth century Cajun or Acadian settlements in the coastal swamps of Louisiana, USA (Laska and Wetmore, 2000), but are rarely used in modern constructions. Other traditional house designs, including coastal houses constructed with their gable ends facing the prevailing winds and tides (making them more robust) and with ground floor drains designed to allow the passage of floodwater beneath floors, also existed until recent redevelopment in Chiswell on the Isle of Portland on the south coast of England (Penning-Rowsell and Parker, 1987). In the northern Italian mountain villages researched by De Marchi *et al.* (2007), in which flash flood and debris floods are the principal hydro-geological risks, villagers are reported to have progressively lost their culture of self-protection over recent decades. They under-estimate flood risks, are unprepared for warnings and emergencies and no longer take precautions against floods. It is not clear whether any building adaptations for flooding have also fallen into disrepair, but in such circumstances they are likely to have done so. In this case, the relevant factors leading to vulnerability to floods (i.e. physical, social and economic vulnerability) appear to be the emergence of a distorted welfare culture in which residents now place the entire responsibility for dealing with floods fairly and squarely with the local authorities. This problem appears to be exacerbated by an aging population of low, mean educational status and strongly suggests that widespread lack of ownership for resilient construction may lead to significant physical vulnerability.

Increased physical vulnerability to floods is sometimes caused by formal urban growth and containment policies. This is a case of social and economic **factors** increasing physical vulnerability, to floods which in turn increase economic and social **vulnerability** to floods, as shown in Figure 14. Throughout much of the past century planners have advocated containment of urban sprawl through regulatory restrictions that include growth boundaries, green belts and limits to utility extensions. Containment is widely practiced in Europe and is a key component of 'smart growth' but it can have serious side-effects including increase exposure and physical vulnerability to natural hazards (Burby *et al.*, 2001). Development in the 'western corridor' along the Thames valley to the west of London towards Windsor and Reading has been constrained by tightly drawn green belt boundaries. The consequence has been that infill residential development of increasing densities has been the main means of accommodating rising household numbers. The density of development in floodplains which are not also green belt land increased greatly between 1950 and 1995 causing an increase in flood damage potential of more than 10-fold (Parker, 1995). This is despite comprehensive land use planning controls being introduced in England in 1947, and despite a series of Government Circulars to planning authorities since that date which seek to avoid development on floodplains (the latest policy document being Policy Planning Statement 25 discussed below). Some of this development has been adapted to flood risk, but even so physical vulnerability has increased dramatically.

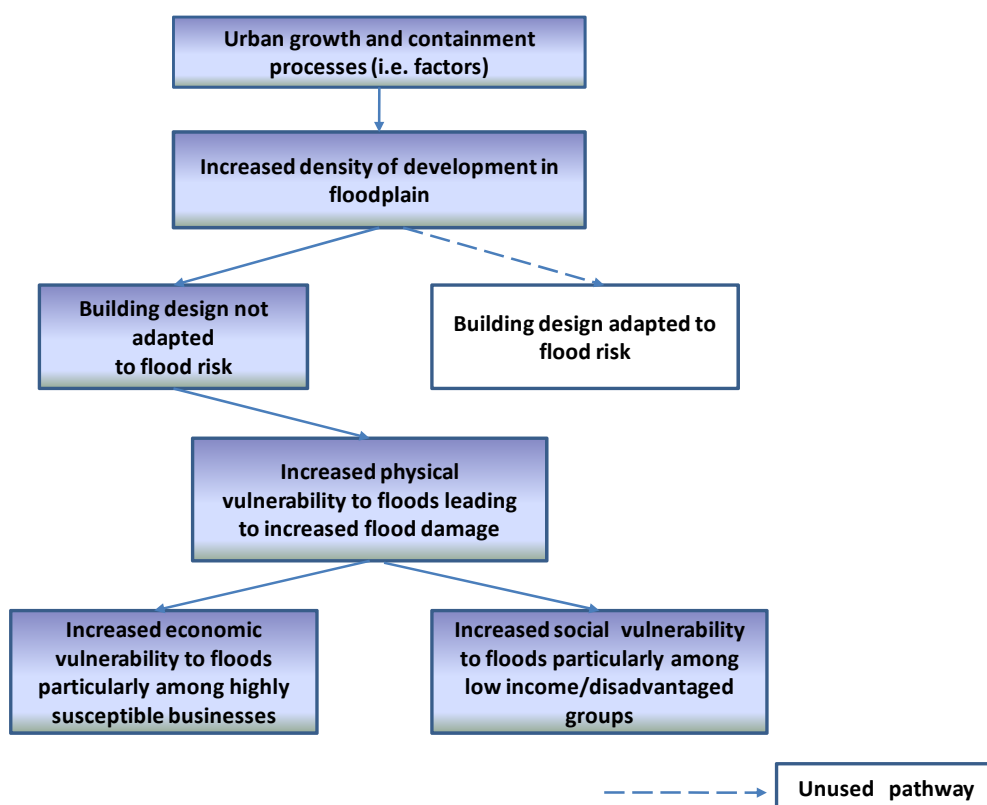


Figure 11: Relations Between 1) Physical Vulnerability and 2) Economic and Social Vulnerability of Floods Produced by Urban Growth and Containment Policies (i.e. 'socio-economic factors') in which Building Designs are Unadapted to Flood Risk

The reasons for this are a) south-east England is very densely populated, b) there is little 'undesigned' (i.e. already protected) land available for development purposes, and c) in the past local planners have sometimes ignored the objections to development on floodplains made by flood risk management agencies. In some cases development in the floodplain has been allowed by planning inspectors on national interest grounds. Generally, planning controls appear to have slowed development on floodplains, but it has far from been prevented and the development of south-east Eng-

land's floodplains appear to have been almost inexorable unless environmental designations and policies prevented it. On the whole this is a wealthy part of the UK, but economic and social vulnerability to floods is likely to select the poorest members of these communities (e.g. pensioners, low income families, recent migrants, single-parent families) and businesses which are particularly susceptible to direct and indirect flood loss (e.g. new starts, businesses on the margins of profitability, businesses with equipment which is particularly susceptible to water damage).

Social and economic regeneration strategies may also cause an increase in physical vulnerability to floods. This is a case of social and economic **vulnerability** leading to increased physical vulnerability to floods, and is well exemplified by the major regeneration developments occurring in east London and the Thames estuary to the east of London to the North Sea. The initial problem is one of social and economic vulnerability in general (i.e. to poverty, poor housing, unemployment etc. and not necessarily to floods). In contrast to west London, east London has always been characterized by low incomes, poverty, immigration to the UK, poor housing, employment insecurity and disadvantage. It has also witnessed major industrial decline and commercial restructuring. A major social and economic regeneration initiative designed to address these problems has been launched in the past decade. However, this initiative is leading to an increase in physical vulnerability to floods because construction associated with this regeneration is being forced into floodplains and has sometimes been poorly adapted to flood risk, as shown in Figure 15. Planning and regeneration policies and strategies have, until recently, been insufficiently adapted to flood risk, and even now with enhanced regulatory instruments, adapting new developments to flood risk presents a significant challenge. Partly because of climate change impacts on flood potential; partly because existing flood defences are deteriorating; and partly because of the existing and planned build-up of investment in these floodplains, an enhanced flood risk management strategy is now being proposed (Environment Agency, 2009).

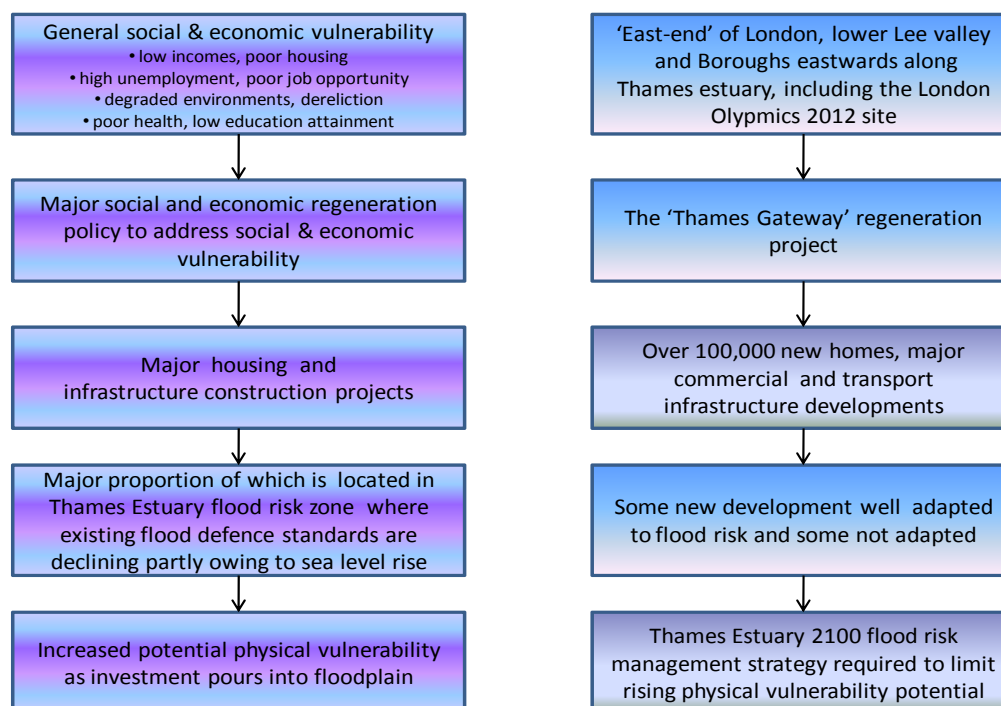


Figure 12: How Regeneration Strategies Designed to Address General Social and Economic Vulnerability can lead to Increase Potential Physical Vulnerability to Floods which Subsequently Requires an Enhanced Flood Risk Management Strategy: the Case of East London and the Thames Estuary

## Stage II: Implementation

### Public Intervention

England has well-developed, but not yet entirely effective, intervention mechanisms for addressing physical or structural vulnerability to floods (Table 7). These mechanisms not only address individual physical structures such as houses, but also infrastructure, development location choices and physical development layouts. They also address sustainable urban drainage systems. These intervention mechanisms have evolved over many years in response to experience (i.e. through periodic review of experience and performance; through changing flood risk management policy paradigms; and through efforts to improve the effectiveness of the mechanisms), thereby changing socio-economic circumstances and European legislative requirements. Since the mid-1990s, England experienced a heightened level of flooding activity and, particularly since the 2000 floods, there has been a much greater focus on refining and improving these mechanisms. Like many of its European partners, England's flood management policies shifted significantly during the first part of the current decade away from a structural (i.e. large-scale engineering), 'flood defence' emphasis. 'Making Space for Water' (Department for Environment, Food and Rural Affairs (Defra), 2005) introduced a 'flood risk management' approach which gives much greater emphasis to non-structural measures (incorporating small-scale structural adaptations) alongside large-scale structural measures. This approach has brought structural adaptations to the forefront of policy interest, experiment and innovation but much remains to be done before such innovations will have a significant impact in reducing England's rapidly rising flood damage potential.

#### Some intervention details for England and Wales:

<b>Physical structures</b>	There are now hundreds of 'flood products' on the market in the UK designed to help property-owners make their properties (most commonly houses) more resilient to flooding. They include floodgates, flood skirts, sump pumps, airbrick covers and so on. Government, the construction industry and the insurance industry, as well as the Environment Agency, also provide advice and recommendations on building new structures in a flood resilient way (i.e. using resilient designs, materials and fittings). Building regulations help with this although they are not yet adjusted to include flood resilience measures.
<b>Land use planning</b>	There is now an elaborate spatial planning system with specific requirements relating to avoiding and mitigating physical vulnerability to flooding.
<b>Building codes</b>	There is a voluntary code (Code for Sustainable Homes) which includes some guidance on flood resilient building standards. There are also Building Regulations, but as yet these do not include flood resilience regulations (this will probably change in the near future). There are however elaborate codes and regulations regarding installing sustainable urban drainage systems (SUDS) and the draft Water and Floods Bill (currently being considered) includes a tightening up on developer's and individual's responsibilities to create paved surfaces. There is an elaborate system of 'building control and inspection' and all new builds require inspection and signing off by planning inspectors at various stages.
<b>Building permission</b>	Almost all buildings and building extensions in England and Wales require 'planning consent' before development can go ahead. There is an elaborate system for planning proposals, planning applications, consents and appeals. 'Planning conditions' (e.g. about ground floor threshold heights) can be set when consents are given.
<b>Other regulations</b>	There are a wide variety of other regulations, for example, about how close to a watercourse development can be positioned; how close to tidal flood defenses development can be positioned; about sewer and drain capacities (re: sewer and surface water flooding); about highway design and surface water runoff; about SUDS; about dam building and building construction near dams (re: dam break flood risk), and so on.
<b>Economic incentives</b>	Central government has recently introduced a grants scheme to incentivise installation of property-specific resilience measures. In Wales this has been done through existing legislation but is proving bureaucratic. In England it is being done through a grants pilot scheme in selected qualifying communities. However, a number of local government bodies, particularly in cities recently severely affected by flooding (e.g. Gloucester, Oxford) have also introduced their own grant schemes for this purpose

	<p>which acts as incentives.</p> <p>There are also economic incentives implicitly built in to the planning consent system because if someone builds or extends a structure without planning consent, the law makes it possible for planning authorities to require the build to be taken down at the cost of the builder/property owner. Similar enforcement capabilities exist regarding illegal or non-consented connections to sewers and drains.</p>
<b>Information and awareness mechanisms</b>	<p>These are well developed in England and Wales and comprise a number of published guides on how to increase the flood resilience of properties and their contents. These guides are produced by the Environment Agency, the insurance industry, central government departments and by the construction industry. In 'at-risk' towns and villages, flood fairs are sometimes held to raise awareness of resilience methods, and the National Flood Forum (which is a pressure group comprising members from many local flood action committees and groups) is heavily engaged in awareness raising and information provision.</p>
<b>Response measures</b>	<p>Responses to reduce the physical vulnerability of structures and developments include the use of demountable flood defenses and community-based contingent response measures linked to early warning. Recent experimentation with demountable flood defenses in the Severn valley communities is leading to their more widespread use in England and Wales. The scope for these and other community-based small-scale structural measures is being researched in the Lower Thames valley in west London, and proposals have been made to implement some of these plans. Emergency evacuation plans exist in many flood prone locations, especially in tidal flood risk zones. These involve removing property from floodplains as well as people.</p>

<b>Private institutions</b>	Disaster continuity planning has become widespread in the private sector and focuses upon reducing flood risk among a range of threats. This is partly to do with reducing the physical vulnerability of structures and related systems. A number of large companies in flood prone areas have invested in measures to reduce the damageability of their properties. The flood insurance industry provides insurance cover for structures and their contents.
<b>Civil society institutions</b>	Among the social capital of floodplain communities, local flood action committees and groups; river groups; the National Flood Forum and a range of other organizations are involved in the process of reducing physical vulnerability to flooding. For example, there are numerous such organizations in the Thames tidal floodplain in London and the Thames estuary.

Table 5: Hazard Types and Interventions to Address Physical Vulnerability

In England institutional arrangements and mechanisms for regulating physical vulnerability to floods comprise an integrated system in which local arrangements and mechanisms are nested within strategic arrangements. At the core of the strategic decision-making process is the Statutory Development Plan which comprises Regional Spatial Strategies and Local Development Frameworks (Figure 16). Central government set out its detailed requirements for managing flood risk in Policy Planning Guidance (PPG) 25 in 2001 titled 'Development and Flood Risk', which was accompanied by a detailed 'Practice Guide Companion' to be treated as 'Living Draft' (i.e. it was to be constantly reviewed and improved in the light of feedback from practitioners) (Department for Communities and Local Government (DCLG), 2006b). This has since been replaced by Planning Policy Statement (PPS) 25 in 2006 and a new Practice Guide in 2008.

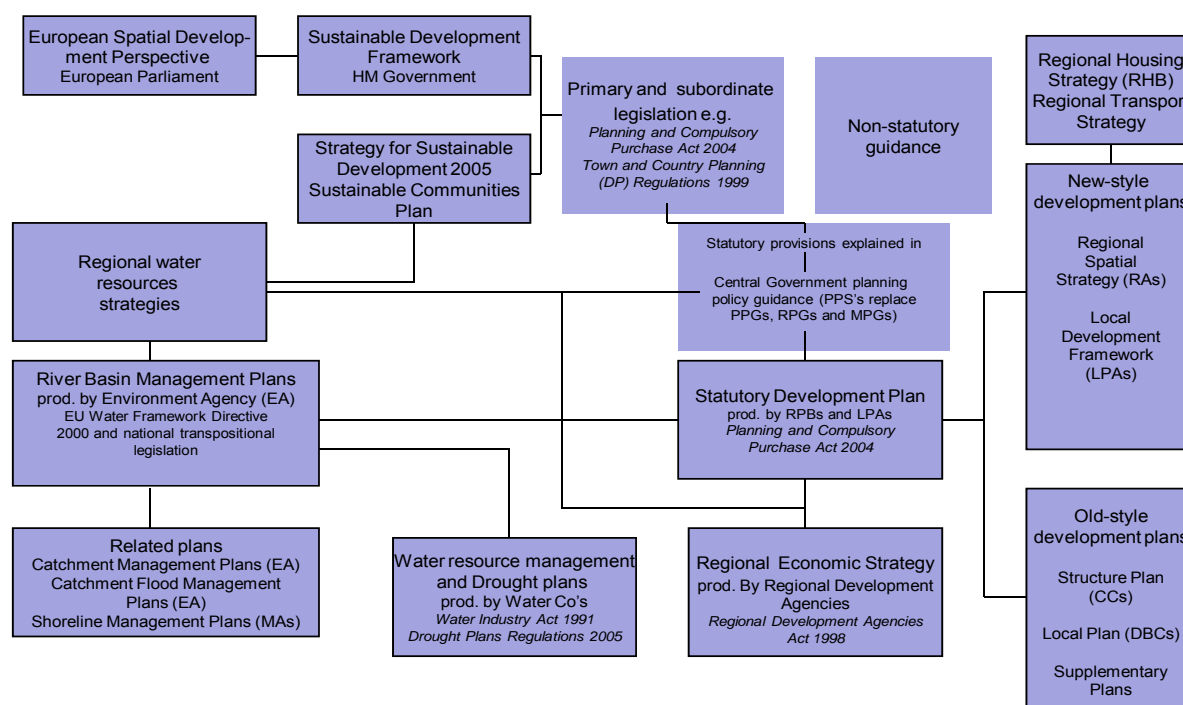


Figure 13: Strategic System for Urban Sustainable Development Planning Linking Land, Water and Related Planning Systems

Development proposals (e.g. to build or extend a house through to major residential or commercial developments, and in future major infrastructure developments) must be progressed through one of several planning processes, the principal one being shown in Figure 17. Planning applications must first undergo a thorough flood risk assessment which must be submitted as part of the application. Where a case is made for development in a flood risk zone, this risk assessment must demonstrate the ways in which development will be adapted to reduce physical vulnerability. Policy is that development in flood risk areas should be avoided unless there are no reasonable alternatives, and where development is proposed for flood risk areas mitigation and/or adaptation measures must be fully developed and implemented. In some parts of England (e.g. in London, parts of the Thames Estuary, in parts of West Yorkshire and so on), floodplains are already heavily-developed and very little alternative flood-free land is available. In such cases it is practically impossible to avoid development in flood risk areas. Where an application for development in a floodplain is approved the application is likely to be subject to conditions relating to floor threshold levels, sustainable urban drainage systems and flood adaptations. Under the Building Act of 1984 a comprehensive set of building regulations exists and is enforced through a process of progressive inspection undertaken at local level during the course of construction (Figure 18).

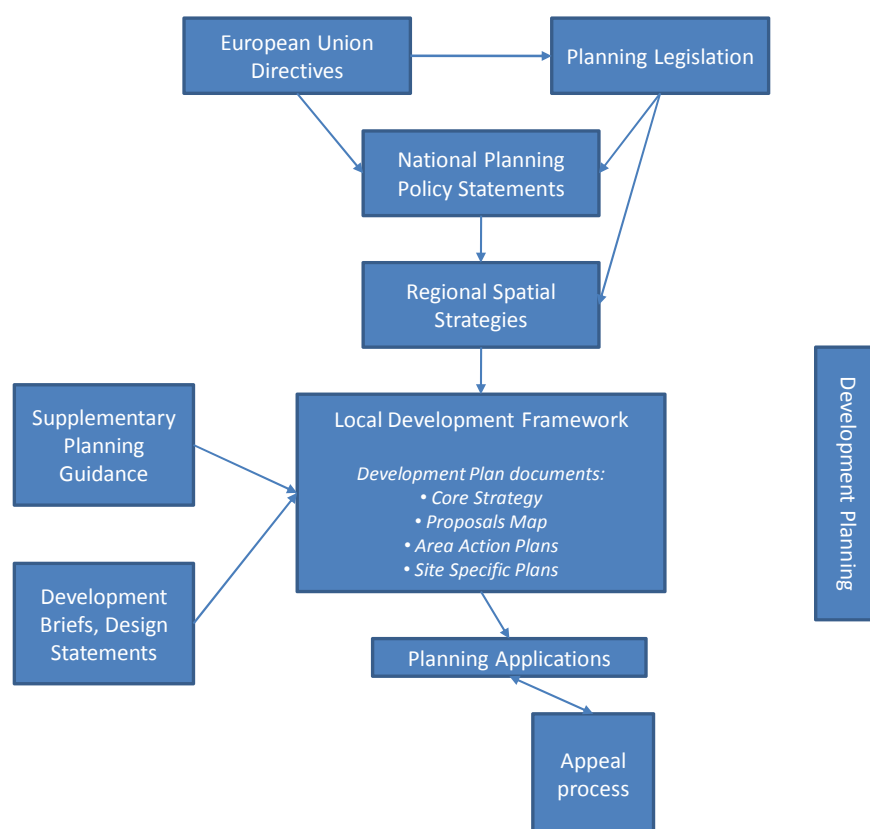


Figure 14: Components of the Planning Process in England

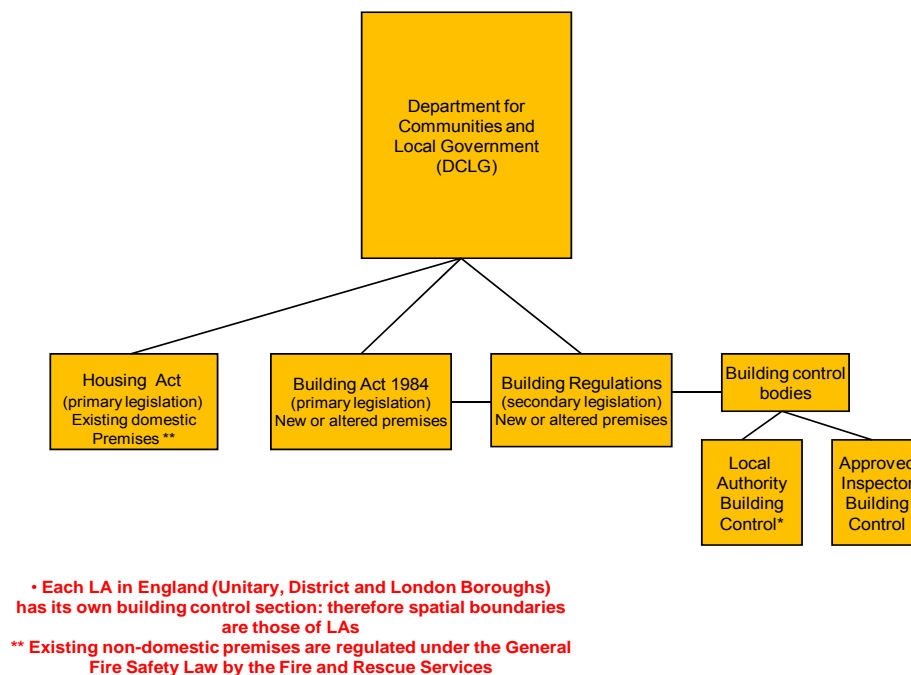


Figure 15: Institutional Arrangements for Building Control and Regulation in England

A weakness of the current arrangements is that the building regulations do not currently address flood proofing measures and flood adaptations although they do embrace other climate change adaptations. However, improvements are likely in the future as more scientific evidence becomes available about building adaptations and especially their economic effectiveness (i.e. their likely benefits compared with their costs under different flood risk conditions). A further weakness in institutional arrangements has recently been addressed by the introduction of House Information Packs (HIPs). Until recently, house vendors were not obliged to provide prospective purchasers with information on such aspects as the energy efficiency of the house or risks to which it may be subject, including flood risk. This has now changed, although a careful house purchaser could have always undertaken their own flood risk 'assessment' by consulting the Environment Agency's flood risk maps available on the web, and/or by commissioning their own environmental assessment (though apparently a minority did so).

There has been considerable interest in England in 'flood resistance and resilience measures' which are examples of 'control' and 'mitigation' measures which are applicable when 'avoidance/prevention' measures are infeasible and where development at risk requires protection. The approach is an adaptive one and incorporates both dry and wet proofing techniques for existing and new properties. The DCLG (2007) has set out a strategy for improving the flood performance of new buildings, and now recommends a series of flood resilient construction methods. Anticipated flood depths and floodwater velocities are important in determining the precise physical vulnerability reduction measures to be used. In the UK there are now over 400 kite-marked flood products on the market which tie into this adaptive approach, and the National Flood Forum (a national pressure group comprising numerous local resident's flood action groups) advocates their use, sometimes combining with the Environment Agency at local 'flood fairs' to provide information on them. Complementary construction guidance is provided by the Construction Industry Research and Information Association (2005) and in The Code for Sustainable Homes (DCLG, 2006b). Much of the recent research interest has surrounded the costs and benefits of employing different portfolios of home flood adaptation

techniques and the extent to which existing homeowners are likely to adopt such measures (Entec UK Ltd, 2007; Defra, 2008a,b).

The current institutional arrangements for encouraging and implementing flood resilient and resilience measures in England present a number of issues. Firstly, in England there is as yet no generally available financial incentive on offer from government to encourage homeowners to adopt adaptive measures to reduce physical vulnerability (though in Wales and Scotland there have been some such incentives), although home improvement grants are a potential vehicle for this. A number of pilot projects in several communities have, however, been funded by government, and following the 2007 floods in the city of Cheltenham, the local authority made small flood resilience grants available to homeowners to improve the flood resilience of their homes. Secondly, homeowners are in many cases unsure about the reaction of their private insurance companies to them investing in costly adaptive measures (i.e. whether this will ensure continuity of insurance coverage for example). However, through their trade association (The Association of British Insurers), the private insurance industry has been consistently stating that it will provide flood insurance cover for all properties which have a less than 1:75 year (1.3% probability) of flooding, and that for properties with a higher risk than this they wish to see evidence of either large-scale flood protection or effective adaptive measures. Thirdly, many homeowners appear unlikely to take-up adaptive measures even where they can be demonstrated to be cost-effective over a period. Take-up is affected by many social and economic factors, including anxiety, people's residential mobility plans, people's time horizon, competing problems and priorities, uncertainties, financial constraints, complacency and apathy, and worries about impacts on property values. In addition, there are significant circumstances in English floodplains where the frequency of flooding is unlikely to be sufficiently high to render adoption of adaptive measures financially attractive.

Institutional arrangements for flood relief and reconstruction are developed in a particular way in England. Until recently, the guiding principle has been to avoid the government compensating individual property-owners for flood damage because this subsidizes decisions to live in flood risk areas. However, severe flooding in Kingston-Upon-Hull in 2007 led to central government emergency recovery funds being passed from local authority hands to some tenants and property owners breaching this principle. Central government came under pressure from the media which labeled Hull – a city with a poor and disadvantaged population – ‘the forgotten city’. Most of the losses suffered were insurable and many received flood insurance payments (though some were uninsured). Two emergency flood funds are available for recovery and reconstruction purposes: the Bellwin Scheme which is a scheme for compensating local authorities' immediate flood response and recovery efforts, and the Flood Recovery Grant which support local recovery work. The latter was new in June 2007 and was used to help people in the greatest and most immediate need. Social funds were also drawn upon for those on benefit and on low incomes. A key underlying issue with the use of insurance payments and compensatory payments from government is that these funds are likely to be used to help reinstate properties that proved to be physically vulnerable and which may well be physically vulnerable again in the future. However, in the city of Doncaster which was badly affected by the summer 2007 floods, repairs to homes incorporated flood resilient principles so that these houses are better equipped to withstand floods in the future.

### ***Stage III: Evaluation***

#### ***Blind Spots***

Few ‘blind spots’ now appear to exist in the arrangements for reducing physical vulnerability to flooding in England and Wales. This is partly owing to the higher intensity of flood activity in the past decade and the wide range of initiatives taken as a consequence. However, only a very small proportion of structures located in flood risk zones in England and Wales have either been constructed to flood resilient standards or have been retrofitted to such standards. It will take many years for such measures to become widespread. The summer 2007 floods revealed two particular blind spots that have been researched since and are now beginning to be addressed (again it will take many years for this process to be implemented). The first blind spot is in the location of the nation's critical and significant infrastructure, particularly electricity sub-stations, large electricity generating stations, wa-

ter treatment plants, sewage farms and similar installations. A surprisingly high proportion of these are located in valley bottoms and are prone to flooding at one level or another. Many are unprotected or not built to flood resilient standards. The second blind spot was the recognition and identification of areas at risk of surface water flooding from intense rainfall in urban areas, and where drainage capacity is inadequate to cope with the large volumes of water produced e.g. in Hull. Surface water flood risk maps are now being developed and the feasibility of developing a warning system is being investigated.

### **What can we learn about the socio-economic factors which increase physical vulnerability?**

Table 7 lists the socio-economic factors which we believe influence (increase/ decrease) physical vulnerability to floods. As with any such list, there is a risk of over-simplification because there is a multitude of circumstances in which physical vulnerability to floods changes.

<b>Factor</b>	<b>Increasing physical vulnerability</b>	<b>Decreasing physical vulnerability</b>
Human ignorance of flood risks: their presence and physical and socio-economic processes which cause flooding	In general and in specific geographical areas and circumstances	Introduction of hazard processes into school curriculum
Progressive loss of indigenous knowledge of local flood problems and adaptations	Caused by breakdown in traditional life-styles and communities, rural-urban migration and family member dispersion	Early recognition of processes causing loss of knowledge and conscious strategies for its retention
Lack of collective family or community memory of past floods	Caused by failure to store and pass on knowledge between generations; lack of community mechanisms for retaining information; fading interest; lack of understanding of the relevance of the past to the present and future	Build flood memorials; celebrate years without flooding; build flood museums; use in schooling etc.
Lack of a learning process within social institutions	Many possible causes, one of which is continued perception of floods as unconnected, one-off processes	Introduce learning organisations, institutions and processes. Undertake comprehensive post-flood inquiries/reviews, identify lessons to be learned, implement actions
Rapidity of urban growth and change	May outstrip the abilities of authorities to control development and to ensure resilience. Other priorities may be upper-most	Ensure robust spatial planning and development control institutions and mechanisms which lead to floodplains being largely avoided
Corruption and abuse of power relations	May have many consequences including ignoring downstream impacts and other externalities; sanctioning of illegal building development; sub-standard construction methods and so on	Anti-corruption measures and ethical practices

Rapidity of change in rural land use practices	May increase runoff and worsen flood regime. Many such practices e.g. certain forms of deforestation; increased upland drainage to lowlands	Comprehensive land use change planning system required to be in place and effective and based on a detailed understanding of catchment processes and plans
Uncertainties over threats from physical environment	May be used as an excuse for moving head with building development	Adopt precautionary principle; invest in scientific evidence
Importing non flood resilient building designs and techniques from areas/regions with limited flood risk to areas/regions with significant flood risk	Very common world-wide and partly based on ignorance but also on inertia and the difficulty of experimenting with innovations rather than simply transferring 'tried and tested' methods	Begin with a strategic risk assessment, identify differences in levels and types of flood risk, adapt designs, materials and techniques to the new environments
Urban containment policies	The evidence is that although these policies prevent the undesirable coalescence of settlements and maintain green spaces, they may also lead to denser urban development and to encroachment into flood risk zones	Recognise the issue; ensure development that must be in flood risk zones is built to flood resilient standards; make a more conscious trade-off between needs and wants
Informal sector development in flood risk areas because the excluded have no alternative	Very common in third world settings e.g. in parts of South Africa, Asia and Latin America. Shanty town development is often 'pushed' into marginal land (i.e. land avoided for all other purposes)	Follow social justice policy agenda; adopt policies to include the excluded
Expansion of the historic cores of settlements from flood-free high ground into surrounding flood prone low land	Very common in Britain. Many towns and cities developed in this way including London	Urban redevelopment coupled with development retreat and resilience measures for existing settlements
Technological change and rising living standards	Many impacts which are negative in terms of increasing physical vulnerability. Rising values of assets at risk. Expansion of electrical and electronic products which are highly susceptible to water damage. Many other examples.	Many impacts which are positive in terms of reducing physical vulnerability. Development of flood resilient materials and construction designs; development of fibre optic cables which are resistant to water damage. Many other examples. Development of 'flood products'.
Regulation compliance failure	When building codes and regulations are avoided and compliance fails, perhaps owing to some form of institutional problem (or institutional vulnerability perhaps) then buildings can be constructed where they should not be, and standards may slip.	Monitoring of compliance and remedial actions to ensure strong compliance.

Table 6: Key Socio-Economic Factors Changing Physical Vulnerability to Floods

### What can we learn about the relationships between physical vulnerability on the one hand, and social and economic vulnerability on the other?

The three cases at the beginning of this paper (i.e. loss of indigenous knowledge in Peninsular Malaysia; Regeneration in east London; Urban containment in west London) each inform about these inter-relations. In Malaysia, increasing social vulnerability appears to lead to increased physical vulnerability, but the increased social vulnerability is not just to flooding but also to almost any potential threat to the traditional kampung communities (e.g. to their continued existence, to life-styles, to well-being). It is worth noting that physical vulnerability can be very specific: in this case physical vulnerability to flooding is increased but physical vulnerability to the closely associated hazards of windstorm and torrential rain is decreased. It is almost as if the resilience to one hazard has been

increased at the expense the resilience to anothers, but the process is unintentional in this case (it is simply a function of the qualities of modern building practice in Malaysia).

In the second case of urban containment in west London socio-economic factors appear to increase physical vulnerability which in turn leads to an increase in economic and social vulnerability which applies to the poorest members of society only. In the third case of socio-economic regeneration it is **general** socio-economic vulnerability (not socio-economic vulnerability to floods per se) which leads to policies being adopted which increase physical vulnerability to floods.

A commonality between the processes at work in these case examples, is that vulnerability (whether it is physical, social or economic) appears to increase in a largely unforeseen way – it is the consequence of decisions made concerning other priorities, or it is part of a ‘run-away’ process of change to do with modernization. However, with time these consequences are often identified, and it is then that policies are introduced to address these vulnerability consequences, if they are introduced at all. What we see, then, is that vulnerabilities change across the dimension of time and it may be many decades before the adverse consequences of an otherwise positive process of change and modernization are identified and addressed. And then it is often a process of ‘catch-up’ because already people and communities have suffered the adverse consequences of increased vulnerability. The hope is that future communities and their members will not be so badly affected in these places, but this flawed process of change and ‘progress’ appears to be deeply embedded in the larger process of human change. This makes it predictable and so we need to identify strategies based upon predictability to break this pattern.

## 4. Forest Fires<sup>16</sup>

### 4.1 Forest fires in Portugal and Mediterranean countries

#### Stage I: Initiation

Human-caused fires are the most important threat to forests and wooded area in the Mediterranean basin. The increasing living standards in Western Europe lead to a migration of population from the rural areas to the city centres. Urbanisation and the expansion of transportation routes have affected people's relationship to their environment with respect to fires (Costa *et al.*, 2007).

Reports of forest fires in France, Greece, Italy, Portugal and Spain show that in these areas more than 450.000 ha burned on average each year between 2000 and 2006. In 2007 the phenomenon got even worse, especially in the south-eastern countries; the total area burned was about 500.000 ha (Bassi *et al.*, 2008). Fires have caused extensive damage in recent years, leading to loss of human lives, affecting human health, burning properties, infrastructures and business, as well as causing extensive environmental damage in forest and agriculture areas.

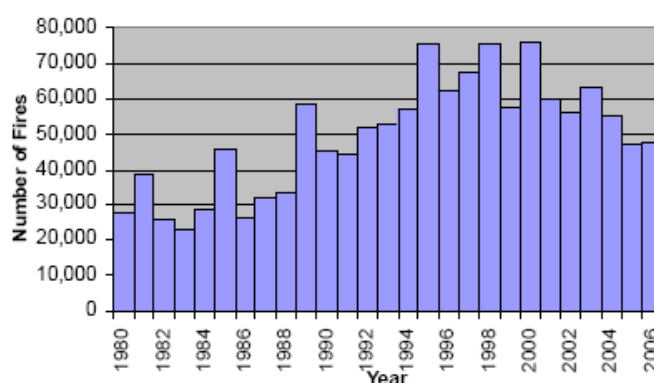


Figure 16: Number of Fires in the EU Southern Member States

<sup>16</sup> Case material provided by PIK, Germany

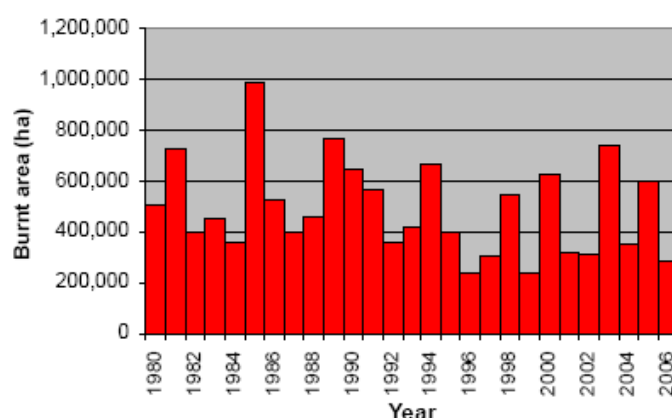


Figure 17: Area Burnt in the EU Southern Member States

Fire statistics vary considerably from one year to the next, indicating how much the burnt area depends on seasonal meteorological conditions. Despite this inter annual variability, it is possible to see that the number of fires in southern Europe increased consistently until the end of the 90ies and then slowly decreased until 2007 (Figure 19). Fire frequency followed an increasing trend during the 1990's, but since 2001 the number of fires has remained more or less stable. Regarding area burnt, no discernible signal of rise in area burnt numbers was noted (Figure 20). For the purpose of this task, the focus lies on two particular southern European countries that have been recently affected by extreme forest fires: Portugal and Greece.

## Factors

One of the most important reasons for fire increase in Portugal is the change in land use. Agricultural land has been progressively abandoned since the mid 1950's, especially in the interior regions, leading to shrub encroachment. Increased labour costs have also made the cutting of shrubs for animal bedding uneconomical, hence eliminating one of the control factors (Pereira *et al.*, 2004). Abandonment leads to less occupation and tending of the landscape by people. Hence leaving new forests or shrublands unattended, and the landscape is decreasingly compartmentalized. All these factors create the conditions for the development of frequent and severe fire cycles, especially when large and continuous areas of shrubland are created (Pereira *et al.*, 2004). Furthermore, the abandonment of crop cultivation leads to conversion of extensive animal husbandry. In many interior regions, shepherds burn the area to maintain the ecosystem in the early succession stage of grassland. This has been an important factor for the increase in fire ignitions (Pereira *et al.*, 2004).

In Portugal, it has been observed that the majority of forest fires are initiated by intentional acts and negligence (DGRF (*Direcção Geral dos Recursos Florestais*), 2007). In Figure 21 it becomes visible how tightly connected the number of ignitions are with the population density and with the percentage of conifers in a forest (adapted from Costa *et al.*, 2007). On one hand, higher population density leads to a higher number of fires. On the other hand, a high population density is usually associated with a quick response of the fire fighters and therefore leads to a reduction of the spatial extent of an average fire.

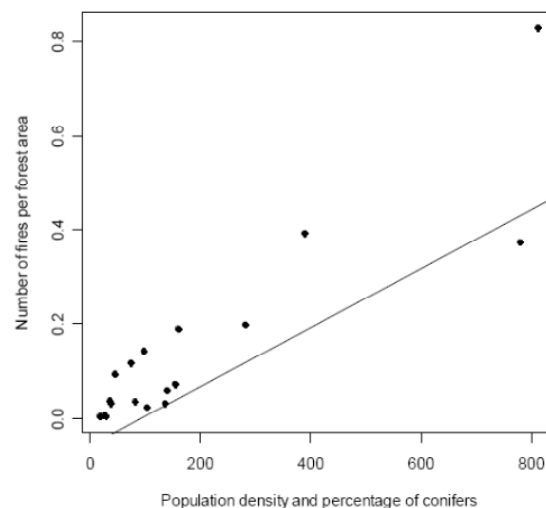


Figure 18: Relation between Number of Fires per Forest Area and Both Population

Costa *et al.* (2007) hypothesize that in districts with high population density the probability of an early detection is higher, leading to a quick response of the fire fighters and therefore to less forest area burnt. Data for the Portuguese mainland regarding average fire size and population density shows a tendency for a decrease in the average size of the fires as the population density gets higher (Figure 22). The time from the moment that a fire is detected to the moment that intervention by the fire fighters starts is crucial to the future extension and severity of a forest fire. A fast detection prevents fires from reaching a high areal extent (Costa *et al.*, 2007).

Economic changes in Western Europe have led to the migration of population from the countryside to the cities, to a slowing down of demographic growth, to abandonment of arable land and to disinterest in the forest as a resource (Alexandrian *et al.*, 1999). It is believed that the perverse economic incentive to clear forests for development has lead to an increase in the number of ignitions in Greece. Greek law prohibits development on land classified as forest, but because there is no forest or lands register it is nearly impossible to prove that burnt land was previously forest. Thus, arson is often suspected in the transition zones between forests and urban areas in order to allow profitable development. This aspect can also be traced to intervention mechanisms that did not support or promote adequately updated land ownership records.

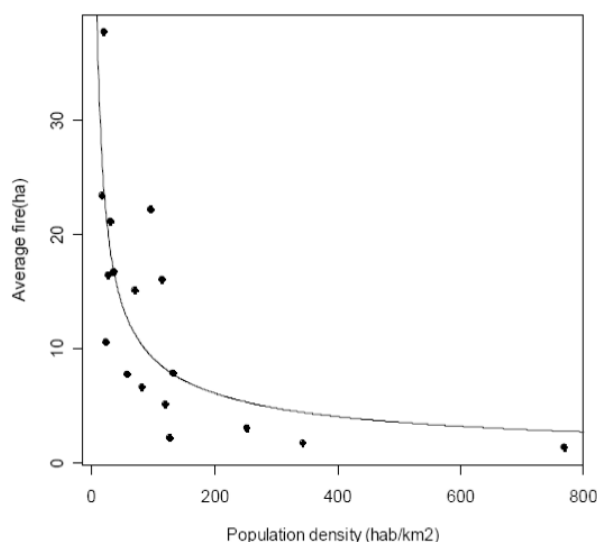


Figure 19: Relation between the Areal Extent of an Average Fire and Population Density in Each Portuguese District (Costa et al. 2007)

In general there is a lack of a traditional economic market for Mediterranean forest products, which discourages investment in forest management because of the lacking profit or financial incentives. In Greece, management of low elevation pine forests was supported by a Greek subsidy for resin, but this was discontinued in the 1980's when Greece joined the EU. Thus, a lack of incentives and the emergence of other financially more attractive opportunities led to low-elevation pine forests being left practically unmanaged. As these forests and villages were gradually abandoned, the number of forest fires and the area burned annually started growing steeply since the end of the 1970's (Xanthopoulos, 2004). Pine forests are especially vulnerable to fire and usually located close to the coastline, to urban centres and on islands. Such land is of high value and forests frequently become the target of arson, aiming at real estate development.

## Stage II: Implementation

In southern Europe, the institutional structure of national forest agencies is context-driven and varies from country to country. In Greece, there are two agencies responsible for forest fires. Historically, the Greek Forest Service was responsible for all aspects of forest fires, but in 1998 the responsibility for fire suppression was transferred to the Greek Fire Service. The severity of the 2007 forest fires could be partially attributed to this division, which was compounded by the fact that funds for prevention have systematically been cut over time, rendering the forests more susceptible to fire.

In Portugal, national coordination used to be scattered, as forestry financial incentives used to be managed by the Ministry of Agriculture, while the Ministry for Internal Affairs managed the fire fighting. Following the extreme fire events of 2003, there has been a significant effort by the Portuguese government to reform forest management. They established a forest fund to implement forest management and fire prevention projects, and have focused on construction and improvement of fire-breaks and water reservoirs. In addition, they have developed forestation programmes that aim to plant diverse broadleaf tree species rather than more vulnerable species such as maritime pine and eucalyptus, reducing the risk of forest fires and therefore the physical vulnerability of both populations and ecosystems. The effect of these policies will be seen in the long run. Unfortunately they have not been able to prevent the forest fire episodes of 2005.

## Public Intervention

The recent developments in the use of prescribed fire were followed with a renewed interest in Portugal in the actual fight against wildfires. In 2006 DGRF created three to four groups of specialists analysing fire behaviour and having the capacity to assess the possibilities to use suppression fire as

well as the skills to actually perform such operations. The Portuguese members in the groups had sufficient expertise in the operational use of prescribed fire during winter, and assistance from the GRAF (Forest Actions Support Group) in Catalonia and the *Plan Nacional de Manejo del Fuego* in Argentina was of great interest.

In summer 2006, these groups intervened in some of the major Portuguese wildfires. The success of the work encouraged the creation of six to seven groups of specialists in 2007. They received further training, and the continued assistance of the above-mentioned Catalanian and Argentinean organisations as well as the French organisation *Espaces Méditerranéens*. In 2007, these groups covered the whole country and were asked by the Civil Protection to assist in most of the large fires. Typically, when fires started during the night and aerial attack was not possible, the groups performed the analysis and the possible interventions with great success. These new initiatives, besides weather conditions, are thought to explain to a large extent the success of fire-fighting during the 2006 and 2007 seasons.

Recent Portuguese programmes tackling forest fires aim at the diversification of tree species composition. More broadleaf species shall be planted, as these are less vulnerable to fire than maritime pine and eucalyptus (Mendes *et al.*, 2004). This is thought to contribute to the reduction of forest fires in the long run. The major effects of these programmes are hardly visible in the short run, as it can take some time for the new species to grow. In addition, these programs are thought not to be able to solve the problem alone, and other problems may offset their effect. This is the case for instance of rural abandonment, with the corresponding abandonment of farming and the increase of scrublands in those places where forestation of abandoned land did not happen (Mendes *et al.*, 2004).

### ***Private Intervention***

Forestry-related programmes and funding in Portugal have generated a demand for technical advice by the non-industrial private forest owners. A growing number of forest owner associations were established since the 1990's, especially in the northern and central regions where small-scale forestry is more salient. The existence and sustainability of these associations is thought to be an important factor contributing to the effectiveness of forestry policy and to sustainable forest management (Mendes *et al.*, 2004). The World Wildlife Foundation, through its cork oak landscapes programme, is active in three priority landscapes (including Southern Portugal) to develop models for good practices in protection, management and restoration based on a multi-purpose management approach. This will aim at conserving all uses, values and services, deriving socio-economic benefit from all values, engaging communities, developing partnerships and promoting certification.

## ***Stage III: Evaluation***

### ***Key Factors***

After identifying social, economic and institutional factors contributing to physical vulnerability, a representation is made of how the factors are interconnected and related. Figure 23 shows a general representation of a forest fire chain sequence, from fire risk to the moment of fire extinction.

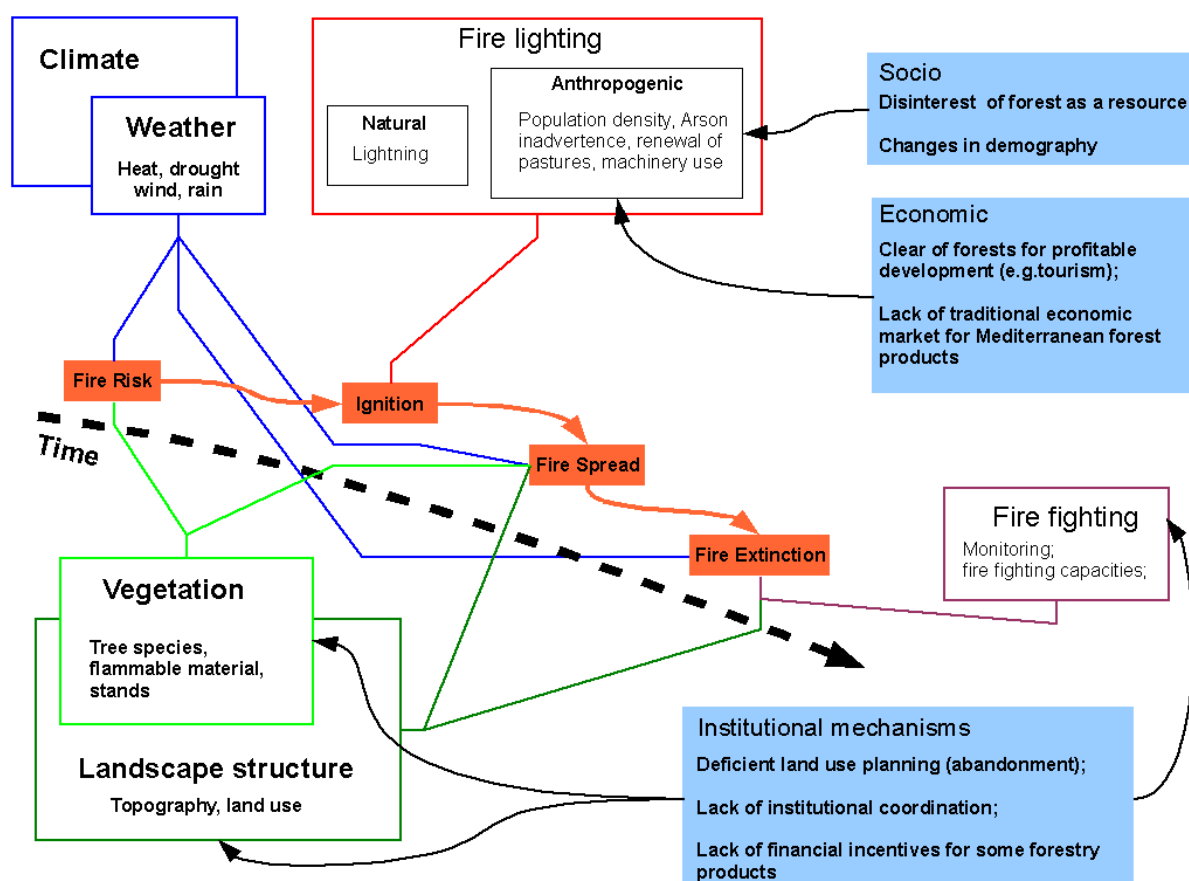


Figure 20: Chain sequence of a forest fire hazard and the key social, economic and institutional factors contributing to physical vulnerability

In blue some key social, economic and institutional factors contributing to physical, vulnerability are stated.

To sum up: a change in demography enhances the probability of fire ignitions (high population density) or the time required for fire detection (low population density). Lack of a traditional economic market for forest products can lead to the burning of forests for profitable development projects. Deficient land use planning and institutional coordination allows the enhancement of the fuel loads available to burn and sets drawbacks to fire fighting efficiency.

## Blind Spots

Decisions on land use planning and prevention are always required. Investments in fire prevention mechanisms can be more effective than investment in fire fighting. Public awareness campaigns are essential due to the large prevalence of human induced fires in the southern European countries. In parallel, monitoring and early warning systems are also crucial.

The use of prescribed fire should be further considered since it is an effective tool for fire prevention by creating discontinuity in forests or burning shrubs and reducing the possibility of big forest fires spreading.

Political commitment is ultimately essential, especially with regard to the provision of adequate budget, the adoption of proactive rather than reactive responses, the amendment of conflicting policies and legislations and the definition of clear responsibilities for fire management.

Although the collection of data on forest fires is improving, it should be encouraged further, especially in light of a harmonization of terminology and definitions, and the development of a common format for regional databases on fire across countries.

Collaboration between countries, within and between regions (e.g. the Portuguese case in public interventions dealing with physical vulnerability) is generally increasing, and should be pursued further.

## 5. Landslides<sup>17</sup>

This chapter will provide an example of incorrect land use planning regarding the case of landslides in Italy. Incorrect land use planning leads to increasing natural vulnerability, resulting in more landslide phenomena and more private intervention. The case study relates to the Chianti region (Virginio river basin, Tuscany – Central Italy) where the realization of a new Chianti vineyard has produced a larger income to the land owners but also an increase of vulnerability, resulting in a larger number of landslides than before.

### ***5.1 Chianti region (Virginio river basin, Tuscany – Central Italy)***

#### ***Stage I: Initiation***

Nowadays, the tight linkage between geological context and wine practices is widely recognized. Furthermore, this linkage should be taken into account by winegrowers during the phases of both production of the wine and management of the vineyards.

In fact, within comparable climatic conditions, on one side, the lithological characteristics and the geomorphological structure influence the pedological peculiarities (and, in turn, the quality of the vineyards in a given area). On the other side, planting a vineyard and the related practices induce important modifications in the geological, geomorphological and hydrogeological context in such a way that some slope instability phenomena can arise. Furthermore, the trigger of a landslide in an area devoted to wine production could directly affect the production of the involved area, as well as more seriously, the wine plant as a whole.

The present work starts with a general analysis of the link between land use and landslides phenomena in the Chianti region, more precisely in the Torrente Virginio basin situated in the Tuscania region (Italy). The aim is to highlight the influence of the presence of the vineyards on the susceptibility towards different typologies of landslides phenomena. The analysis takes into consideration both the natural and the anthropic factors.

#### ***Factors***

The Torrente Virginio basin is the main tributary of Torrente Pisa and constitutes one of its secondary basins. The confluence of the two little rivers is located next to Ginestra Fiorentina, a municipality situated in the province of Florence.

The main waterway and its two most important tributaries, Rio Virginiolo and Borro of Baccaiano, are typical torrential rivers. Those are characterized by a significant reduction of flows in the summer period and by short time floods at the same time as intensive rainfalls during the autumn and the spring period.

Regarding the land use of the basin, 20% of the whole basin surface is devoted to vineyards.

#### ***Vulnerabilities***

The starting point for examining the influence of the presence of vineyards on the susceptibility to landslides is the 'state of nature'. The state of nature consists of an analysis focused on the dimen-

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<sup>17</sup> The case is provided by partner T6 Ecosystems, Italy.

sion and the location of the area potentially affected by a likely destructive event. The inventory of the landslides phenomena, together with maps reporting slopes and the emerging lithologies, have been used to realize such state of nature.

The inventory takes into account both the neoformation phenomena and the reactivated ones. This is so as this distinction appears to be fundamental for a correct assessment of the susceptibility, according to the adopted methodology.

The analysis has highlighted the following typologies of phenomena:

- Rotational slide of new formation;
- Falls of new formation;
- Reactivated rotational slides;
- Reactivated slow flows.

Another kind of flows, classifiable as mud flows, have been recognized even though such flows are secondary phenomena according to their number and to the reduced area involved.

Based on the lithological map, the deposits have been divided into four categories:

- Cobbles and gravel (Pcg);
- Gravel and sands (Pcg-S);
- Sands (Ps);
- Sands and Clays(Ps-Ag).

The slope map has been extrapolated by a DEM (Digital Elevation Model), in turn built by digitalizing the isohypses of the technical regional map at 1:5.000 and 1:10.000 scale.

This analysis has allowed the sketching of an evolutionary model of the area in which both the slope range and the lithological units are taken into account with respect to the different typologies of landslides phenomena. Such data have been synthesized in a table (Table 9).

Typology of phenomena	Slope range (°)	Lithological unit
Rotational slides and falls of new-formation	30-90	Pcg, Pcg-Ps, Ps
Reactivated rotational slides	15-30	Pcg-Ps, Ps, Ps-Ag
Slow flows	10-20	Ps, Ps-Ag

*Table 7: Relationship between the Slope Range and the Lithological Unit for the Activation of a Particular Typology of Landslide Phenomena*

According to Abbatisa *et al.* (2005), the conditions that are shown in Table 9 are those responsible for determining the susceptibility of a given area to a particular landslide phenomenon. The assessment of the level of susceptibility is made depending on other factors that negatively affect the stability of the slope as well. Such factors can be considered 'predisposing' factors for triggering a given landslide event. Taking this perspective, the presence of the vineyard plays a central role for determining the level of susceptibility towards a particular type of landslide.

## ***Stage II: Implementation***

### ***Public Intervention***

Normally, agricultural practices are mainly dependent on the market and sometimes national and European incentives play a role. In this case, due to the high quality and economic value of Chianti wine private intervention prevails. The state is involved when allowing a change of land use.

## ***Private Intervention***

In the Chianti area, and more precisely in the Greve basin that is a Torrente Virginio adjacent area, the land use devoted to vineyards growing, represents 7,7%.

The landslide phenomena occur mainly in lithologies characterized by an arenaceous-pelitic complex structure, which is common in the area. It is represented essentially by quiescent slides and other secondary phenomena (equivalent to a 12% surface distribution), related to slow deformations (Figure 28).

It is worth underlining that 20% (208 events of a total of 1045) of instability phenomena recognized in the Chianti region occur in this basin that has 7% total surface devoted to vineyards growing. This observation confirms and supports the thesis that there is a great influence of the presence of the vineyards on the stability of the area with respect to the trigger of the events.

## ***Stage III: Evaluation***

To sum up, in the light of the study carried out in the Chianti area, and in detail in the Virginio basin, it is possible to state that many of the landslides phenomena involve areas in which some vineyards are planted.

Some examples of landslides, a slow flow and a rotational slide are shown in Figures 24 and 25, respectively.



*Figure 22: Slow Slide on a Vineyard in the Chianti Region*



*Figure 21: Rotational Slide on a Vineyard in the Chianti Region*

The roots of such behavior (Picarelli and Russo, 2004) can be found in the continuous modifications of the ground pressures regime. Modifications are due to the fluctuation of the internal pressures and the erosion, across time, in the geotechnical parameters and the alterations of stresses. The role of the ground internal pressures is fundamental with respect to slides with a limited thickness. Creep, superficial pressures and other phenomena related to the alteration of superficial stresses are the main causes of other instability phenomena like deep deformations and lateral spread.

In this case, these effects are not linked to the land use typologies, but they essentially depend on the 'construction' and management typology of the vineyards. For example, a preliminary action for planting a vineyard consists of digging the ground for the extension of the vineyards by arranging the drainages needed for guaranteeing the adequate level of moisture to the plants. In this way, an artificial discontinuity surface arises, which is placed along the maximum slope direction and divides the cultivated ground from the bedrock. Furthermore, it is worth reporting that the bedrock is often constituted by pelitic rock that has a very low permeability. The characteristics of the displaced

ground are, in terms of shear resistance, not equivalent to the original ones when the natural cover was in 'in place'. Besides, due to the scarce geotechnical conditions of the replacing ground, especially where the slopes are not high, some phenomena as slow deformations (creep) can evolve into slow flows. In the light of this explanation, the model proposed by Picarelli and Russo (2004) can be correctly applied to this case study.

The above-described situation is further aggravated if the drainages are not adequately designed to sufficiently drain exceeding water. As a consequence, the cover surface can reach conditions of saturation and determine an increase of the local internal pressures.

## 6. Volcanoes<sup>18</sup>

This chapter will discuss a case description of volcanic hazards, according to the three stages Initiation, Implementation and Evaluation.

### 6.1 Kilauea volcano in Hawaii

#### *Stage I: Initiation*

Kilauea Volcano in Hawaii has been erupting nearly continuously from its lower, eastern flank since 1983. Prior to this, there were eruptions in the same general area in 1955, 1960 and 1977, but a long period of quiescence occurred between 1840 and 1955. Since the eruptions in the mid-20<sup>th</sup> Century, thousands of residential lots in the area were subdivided and made available for settling. The land, people and development are at risk from several primary volcanic hazards, including acidic airborne gases and aerosols, lava flows and minor ash fall, but also secondary hazards such as fire, earthquakes, ground subsidence, sea-level rise/flooding, storm surge and tsunamis. Each of these hazards poses different risks to the people living in the area, known as the Puna District. It is a relatively rural setting with a few small towns and villages, with a rich mix of social, cultural, environmental and economic characteristics. For example, the area has been the fastest growing district in the state of Hawaii for many years (primarily due to the availability of inexpensive, rural, isolated land, much of which is located within areas of high lava flow, gas/aerosol, and ashfall hazard), racial and ethnic diversity (i.e., there is a mixture of Asian, Pacific Islander, Hawaiian and Caucasians groups), lack of availability of some utilities (e.g., running water, electricity), and t

he scarcity of primary roads and employment opportunities. The growing population in Puna, combined with socio-economic factors, presents an interesting scenario with respect to physical vulnerability to volcanic hazards. Some examples of social and economic factors that influence physical vulnerability in Puna are discussed below. Unless stated otherwise, the discussion is limited to factors relating to lava flow hazards only.

#### *Factors*

Socio-demographic factors influence social vulnerability because of low income and education levels, lack of availability of running water and electricity in areas, and the heterogeneity of racial and ethnic groups, which make it more difficult to decrease vulnerability through educational initiatives. Moreover, social vulnerability is influenced by the limited number of roads that people could use to escape lava, when it poses a threat.

Economic vulnerability is influenced by a variety of factors which may increase or decrease vulnerability. For example, there is no large private or government employment base in Puna. There are few commercial businesses, some specialty agriculture and a geothermal plant, but most employment is found several tens of kilometres away in the island's largest city, Hilo. The lack of a large employment base in the lower Puna District, where volcanic hazards are high, means that less is at risk. However, maintaining the ability of Puna residents to access their job places in Hilo requires

<sup>18</sup> Partner University of Geneva, Switzerland provides the contribution.

protection of the one road connecting the residential areas of Puna to the employment base in Hilo. Considering that lava flows are a primary hazard in Puna, protecting this road connector (Highway 130) would be difficult in the event lava tries to cross it. The seriousness of this threat was made clear to people in Hawaii state-wide in 2008, when lava flows began advancing through remote forests and toward Highway 130. Fortunately, the eruption and its lava flows reverted back to the previous paths, for the time being sparing the highway and most residents of Puna.

Physical vulnerability to volcanic hazards in Puna principally centres on the susceptibility of residential homes, key infrastructure (e.g., roads, especially Highway 130; the geothermal plant; schools; and police and fires stations) and historic sites, parks and agriculturally productive land to inundation or isolation by lava flows. Besides, also corrosive volcanic gases also pose a serious threat. With respect to the threat of lava flows, however, there is little that can be done to protect land and structures, the exception being to construct lava diversion or retention barriers or artificial channels to either hold back lava from a given area or force lava around it. However, diverting lava onto land that might not otherwise be naturally affected has serious legal consequences and superimposed on these are moral, ethical, cultural, environmental, and political considerations that must be addressed before such engineered mitigation strategies would be used. Such barriers have been tried in Puna during Kilauea's eruptions in 1955 and 1960 and during an earlier eruption of nearby Mauna Loa volcano in 1881. Barriers constructed high on Mauna Loa's flank to protect a weather observatory have not yet been tested by an eruption. Other hazard mitigation options used in Hawaii have involved using aerial bombs and water. Aerial bombs were used on eruptions of Mauna Loa during eruptions in 1935 and 1942. Finally, water was used to cool lava during several Kilauea eruptions (e.g., 1955, 1960, and the current and on-going eruption). Private landowners built barriers constructed on Kilauea in 1955; in 1960 it was the government, so there are examples of public and private mitigation efforts.

The physical vulnerability of land and development to lava flows involves inundation and ignition by lava, in addition to isolation. For example, lava flows can crush, inundate and burn property. Property is not necessarily destroyed but may be rendered useless for considerable time when lava flows isolate a given area by severing roads. The typology of structures or type of lava flow (i.e., pahoehoe or a'a) may each determine the way in which structures such as homes are destroyed. Wood frame or wood exterior homes are the common typology in Hawaii. Such homes are more readily ignited than non-traditional block, stone or brick homes, and perhaps more likely to be ignited in advance of being crushed or inundated during a'a flows compared to pahoehoe flows. Which comes first, destruction by inundation or crushing from the force of lava versus burning by ignition from the heat of lava has been an important factor in determining the eligibility of structures to be covered by fire insurance. In terms of physical vulnerability to volcanic gases, volcanic emissions of sulfur dioxide gases create sulphuric acid which damages foliage on plants and corrodes metals. These and other gases also pose serious health concerns.

## ***Stage II: Implementation***

### ***Public Intervention***

Again, using Kilauea volcano in Hawaii as a case study, several institutional mechanisms available for consideration to reduce risk from volcanic hazards can be discussed. In an ideal world land-use planning would have been a powerful mitigation tool to limit the social and economic and physical vulnerability to lava flows in the lower Puna District of Kilauea. However, vast acreage of rural land was opened for development, presumably prior to understanding of the persistent threat that lava flows and gas and aerosols would pose to future development. Before land was subdivided and sold in the mid-20<sup>th</sup> century (1958), the last major eruption in the region had been in 1840, although one destructive eruption occurred just a few years before the subdivision in 1955. While there were later eruptions in 1960 and 1977, the practice of subdividing lava covered land of little to no other known significant economic value was already underway. It is the rapid subdivision of land that was approved which has caused the observed population growth and availability of lots to be built upon and settled. It is this settling on hazardous land that creates the social, economic and physical vulnerabil-

ity tied to the area. To deal with this vulnerability, a variety of institutional mechanisms are available as mitigation options. Before discussing these, a point of clarification about land-use planning in Hawaii is necessary.

The example of County government approving hazardous land on Kilauea for residential subdividing does not go without saying that there are no good examples of wise land-use planning in the County. On the contrary, all one needs to do is examine the history of land-use planning along the shores of Hilo, where sound land-use planning policies have limited but not necessarily precluded development in some areas of high tsunami hazard since the deadly 1946 tsunami. Residential areas hit hard by the deadly 1946 and 1960 tsunamis were set aside for recreational use only, considerably limiting vulnerability and risk of people and property.

Back to the case study of institutional measures to mitigate volcanic hazards and their effects, especially lava flows. Apart from hardened or engineered strategies to mitigate lava flow hazards, other options include land-use planning to avoid or minimize development in hazardous areas, insurance, and simply bearing of losses. The lack of planning has already been discussed, but the role of residential insurance to protect against losses from lava flow hazards has not. Prior to the destruction of over 200 homes in the on-going eruption of Kilauea, known as the Puu Oo-Kupaianaha eruption, homeowners could insure their homes against damage from fire, even when the home was located in the highest hazard zones. But, with the loss of so many homes in the late 1980's and early 1990's, private insurers began declining homeowner coverage for homes in specific high hazard zones. Since this meant hundreds of potential homeowners would be without insurance, the Hawaii Legislature established the Hawaii Property Insurance Association (HPIA) in 1991 to provide insurance to homeowners, even those in the areas of highest lava flow hazard.

### ***Private Intervention***

There are many actions that can be taken by private individuals to reduce the physical vulnerability of property to volcanic hazards. During the eruption of Kilauea volcano, Hawaii, in 1955, local businessmen hastily constructed earthen barriers with bulldozers to hold back lava from specific land areas. While the barriers at Kilauea were overcome, they provided valuable insight for publicly constructed barriers built during a nearby eruption five years later in 1960. In terms of private interventions dealing with physical vulnerability of buildings to ash fall, individuals are advised to remove ash from rooftops and take precautionary measures to prevent ash from entering buildings. Similarly, they are advised to take actions that prevent the entry of ash into air intake systems associated with mechanical equipment such as automobiles and air conditioning systems.

### ***Civil Society Intervention***

In Hawaii, much land in areas of high lava flow hazard on the southern and southwestern flanks of Mauna Loa volcano have been recently purchased by the US National Park Service to add to the acreage of the Hawaii Volcanoes National Park, which covers portions of both Mauna Loa and Kilauea volcanoes, and by not-for-profit nature conservancies.

## ***Stage III: Evaluation***

### ***Key Factors***

Key social factors that influence physical vulnerability to lava flow hazards in Hawaii are factors such as race and ethnicity, culture, and income. These factors influence the 'culture' of living in areas of high lava flow hazard and beliefs about a) whether or not the hazard can be mitigated and b) whether or not the hazard *should* be mitigated. There are few options for mitigating lava flow hazards. The lack of sound land-use planning to avoid the hazard means that current and future populations are vulnerable. The finding that many people believe there is nothing that can be done to hold back or divert lava leaves the culturally sensitive political decision of planning for, let alone implementing, mitigation actions involving lava retention and diversion postponed until the verge of disas-

ter. While the economic vulnerability to lava flow hazards in lower Puna District is low because of the limited commercial and industrial base there, the limited options for mitigating lava flows and the lack of open planning for mitigating lava flows with available means (barriers, etc) defines the physical vulnerability of all areas susceptible to inundation or isolation by lava. While this discussion has focused mostly on lava flow hazards, volcanic ash and tephra (all particle sizes) and gases are also pose threats, but how people and government approach the ideas of mitigating lava flows hazards with engineered measures is expensive and the cultural, environmental, legal and political ramifications of doing mean that their use is uncertain in future eruptions.