ENSURE PROJECT

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ENSURE E-LERNING TOOL

F19
Examples of methodologies assessing territorial vulnerability

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1 Examples at the regional level

Vulnerability Assessment in the context of the "Disaster Risk Index"
(UNDP, Bureau for Crisis Prevention and Recovery, 2004)

In the case of DRI risk is a function of hazard occurrence probability, the population at risk and vulnerability. In particular, the equation conveying the conceptualized relationship between risk and vulnerability is the following:

R = H ∗ Pop ∗ Vul

Where **R** is the risk (number of people killed)

H is the hazard, depending on the frequency and strength of a given hazard

Pop is the population living in a given exposed area

Vul is the vulnerability and depends on the socio-political-economical context of this population.

The product of hazard multiplied by the population is considered to reflect physical exposure and the above equation turns into :

R = PhExp. Vul

Where **PhExp** is the physical exposure, i.e. the frequency and severity of a hazard multiplied by exposed population

For the calculation of physical exposure of each country to each of the hazard types under examination (earthquakes, tropical cyclones, floods), the area exposed to respective events was identified and the population living there was counted. The result is the average number of people exposed to a hazard event in a given year. Geographical information systems were used for mapping physical exposure to each hazard. Physical exposure varies both according to the number of people as well as to the frequency of hazard events. In the DRI physical exposure is expressed both in absolute and relative terms (i.e. the number exposed per million people).

As to the calculation of Relative Vulnerability the DRI assumes that people are more or less vulnerable to a given hazard depending on a range of social, economic, cultural, political and physical variables. DRI has used the number of people killed by each hazard type in each country as a proxy for manifest risk. The assumption is that the occurrence of past disasters manifests by definition, the existence of conditions of physical exposure and vulnerability (UNDP 2004). Besides DRI considered as manifested Relative Vulnerability –of a country to a given hazard- the quotient of the number of killed people by the number of those exposed.

Consequently the manifest risk was examined against a bundle of social, economic and environmental indicators through a statistical analysis using a multiple logarithmic regression model. A total of 26 variables selected through expert opinions were available as global datasets and analyzed for each hazard type; it was then possible to pick up those vulnerability indicators that were most associated with risk for each hazard type (UNDP 2004). The vulnerability indicators that were found relevant to flood, earthquake and cyclone hazards are presented in the following Table 1.

Table 1: Critical Vulnerability Indicators for Earthquake, Flood and Cyclone Hazards

CATEGORIES OF VULNERABILITY	INDICATORS
ECONOMIC	Gross Domestic Product per inhabitant at Purchasing Power Parities
	Total Debt Service (% of the exports of goods and services)
	Inflation, food prices (annual %)
	Unemployment, total (% of the exports of goods and services)
TYPE OF ECONOMIC ACTIVITIES	Arable land (in thousand hectares)
	% of arable land and permanent crops
	% of urban population
DEPENDENCY & QUALITY OF THE ENVIRONMENT	Forests and woodland (in % of land area)
	Human induced soil-degradation
DEMOGRAPHY	Population Growth
	Urban Growth
	Population Density
	Age Dependency Ratio
HEALTH AND SANITATION	Number of physicians (per 1.000 inhabitants)
	Number of Hospital Beds
	Life Expectancy at Birth for both sexes
EARLY WARNING CAPACITY	Number of Radios (per 1.#000 inhabitants)
EDUCATION	Illiteracy Rate
DEVELOPMENT	Human Development Index (HDI)

Source : UNDP/UNEP

The statistical analysis was based on two major hypotheses. First, that risk can be understood in terms of the number of victims of past disaster events. Secondly, that the equation of risk follows a multiplicative model as in the following equation (UNDP 2004):

$$\mathbf{K = C * PhExp^{a} * V_1^{a1} * V_2^{a2} * \ldots\ldots * V_p^{ap}}$$

Where **K** is the number of persons killed by a certain type of hazard

C is the multiplicative constant

PhExp is the physical exposure, i.e. population living in exposed areas multiplied by the frequency of occurrence of the hazard

Vi are the socio-economic parameters
$\mathbf{a_i}$ is the exponent of Vi which can be negative (for ratio)

By using logarithmic properties the equation was reformulated as follows:

$$\mathbf{ln(K) = ln(C) + aln(PhExp) + a_1ln(V_1) + a_2ln(V_2) + ...+ a_pln(V_p)}$$

This equation creates a linear relationship between logarithmic sets of values. This allowed significant socio-economic parameters Vi and exponents ai to be determined using linear regression.

Since evaluation of DRI referred to the time period 1980-2000 the socio-economic variables that would be tested had to be converted into 21-year averages and only then transformed into a logarithmic value. For those expressed as a percentage a transformation was applied in order that all variables would range between $-\infty$ and $+\infty$ (see equation below). For others no logarithmic transformation was needed (UNDP 2004).

Transformation for variables ranging between 0 and 1

$$\mathbf{V_i' = V_i / (1 - V_i)}$$

Where $\mathbf{V_i'}$ is the transformed variable (ranging from $-\infty$ to $+\infty$)
$\mathbf{V_i}$ is the socio-economic variable (ranging from 0 to 1)

The model of DRI allowed the identification of parameters leading to higher and lower risk. However, it should not be used as a predictive model. Small differences in the logarithmic scale can induce large ones in the modeled number of deaths (UNDP 2004). The respective report of UNDP ("Reducing Disaster Risk – A Challenge for Development") speaks for high and relevant results. Finally, mapping the input and output parameters, factors and synthetic indicators (e.g. numbers of killed, killed per million inhabitants, killed per population exposed) has been an integral part of the whole DRI procedure.

Assessing Regional Vulnerability in the ESPON Hazards Project (2005)
(Kumpulainen 2006)

As it has already been mentioned the methodology of the ESPON Hazards Project has been based on the integrative model for the "Vulnerability of Places" proposed by Cutter (1996). The area unit used for the application of the methodology has been the so-called NUTS 3 region and the results are shown on maps of the EU 27+2. The indicators used have been chosen in order to cover damage potential and coping capacity, as well as the range of all three vulnerability dimensions. The Coping Capacity indicators measure the ability of a region to prepare for, or respond to, a hazard. They measure either human properties or the existence of appropriate infrastructure.

More specifically the methodology considers 6 indicators for the "damage potential" of vulnerability and 11 indicators for "coping capacity". Of the 6 indicators referring to damage potential two are economic, another two have both economic and social content and the remaining two are ecological. In detail the damage potential indicators are the following:

- ✓ Regional GDP/capita
- ✓ Population density
- ✓ Number of tourists or number of hotel beds (this is considered as a coping capacity indicator too)
- ✓ Number and area size of significant natural areas
- ✓ Number and area size of fragmented natural areas
- ✓ Culturally significant sites (e.g. sites included in the UNESCO world heritage list)

The coping capacity indicators are:

- ✓ National GDP/capita
- ✓ Education rate
- ✓ Dependency ratio
- ✓ Risk perception
- ✓ Institutional preparedness
- ✓ Medical infrastructure
- ✓ Technical infrastructure
- ✓ Alarm systems
- ✓ Share of budget spent on civil defense
- ✓ Share of budget spent on research and development

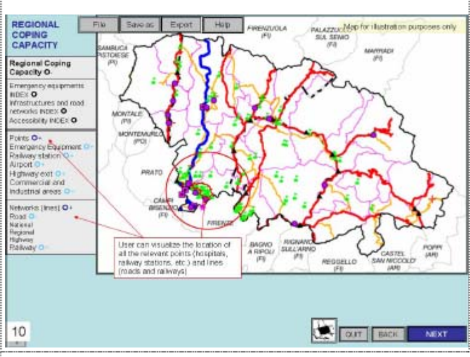
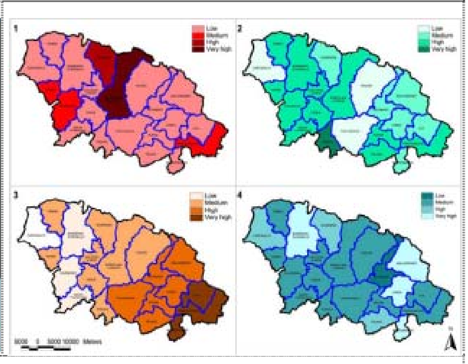
When it came to actual application however, some serious problems emerged; several indicators could not be used or evaluated due to a lack of data or difficulties in quantification (for instance institutional preparedness and risk perception proved impossible to measure). Due to these difficulties only four indicators were finally used (regional GDP/capita, population density and the extent of fragmented natural areas as damage potential indicators and national GDP/capita as coping capacity indicator). The integrated then regional vulnerability index (and consequently map) results as the aggregate of the homogenized indicators where regional GDP contributes with a weight of 30%, population density with 30%, fragmented natural areas with 10% and national GDP with 30%.

Mapping Regional Vulnerability in the context of ARMONIA (Framework Programme "Applied multi Risk Mapping of Natural Hazards for Impact Assessment"), Deliverable 5.1, EU STREP VI 2004-2007
(Galderisi and Menoni, 2007)

This methodology is representative of the strand dealing with vulnerability of territorial systems for the purpose of supporting spatial planning risk mitigation policies. The following Table 2 summarizes the basic features of the methodology.

Table 2: ARMONIA methodology for Regional Vulnerability Mapping
with reference to Multi-Hazard conditions (Galderisi and Menoni, 2007)

Type of hazard:	Multi risk (earthquake, landslide, flood, forest fire, volcanic risk)
Scale:	Regional
Territorial vulnerability approach:	The multi-dimensional concept of vulnerability expresses the capacity of a system to face a hazardous event, with respect to direct damages, such as physical damages and consequent human suffering, and indirect damages due to incapacity of a system to face the event (e.g. inadequacy of road network which impedes rescue team access). The methodology takes into account: physical vulnerability of building stock; vulnerability of population; coping capacity, i.e. the availability of resources (quantity and hierarchical level of emergency equipment; infrastructure and roads; accessibility from the external territory) enabling each municipality to face a hazardous event.
Aim:	The aim of the ARMONIA project is to provide the EU Commission with a harmonized methodology for producing integrated risk maps to achieve more effective spatial planning procedures in areas prone to natural hazards. The assessment is part of a Decision Support System for achieving land-use planning processes fully informed both about the hazard, exposure and vulnerability of different land-uses and the options available to mitigate the risks.

General description of the methodology:	For each hazard, exposure and vulnerability of people and building stock are considered. The coping capacity is the same for all hazards. The coping capacity indicators are aimed at evaluating the services (in terms of strategic equipments such as hospitals, fire brigades, etc. and in terms of road networks) of different regional areas (municipalities) for facing the emergency phase following a hazardous event and the accessibility from external areas to each municipality. The lack of aggregate indexes of vulnerability is due to the deliberate choice of providing land-use planners with disaggregated information as supporting tool for the definition of mitigation measures.
Assessment procedure:	Coping capacity indicators referred to strategic facilities, infrastructures and road network accessibility, are applied with respect to municipalities and are defined as the product of the density of the considered element (e.g. the number of emergency facilities in the municipal area) by a weight coefficient from 1 to 3 representing its hierarchical level. The values obtained are ranked into 4 classes with a "natural breaks" statistical method. Aggregated indexes are not provided.
Main indicators of territorial vulnerability:	The emergency equipment index for each municipality ($Iem=(\Sigma iWi*Ei)/Sa$) is related to the number of emergency equipments (Ei) and to their hierarchical level (Wi is a weight coefficient from 1 to 3 for local, urban, regional level). The Infrastructures and road networks equipment index ($If=Inf+Ip$) is the sum of an index ($Inf=(\Sigma iWi*INFi)/Sa$) related to the surface of infrastructures ($INFi$) and their hierarchical level (Wi is a weight coefficient from 1 to 3 for local, urban, regional level) and an index ($Ip=(i\ Wj*Rj)\ /Sa$) related to the length of roads (Rj) and their hierarchical level (Wi is a weight coefficient from 1 to 3 for highway, national, regional roads). The accessibility index ($Ia=(\Sigma i\ Wi*Ai)/Sa$) takes into account the number (Ai) and the hierarchical level (Wi is a weight coefficient from 1 to 3) of the 3 classes of main access road typology (highway, national, provincial). All the indexes have been referred to the surface of the municipality (Sa) and ranked into 4 classes.
Input data:	The assessment is implemented within a GIS environment. Data have been collected and processed with regard to census units and aggregated with respect to each land-use within a municipality. Data referred to the coping capacity have been collected and processed directly at municipality level. Although census data have been used for exposure and vulnerability, coping capacity data have been collected from cartographical material and thematic maps.
Example views:	 

Assessing and Mapping Vulnerability of Lifelines to Earthquakes: An Italian Research Work developed within the POLIMI Activity Programme 2001-2003
(Menoni et al., 2007)

The present case refers to lifelines, where a territorial approach has been clearly adopted in order to address the vulnerability of such systems that clearly goes beyond the sum of the vulnerability of individual elements, be them joints, plants, or segments. The notion of systemic vulnerability, meaning interdependence between lifelines and between the latter and other urban and regional systems is central to the developed methodology (see Menoni et al. 2007)

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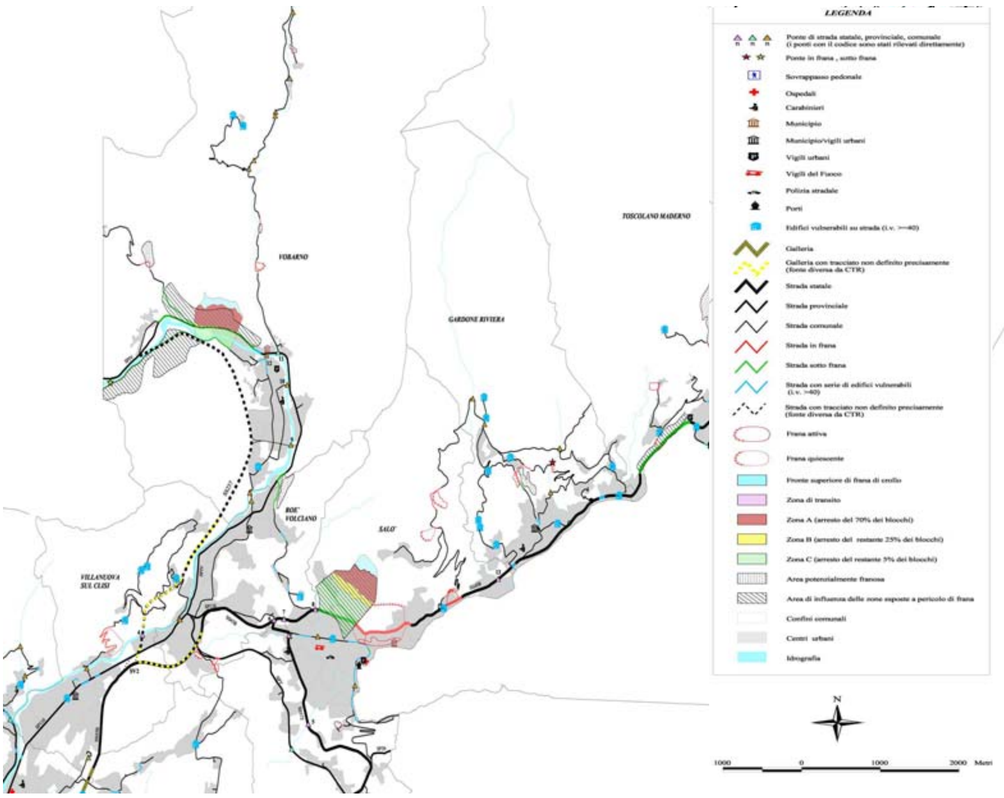
Table 3: Lifelines vulnerability assessment to earthquakes

Type of hazard	Seismic
Scale	Large areas
Territorial vulnerability approach	Vulnerability is interpreted as a complex concept comprising physical, systemic, functional and organisational aspects, addressing the main issue of how prone are lifelines to stop functioning as a consequence of physical damage and service interruption after an earthquake
Aim	To provide a methodology for assessing the vulnerability of lifelines to earthquakes, considering both the emergency and the recovery/reconstruction phases.
General description of the methodology	The methodology is based on an assessment matrix comprising physical, systemic and organisational vulnerabilities related to lifelines and to urban and regional systems dependence on lifelines. The result of the assessment matrix can be represented in tables and in maps
Assessment procedure	The method can be run either at a municipal level or evaluating the individual lifelines segments whenever data are available for a more detailed survey and assessment
Main indicators of territorial vulnerability	Systemic and organisational parameters are territorial in their very nature, as they refer to systems' relations and to the consequences public administrations' decisions have on lifelines functioning. Indicators such as redundancy versus uniqueness, accessibility, siting of lifelines with respect to each other are some of the key parameters that have been proposed and assessed in the application to the Brescia province (Lombardia).
Input data	The assessment is implemented in a GIS environment composed of point shaped elements, corresponding to plants, and linear elements, corresponding to segments of the network. The input data are obtained by cartography, surveys, structured interviews with responsible personnel of lifelines managing companies.

Example views	

2 Examples for a Functional Urban Area (FUA) or at the metropolitan level

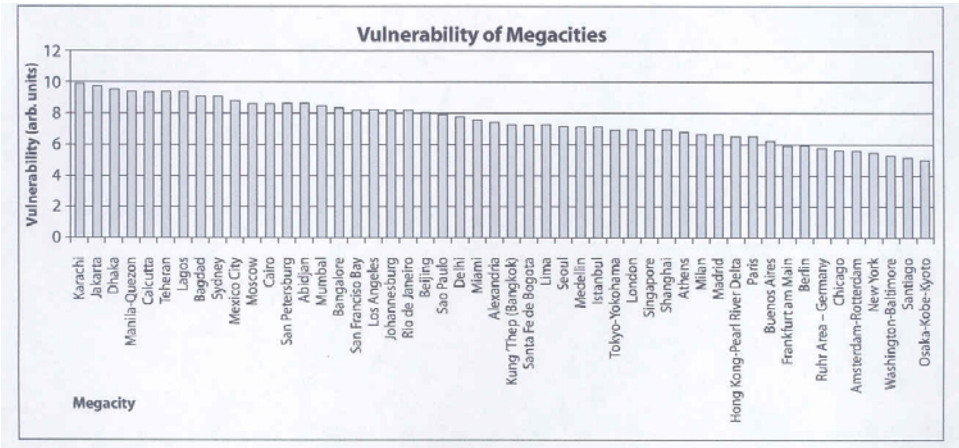
<u>Physical Vulnerability at Mega-city Scale: The Munich Re Approach</u>
(Munich Re 2003)

As the method attempts to evaluate the fragility of the physical structure of Mega-cities the determinant parameters used represent issues that express or influence the structural resistance of the urban fabric:

- Structural vulnerability: related to the building classes most predominant in the city;
- Standard of preparedness / safeguards: associated with the existence of building regulations, town and country planning with respect to hazards; and
- General quality of construction and building density.

Structural vulnerability, preparedness and quality of construction were assessed using a four degree scale (very good, good, average and below average). Building density was represented through population density and was normalized in a range from 0 to 4 units. The three components were assigned equal weights and combined to generate a single indicator for each city. Figure 1 displays vulnerability -in arbitrary units- of several mega-cities. The list is headed by Karachi, Jakarta, Dhaka, Manila and Calcutta. The cities with the lowest vulnerabilities are Washington-Baltimore, Santiago and Osaka-Kobe-Kyoto. What is interesting about the findings of the approach is that vulnerability of cities does not seem to correlate with their population size (Villagrán de León, 2006).

Figure 1: Vulnerability of several Megacities according to the Munich Re approach
Source: Villagrán de León (2006)



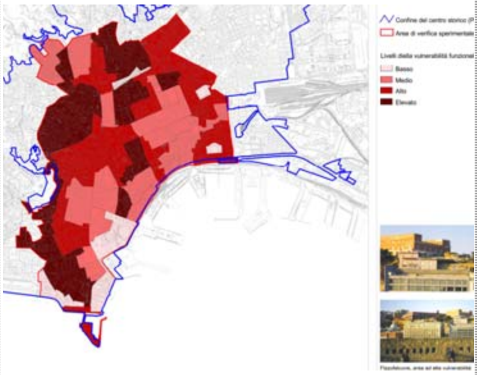
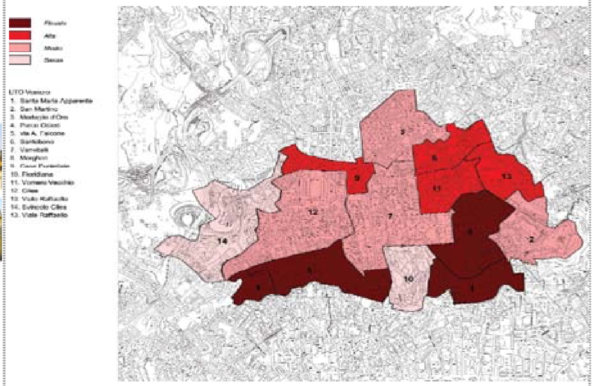
City-Metropolitan Vulnerability according to the Italian CIPE-MURST Research Project: "The seismic risk protection: vulnerability, analysis and requalification of the physical and built environment with innovative techniques"
(UNINA / Di.Pi.S.T. 2003; Galderisi, 2004)

This methodology too is representative of the Italian strand dealing with vulnerability of territorial systems for the purpose of supporting spatial planning risk mitigation policies. The following Table 4 summarizes the basic features of the methodology.

Table 4: CIPE-MURST methodology for City-Metropolitan level Vulnerability Mapping with reference to Earthquakes (UNINA / Di.Pi.S.T. 2003, Galderisi 2004)

Type of hazard	Earthquake
Scale	City – Metropolitan urban areas
Territorial vulnerability approach	The urban system vulnerability is due to many factors, such as physical, functional, social, enabling the city to cope with a seismic event. The focus of the research work is on functional vulnerability, interpreted as tendency of the city towards functional crisis due to the lack of correspondence between the high demand for activities and services from the population hit by the earthquake and the spatial organization of urban fabric.

Aim:	To provide an easy-to-apply seismic risk assessment procedure for large urban systems in order to define priority intervention areas.
General description	First, spatial units, representing the cells of a spatial orthogonal grid for the assessment, have been singled out on the basis of site morphology, census unit borders, and on functional and physical features of the settlement being analyzed. In the spatial units so defined, the exposure and functional vulnerability assessment has been carried out. The values obtained from the exposure and functional vulnerability indicators have been ranked into 4 classes (Low, Medium, High, Very High) through the natural breaks method.
Assessment procedure	The level of functional vulnerability is expressed by ranking into four levels (Low, Medium, High, Very High) the Ivf indicator. The latter is obtained as the product of two indicators representing the regularity of the form of the urban fabric (Ivm) and the type of spatial concentration of physical town planning elements characterizing the urban fabric (Iva). The first indicator, which varies from 1 to 2, is defined on the basis of a typological classification of urban fabrics according to their regularity of form. The second one is the sum of six basic indicators, normalized between 0 and 1, representing building density and other elements of the urban fabric, such as public and private open spaces, roads, buildings, etc.
Main indicators of territorial vulnerability	The basic indicators (I1 to I6) that define the Iva indicator, are the following: • the relation between the surface occupied by buildings (Sc) and the area of the spatial unit under consideration $(Sc/St)^{-2}$; • the ratio between private open spaces (Sa) and the surface occupied by buildings $[1 - (Sa/Sc)]^2$; • the ratio between public open spaces (Sp) and the area of the spatial unit under consideration $[1-(Sp/St)]^2$; • the ratio between road surface (Sm) and the area of the spatial unit under consideration $[1 - (Sm/St)]^2$; • the building density $(Dt/10)^{-2}$; • the average distance expressed in meters (Lm) between the fronts of the buildings and street line along the road network (if Lm < 5 m then I6 = 1; if Lm > 15 m then I6 = 0, if 5m < Lm < 15 m then I6 = (15-Lm)/10).
Input data	The vulnerability assessment is implemented through a GIS, processing data obtained from cartographical material; only building heights have been reported from in situ surveys.

Example views:		

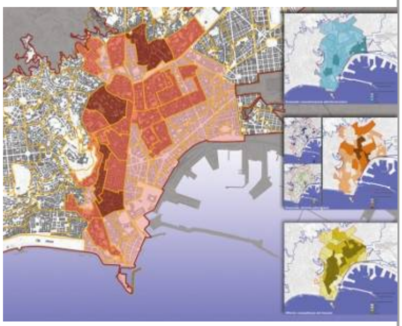
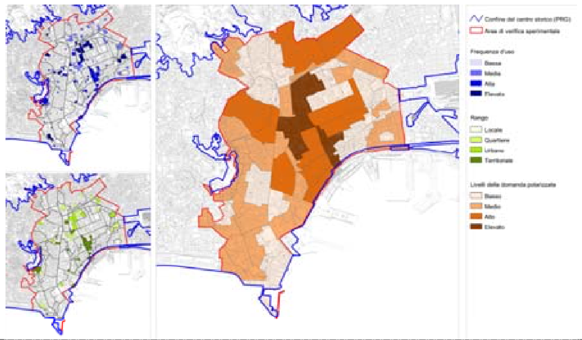
<u>*Mapping Vulnerability of Historical City-Centres: An Italian Research Project*</u>
(UNINA / Di.Pi.S.T. 2004; Menoni, 2004; Ceudech, 2007)

The methodology is again characteristic of the Italian strand that focuses on the concept of vulnerability of "territorial systems" for the purpose of optimizing risk mitigation and particularly seismic protection policies through spatial planning. The following Table 5 summarizes the basic features of the methodology.

Table 5: Systemic Vulnerability in Italian Historical City-Centres
(The methodology of the Italian research project "The Safeguard of the Historical Landscape and Cultural Heritage of the Italian Seismic Risk Areas" 2002-2004)

Type of hazard	Earthquake
Scale:	City – Metropolitan urban areas with relevant historical centre
Territorial vulnerability approach	Vulnerability is a multi-dimensional concept, interpreted as propensity of the city to be damaged by a seismic event. The systemic vulnerability concept highlights the incapacity of the urban system to cope with the seismic event and it is referred to the relationships among urban sub-systems, to the functional interdependency of urban areas, to the incapacity of the city to supply the population hit by the earthquake with adequate services and equipments.
Aim	To single out priority areas characterized by high levels of systemic vulnerability in historical centres of large urban systems

General description of the methodology	The systemic vulnerability assessment is based on the definition of territorial units (HTU) which are homogeneous in terms of age, types and features of urban fabrics and demarcated with reference to census unit boundaries. The demand assessment has been related to the number of users both of residential and tertiary activity and of urban activities. The supply depends on the functional and spatial features of territorial units, which can be measured through indexes referred to the compactness of the urban fabric, the permeability of the road network, the accessibility for the rescue teams. The comparison between demand and supply defines "critical" areas.
Assessment procedure	The demand assessment is referred both to spatially distributed activities (PId) and to polarized ones (PIp). For what concerns the former, 2 indicators have been selected (population density and concentration of tertiary activities). The values obtained have been ranked into 3 classes (high, medium, low) and then scores varying from 3 to 1 have been assigned to each class. The ranking into 3 classes of the sum of these scores defines the level of demand arising from spatially distributed activities. For what concerns polarized activities, the hierarchical role and frequency of use have been considered. The sum of all the scores, normalized and then ranked into 3 classes, assigned to each activity which is included in the HTU under consideration defines the level of demand generated by polarized activities (Pp). The sum of PId and PIp, obtained by assigning scores to the demand levels (3 for High, 2 for Medium and 1 for Low), ranked into 3 classes, defines the demand level of each HTU (1-2 Low, 3 Medium; 4-6 High). For what concerns supply assessment, indicators referred to the amount of infrastructures which can be found in each HTU, the compactness of urban fabric, the permeability of secondary road network and the accessibility to rescue teams have been taken into account. Each indicator has been normalized and ranked into 3 classes (low, medium, high). The supply level of HTUs is defined by ranking into 3 classes the ratio between the sum of the scores obtained for each indicator and the maximum possible supply score. The systemic vulnerability level is obtained through the difference between the demand and supply levels of each HTU obtained by assigning a score variable from 1 (low) to 3 (high).
Main indicators of territorial vulnerability	For what concerns the demand of spatially distributed activities, the ratio between population density of the HTU and the average population density of the analyzed area and the tertiary density index, defined as ratio between number of tertiary activities and total amount of tertiary activities of the study area per 1000, have been considered. For what concerns the polarized activities, to each activity a score, variable from 1 to 3, related to its hierarchical role is assigned (territorial, urban and neighbourhood level). The frequency of use is defined as the amount per month of operating hours for each activity (low frequency for 26 hours/month, high frequency for over 240 hours/month). For what concerns the supply, the infrastructure index (Sv\St) expresses the ratio between road surface (Sv) and the area of the HTU (St); the index expressing compactness of the urban fabric is defined as the sum of 3 indexes: building density (Dt), ratio between the area covered by buildings and the HTU surface (Sc\St), ratio between open spaces and surface of the HTU (1 - Sa\St); the permeability of secondary road network is obtained through the sum of 3 indexes referred to the average length of the secondary roads (Lm), average gradient of secondary roads (Pm), average of the percentage of the length of curved roads over the total length of secondary roads. The accessibility index takes into account the gravitational areas of each emergency activity and the redundancy due to the presence of more facilities in the area.

Input data	The systemic vulnerability assessment is implemented through a GIS. Inputs used were processed census data, data obtained from cartographical sources and some data obtained from *in situ* surveys such as building height.
Example views	 

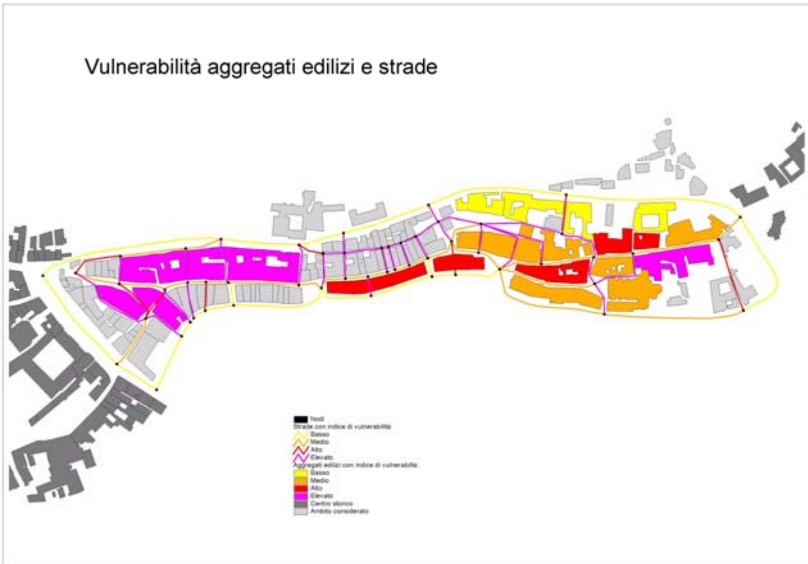
Assessing Vulnerability to Earthquakes of Historical City-Centres: An Italian Research Project

(The methodology within the Italian research Activity Programme of the POLIMI 2002-2004)

The present case relates to the vulnerability assessment of a small historic centre; in this case the key notion is the identification of specific characteristics of historic towns that make them unique and therefore vulnerable also to the potential loss of cultural identity.

Table 6: Assessment of historic centres vulnerability to earthquakes

Type of hazard	Seismic
Scale	Local scale
Territorial vulnerability approach	Vulnerability is interpreted as a complex concept comprising physical, systemic, functional aspects, related to the influence of buildings vulnerability on city functions and to the vulnerable features that are specific to historic centres (structural blocks, relationship between built and open space, accessibility)
Aim	To provide a methodology for assessing the vulnerability of small historic centres
Description of the methodology	The methodology is based on a number of consequent vulnerability assessment maps and tables, addressing the vulnerability of buildings, structural blocks, roads, electric lines, open spaces.
Assessment	Each aspect is addressed separately and then combined in the damage scenario

procedure	assessment
Main indicators of territorial vulnerability	Indicators of vulnerability include the vulnerability of blocks considered as a unique structure as oppose to the vulnerability of individual buildings, the vulnerability of decorative elements, that, though not fundamental for resistance purposes are important for keeping the historic centre ambience.
Input data	The assessment is implemented in a GIS environment composed of point shaped elements, corresponding to buildings, open spaces and linear elements, corresponding to segments of the road and electric network. The input data are obtained by cartography, in situ surveys.
Example views	

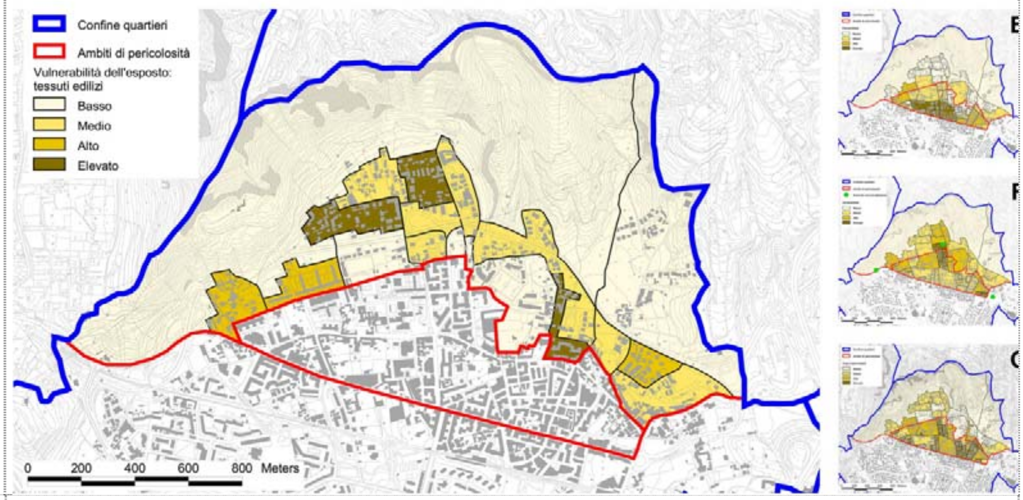
3 Examples at the neighbourhood level

Mapping Neighbourhood Vulnerability and Risk to Mud Flows: An Italian Research Work developed within the UNINA-DIPIST Activity Programme 2006-2008
(UNINA / Di.Pi.S.T. 2008; Galderisi and Ceudech, 2008)

The methodology is again characteristic of the Italian strand that focuses on the concept of vulnerability of "territorial systems" for the purpose of optimizing risk mitigation (in this case protection against mud flows) through spatial planning. The following Table 7 summarizes the basic features of the methodology.

Table 7: Neighbourhood Vulnerability to mud flows
(The methodology within the Italian research Activity Programme
of the UNINA / DiPiST 2006-2008)

Type of hazard	Hydro geological – Rapid mud flows
Scale	Neighbourhood - Urban areas prone to mud flows
Territorial vulnerability approach	Vulnerability is interpreted as result both of the physical features of individual buildings and of specific features of urban fabric such as, for example, accessibility from the main road network or the permeability of the local road network, which may affect the possible exodus of population from the affected area and the access of emergency rescue teams.
Aim	To provide a method for assessing the risk related to rapid mud flows aimed at supporting mitigation actions to be implemented through local urban plans.
General description of the methodology	Based on the available hazard maps and on back-analyses, the different areas prone to the mud flows are defined. In the two types of identified hazard areas (impact and mud deposit), the exposed elements of any given spatial reference unit (census unit) are identified. The selected exposed elements are population, urban fabric, productive activities, public activities, infrastructures, agricultural areas, forests. For the linear, such as roads and railways, and areal elements exposure and vulnerability indicators are applied in order to obtain a relative and not aggregated assessment.
Assessment procedure	In each census unit, indicators of each exposed element are applied. The values obtained are ranked into 4 classes (low, medium, high, very high) through a "natural breaks" statistical method and a score, with values from 1 (low) to 4 (very high), is assigned to each class. For each exposed element, the final vulnerability level is defined as the sum of the assigned scores of each indicator, ranked into 4 classes.
Main indicators of territorial vulnerability	For the exposed urban fabric, apart from indicators describing physical vulnerability, two indicators, specifically aimed at taking into account the territorial aspects of vulnerability, are defined: the accessibility index, related to the minimum real distance from the gravity centre of each census unit to the point of access to an urban highway; the permeability index which depends on the length of road network, broken down to road classes, and on weight coefficients related to the average width, gradient and regularity of the road network.
Input data	The assessment is implemented in a GIS environment composed of areal elements, corresponding to census units, and linear elements, corresponding to infrastructure networks. The input data are both statistical data and data obtained by cartography, aerial photos and *in situ* surveys.

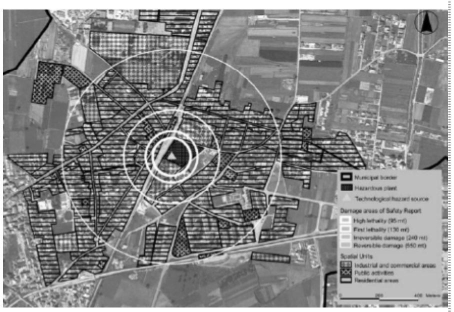
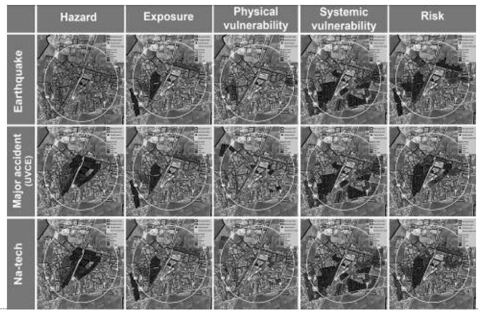
Example views	

<u>Assessing and Mapping Neighbourhood Vulnerability to Natechs: An Italian Research Work developed within the UNINA-DIPIST Activity Programme 2005-2008</u>
(UNINA / Di.Pi.S.T. 2008; Galderisi and Ceudech, 2008)

The methodology is again characteristic of the Italian strand that focuses on the concept of vulnerability of "territorial systems" for the purpose of optimizing risk mitigation (in this case protection against Na-techs) through spatial planning. The specific case considered is UVCE triggered by seismic event. The following Table 8 summarizes the basic features of the methodology.

Table 8: Neighbourhood Vulnerability to Na-techs

Type of hazard	Na-tech – Seismic event triggering UVCE
Scale	Neighbourhood - Urban area prone to Na-tech event
Territorial vulnerability approach	The vulnerability concept includes physical, systemic, organizational and social vulnerability. The method is focused on the first two components, since these are the most directly related to the spatial and functional organization of the city which are, in turn, the main field of action of land use planning and management. Systemic vulnerability mainly refers to the features of the territorial system which may influence the emergency response and management activities following the event, such as the accessibility to the emergency equipment in the impacted area.
Aim	A risk assessment method as a supporting tool for land use planning strategies aimed at reducing Na-tech risk in urban areas is developed.

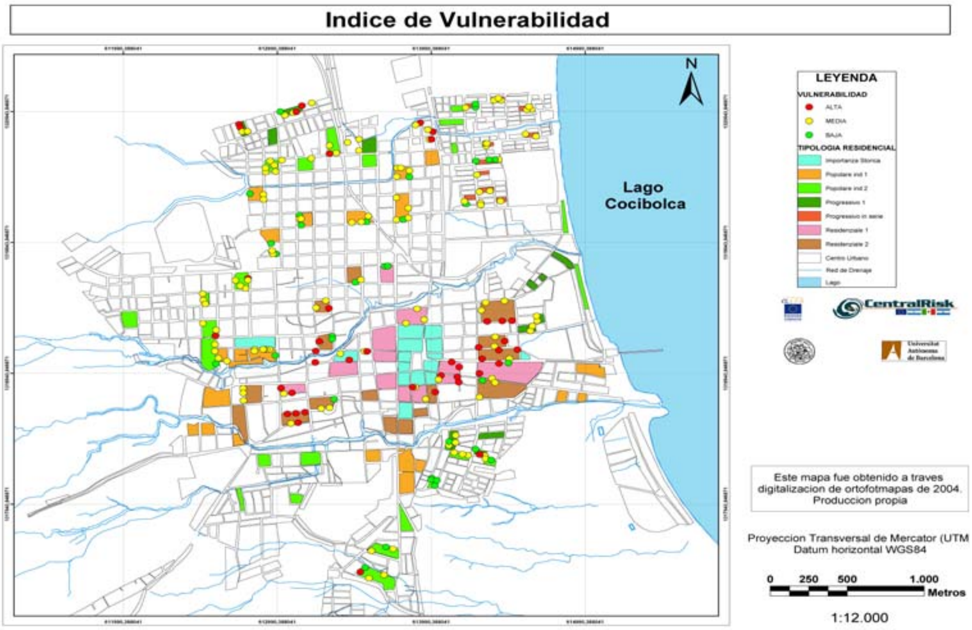
General description of the methodology	The method allows planners to take into account all the individual Na-tech risk factors, measured through both quantitative and qualitative parameters, while providing them with a Na-tech risk index, useful to rank territorial units and to single out the priority intervention areas. The method is designed to process information generally available about hazardous plants (safety reports), natural hazards (hazard maps) and features of urban systems mainly influencing their exposure and vulnerability to Na-tech events. The necessity of dealing with heterogeneous data coming from several disciplines and related to different risk factors, and of considering "uncertainties", has motivated us to adopt fuzzy techniques to handle unquantifiable or linguistic information.
Assessment procedure	Based on available maps and information, the identification of Na-tech-prone areas can be carried out through the overlaying of the natural and technological hazard-prone areas. The latter can be divided into spatial units (SUs) based on census units, combined with the main land uses (residential, industrial, agricultural, etc.). Then hazard, exposure and vulnerability features for each SU have to be measured using fuzzy techniques and indicators normalized and processed through a MADM. The SUs are the "alternatives" of the MADM, while hazard, exposure and vulnerability indicators are the "attributes". The aggregate Na-tech risk index can be defined through the final rating of the attributes (average of the attributes' values). Priority intervention areas can be singled out through the ranking order of the alternatives with respect to the Na-tech risk index.
Main indicators of territorial vulnerability	Parameters related to systemic vulnerability refer to the accessibility to emergency equipment (hospitals and fire brigades), measured through the maximum distance between the gravity centre of the SU and the emergency equipments, and to the accessibility of the SUs by the rescue teams (only the residential ones). The latter (internal accessibility) has been defined through the normalized sum of qualitative judgments (high, medium, low), converted through fuzzy techniques into numerical scores, related to the urban fabric compactness (building density, presence of open spaces, etc.), the gradients of the secondary road network and its irregularity (orthogonality of crossroads, regularity of building plots, presence of winding roads).
Input data	The method is implemented in a GIS framework to easily provide planners with comparable maps able to figure out the hazard factors and the territorial features influencing the exposure and vulnerability and is fully based on common census data.
Example views	 

Urban Vulnerability Assessment in a Developing Country: Implementation of the POLIMI methodology within the Alfa funded project Centralrisk 2004-2006
(Andrés and Rodriguez, 2008)

This case refers to an experience developed in the context of a EU funded project under the Alfa program of cooperation with Central America. It is shown how the methodology can be applied at relatively moderate costs also in developing countries, providing as an output interesting suggestions for retrofitting and mitigation.

Table 9: Urban vulnerability assessment in a developing country adopting the POLIMI methodology

Type of hazard	Seismic
Scale	Local scale
Territorial vulnerability approach	Vulnerability is interpreted as a complex concept comprising physical, systemic, functional aspects, related to the influence of buildings vulnerability on city functions
Aim	To provide a methodology for assessing the vulnerability of cities in developing countries
General description of the methodology	The methodology is based on a number of consequent vulnerability assessment maps and tables, addressing the vulnerability of buildings, structural blocks, roads, electric lines, water conducts, open spaces. It is shown how the methodology can be applied and provide useful mitigation suggestions in a developing country. In particular this work has been conducted in the city of Granada, Nicaragua, in the context of an Alfa funded project, Centralrisk.
Assessment procedure	Each aspect is addressed separately and then combined in the damage scenario assessment
Main indicators of territorial vulnerability	Indicators of vulnerability include the vulnerability of buildings, block of buildings, lifelines, public facilities. It considers also induced risks, due to the presence of industrial facilities.
Input data	The assessment is implemented in a GIS environment composed of point shaped elements, corresponding to buildings, open spaces and linear elements, corresponding to segments of the road and electric network. The input data are obtained by cartography, in situ surveys.

Example views	

Processes of Seismic Vulnerability Redistribution: Small Manufacturing Firms in Western Athens after the Earthquake of September 9/1999

(HUA research project 2003 and Sapountzaki 2005)

The whole approach has been based on two basic methodological assumptions:

(a) The breakdown of vulnerability into three constituent components as these have been perceived by Pelling (2003), namely exposure, resistance and resilience.

(b) The conceptual division of urban entities (or micro-territorial units or social domains) into two basic categories the producers and carriers of vulnerability.

As it has been already mentioned the approach does not assess territorial vulnerability to seismic hazard (of the area covered by eight Municipalities of Western Athens) with conventional methods (i.e. GIS, mapping etc). It outlines instead processes of transference of vulnerability from macrostructures to individual agencies and micro-territories, from institutions and the political-administrative system to individual building structures and private social entities, or vice versa from one social domain to another and finally to the wider urban territory. Hence, the value of this approach as regards territorial vulnerability rests on the possibility it offers to locate the origins of territorial vulnerability and its dynamics (from and towards private and collective entities and institutions, higher and lower order spatial scales).

As regards the Exposure element of vulnerability to seismic hazard of SMFs in Western Athens, it has been documented by the study that this is more or less external and involuntary, i.e. beyond the control and coping capabilities of the entrepreneurs. Exposure in this case originated mostly from macro-structures and institutional factors: the location and structure of the wider Metropolitan Region, the vulnerable conditions of the physical structure of the western Athenian districts, the building networks that breach building law and land use regulations, the Governmental authorities that turn a blind eye to breaches of the law. The responsibility of SMFs for their overall exposure has been limited, owing basically to contraventions of health and safety rules in industrial premises. This has been evidently the case in rented accommodation. In such cases producers of vulnerability have been the landowners, the builders and all those whose actions had had harmful effects on the endurance of the industrial premises. Among the vulnerability producers are governmental agencies and administrative authorities, which allowed thousands of builders and private individuals to form and change for the worse the built environment of Western Athens. Thereby institutions and macro-economic structures in Greece produced over and there vulnerable urban districts and increased the exposure element of vulnerability of distinct social domains and micro-territorial units (Sapountzaki 2005).

Resistance in the case of SMFs was defined by the study in terms of their economic and other reserves that are not directly impaired by physical damage and which the firms can afford to draw on for their post-disaster recovery. (In this sense profitability, liquidity, the degree of dispersal of fixed capital, being a franchise or part of a chain instead of an individual, single location firm, the proportion of reserve funds vis-a-vis net fixed assets, outstanding debts, staff commitment and company reputation are all factors that affect the firm’s resistance potential).

The resistance potential of the SMFs of Western Athens has been found by the study to be very low, due basically to their smallness. These were found to be individual, single location firms with low levels of profitability and an extremely restricted cash flow. They were saddled with debts, had a minimal number of long-term, regular employees committed to the firm and their fixed capital was more or less concentrated in one place. In this regard increase of the resistance potential depended on growth and development of the firm. It was proved then that resistance is an attribute that is determined primarily by the same the agency or the socio-spatial domain under stress. Surely, governmental institutions may increase or decrease resistance of firms and other agencies by means of public policies but resistance rarely is a property that is transferable from one agency to another within the context of the free-market regime.

By contrast with resistance the Resilience potential of SMFs in Western Athens proved to be high and most of them owe their recovery to this potential. This was related to flexibility and the capability of firms to operate with the help of informal practices that eliminate and externalize recovery costs. Such practices however may increase the vulnerability burden placed on interconnected agencies, subsystems or social domains. The study acknowledged as resilience assets the following availabilities: access to credit; multiple suppliers and customers and/or product markets that are geographically dispersed; family and social support networks; formal or informal insurance; rental status facilitating mobility; flexible forms of employment; access to political and administrative mechanisms and trade union membership providing access to resources and political power. The SMFs considered were in a position to draw on several of these assets. According to the study the most important "asset" was the informal, semi-illegal character of the socio-economic environment within which SMFs operated. As a result the owner and family members could work extra hours, illegal immigrants could be employed, mandatory contributions did not have to be paid, activities and assets could be concealed and companies could function without a legal permit from the appropriate agencies (HUA 2003). These defensive practices facilitate externalization of recovery costs and act as a lifebelt for firms that otherwise would face definite closure The same spatial, institutional and socio-economic macro-structure that created exposure problems for SMFs lend them resilience through a diffused nexus of informal conveniences and relieved them of a part of their vulnerability (Sapountzaki 2005).

The recovery process after the seismic event of September 7, 1999 in Western Athens has been a series of successive comings and goings of vulnerability. When governmental institutions had the upper hand they attempted redistribution of vulnerability by favouring decrease of physical vulnerability alone and leaving socio-economic vulnerability to increase (i.e. to be transferred to disadvantaged social and economic agencies). Conversely when individual agencies assume the leading role in recovery they shift vulnerability burden to other (interconnected) agencies and the macro-structure of the city.

4 Examples at an *ad hoc* spatial scale for territorial vulnerability to floods

Considerations of territoriality and vulnerability to floods introduce the complication of hydrological/hydrographical territorial units and the scalar hierarchy which is commonly used in flood risk research, planning and management:

- river basin/catchment level (which may in some circumstances be international in composition);
- compound catchment level e.g. estuary planning units;
- sub-catchment level or shoreline (coastal) unit level;
- floodplain management units.

However, existing approaches to territorial vulnerability to floods are also commonly organized using the following scalar hierarchy:

- regional level (this may be equated with the river basin/catchment level)
- functional urban area or metropolitan level (may be located within or span compound catchments, catchments or sub-catchments)
- floodplain community level (may be located within compound catchments, catchments or sub-catchments)

- individual household, individual business or individual person level (may be located within compound catchments, catchments or sub-catchments)

The research team of Middlesex University has elected to employ a combination of these scales, distinguishing between six levels which reflect our consideration of territorial vulnerability and floods. Methodologies are numbered in parentheses so that they may be cross-referenced to Table 7 below. Hewitt's (1997) methodology is not referred to further below because, although his methodology can be described as a human ecology perspective on disaster, his work addresses territories at all scales.

The identity given to the methodologies below is hardly ever clearly named and expressed in the publications to which MDX refers, and therefore the titles given to these methodologies have been chosen by the MDX team. Note that the numbers in parentheses in the left-hand column of Table 10 refer to the same numbers also in parentheses in the following sections discussed below.

Table 10: Parameters/indicators according to scale of territory

Parameter or indicator used in methodology (methodology number)	River basin/ catchment / regional level	Compound catchment/ metropolitan level	Functional urban/ metropolitan level	Sub-catchment / shoreline unit level	Floodplain community/ floodplain management unit level	Individual household, business and floodplain occupant level
River discharge (1)	✓					
Floodplain type (1) (2)	✓					
Flooding type (1) (4) (6) (12) (13)	✓	✓				✓
Depth of flooding (1) (2) (6) (10) (12) (13)	✓			✓		✓
Speed of flooding onset (13)						✓
Physiographic & agro-ecological region type (1)	✓					
Degree of adaptation of building or settlement patterns and infrastructure to flooding (1) (2) (6) (10) (13)	✓	✓		✓		✓
Land ownership type (owner/tenant) (1) (9) (10) (13)	✓			✓	✓	✓
Degree of adaptation of cropping patterns to flooding (1)	✓					
Environmental factors (changes in river courses, human interventions, global warming (1) (6)	✓					

Parameter or indicator used in methodology (methodology number)	River basin/ catchment / regional level	Compound catchment/ metropolitan level	Functional urban/ metropolitan level	Sub-catchment / shoreline unit level	Floodplain community/ floodplain management unit level	Individual household, business and floodplain occupant level
Dwelling type distinguished by construction materials used or no. of storeys (2) (10)	✓			✓		
Size of business enterprise (2)	✓					
Type of business enterprise (2)	✓					
Flood awareness (2) (6) (10) (12) (13)	✓	✓		✓		✓
Flood forecasting accuracy (6)		✓				
Flood warning response (2) (6) (10) (12) (13)	✓	✓		✓		✓
Household characteristics (affecting health damage) (2) (7) (8) (9) (10) (12) (13)	✓		✓	✓		✓
Monthly income compared to monthly house rental values (7)			✓			
Existing health status (12)						✓
Incidence of diaorrhoeal disease & causes of morbidity (2) (7)	✓		✓			
Capital intensity of business enterprises (affecting flood damage) (2)	✓					
Linkage effects in the economy (2)	✓					
Urban sprawl and development, regeneration of floodplains (3) (6)		✓				
Co-location of premier banking and finance centre within floodplains (4)		✓				
Income inequality and social polarization (3) (9)		✓		✓	✓	
Public flood risk information accessibility and availability (3) (6) (7) (8) (13)		✓	✓			

Parameter or indicator used in methodology (methodology number)	River basin/ catchment / regional level	Compound catchment/ metropolitan level	Functional urban/ metropolitan level	Sub-catchment / shoreline unit level	Floodplain community/ floodplain management unit level	Individual household, business and floodplain occupant level
Degree and effectiveness of institutional or community learning (3) (13)		✓				✓
Gender of motorists/drivers/ householders (5) (8) (12)		✓	✓			✓
Optimism bias of drivers (under-estimation of flood risk) (5) (8)		✓	✓			
Degree of flood experience (4) (5) (8) (12) (13)		✓	✓			✓
Direction of change of flood risk management policy (i.e. increasing or decreasing the flood risk) (6)		✓				
Climate change (6)		✓				
Rate of deterioration of existing flood defences (6)		✓				
Risk of failure of flood defences (6)		✓				✓
Degree of organisation and effectiveness potential of emergency services (6) (13)		✓				✓
Population density (6) (9)		✓		✓	✓	
Homelessness (6) (12)		✓			✓	
Social deprivation (6) (12) (13)		✓			✓	✓
Flood insurance ownership (6) (12) (13)		✓				✓
Access by the poor to resources (e.g. low-interest loans) (7) (9) (11)			✓	✓	✓	
Influence of power alliances (9) (10) (11)				✓	✓	
Ethnic group or composition (12)						✓
Influence of apartheid (11)					✓	

River basin/catchment/regional level

Three empirical assessment methodologies are represented in the project's conceptual approaches. The first is an integrated *"Man and Environment" methodology* reflecting geographical origins, in which the "physical setting" (i.e. river catchments, flood plain types, flooding types, physiographic regions agro-ecological regions) are related to "human use" systems including settlement and infrastructure, population, land use, cropping patterns and political responses to floods (Brammer, 2000). Vulnerability is viewed as an outcome of these "overlays", and the methodology is designed to generate an "explanation" of the plight of the relevant territory e.g. Bangladesh with regard to flooding. The definition and use of the concept of vulnerability in this case is very general and the explanation of vulnerability is shallow. The methodology requires national level data (e.g. on physiography, flood types etc.) broken down into mapped regions, a mix of quantitative and qualitative data (e.g. on cropping patterns, flood depths etc.) most of which are available in reliable form from Flood Action Plan outputs.

The second is a *"Micro and macro economic" methodology*, focused upon three urban areas but subsequently generalized to the regional/national level (Islam 2005, 2006). The origins of the methodology are part geographical (land use studies) and part applied economics, being a blend of the two. With regards to Bangladesh, the author's aim was to contribute to an understanding of urban flood loss potential and its regional and national impact potential in the country, and the analysis benefits the broad drive to reduced flooding in that country. Economic values representing flood losses to major land use types (e.g. dwellings, businesses) are used to assess vulnerability to flooding of different socio-economic groups in Bangladesh. Subsequently the vulnerability of the urban economy to floods is modeled using input-output methods to determine the differential vulnerability of economic sectors and urban areas. The methods have many strengths (the data collection and analysis is almost heroic) and few weaknesses, except that only 3 urban areas are used to generate the national assessment and some data reliability issues arise. Quantitative data are required at individual household and business level, and are gathered from primary survey sources, but the macro analysis uses nationally available quantitative data on flows and stocks. Output data are impact values for floods in Bangladesh at different scales, local, regional and national.

The third is a "*Planning" methodology* used in England, but also we believe in many other countries, which employs the river catchment as a basis for examining flood generating processes, exposure, vulnerability, resilience and other dimensions, and for constructing flood risk management plans which partly aim to reduce vulnerability (but also to reduce flood risk, flood exposure and so on).

Compound catchment / metropolitan level

Three quite different empirical assessment methodologies are represented in the project's conceptual approaches. Here the first *Man and Environment" methodology* reflects geographical origins in which physical setting and human use systems are analysed to uncover spatial and temporal patterns of risk, exposure and vulnerability in the context of a "Mega-city" (e.g. London, Seoul). The London mega-city spans at least 8 major river catchments. The authors (Parker, 1999a; Kiw-Gon Kim, 1999) sought to deepen understanding of the special (i.e. unique) risks and opportunities which mega-cities and their governments face in combating floods. The methodology suffers from lack of data at the mega-city level, and the incompatibility of data at the intra-governmental unit level, and a lack of GIS representations of these data for mega-city spatial scale (although in the case of London this problem has receded since the London study was completed). Data are required, for example, on the number of properties and lengths of transportation links of different types in floodplain units across the mega-city with accurate altitudinal data for each. Data is also required for the population characteristics of discrete floodplain units but these data are only just becoming available in London, and not for the entire mega-city. Output data include qualitative assessments of trends in risk, exposure and vulnerability in the past and future (see Parker and Penning-Rowsell, 2005).

The second approach is Ruin et al's (2007) *"Cognitive mapping and interview" methodology* employed to "map" and understand French motorists' decisions about driving (or not) and route-taking through compound catchments in the Gard department of southern France. The intent was to develop output data and understanding which can be used to improve public education and transportation planning to make motorists safer, and the research generates some very useful findings. The methodology has no apparent weaknesses with the exception that the sample size could have been larger. Output data are cognitive maps, binary and qualitative data.

The third approach is the TE2100 flood risk management plan: the Thames estuary includes the catchments of numerous rivers and streams as well as the Thames (Environment Agency 2007, 2008). The methodology is a *"Fully integrated, multi-dimensional and multi-disciplinary risk assessment with embedded vulnerability assessment" methodologies*. The anticipated results are a comprehensive flood risk management plan focused upon reducing flood risk (through preventative and adaptive strategies) and managing economic and social exposure and vulnerability to floods to 2100 and beyond. It is difficult to identify shortcomings in this vast study at this stage, prior to final plan publication, but data deficiencies are unlikely to be problematic since so much effort has gone into generating the data required. Data used in this methodology are multi-faceted (i.e. "you name it and it is available in this study"), but the vulnerability data include very detailed population, social, economic and property level data for over 20 "policy management units" which comprise the estuary study area. Data is predominantly qualitative and is represented in tabular and GIS format. About 20 flood risk indicators (quantitative and qualitative) are used and monitored and comprise one set of outputs. Other outputs include investment plans, infrastructure development plans, and many other options plans as well as comprehensive stakeholder guidance.

Functional urban or metropolitan level

Two assessment methodologies are representative of this level of analysis. The first is the study by Zoleta-Nantes (2000) of vulnerability to floods in Metro Manila. This is a *"Social geography survey" methodology* in which a sample of respondents from the urban poor sector of the metropolis are subjected to in-depth interviews about their experiences; with this survey being embedded within a metropolitan-wide social geography analysis of poverty, income, morbidity, coping strategies and government policies. The results are intended to shed light upon the plight of the urban poor in regard to flooding and related poverty-reinforcing processes. The methodology is limited by the smallness of the sample (39 respondents) used for the interviews although extracts from these interviews generate interesting and illuminating output data, qualitative in nature. The input data are interview records and secondary sources data on income and morbidity levels. The second case is the Drobot et al study of car driver perceptions and reactions to flooding in Denver, Colorado and Austin Texas. Respondents come from all parts of these metropolises. The methodology is a *"Social-psychology-based quantitative statistical analysis" methodology* based upon responses from thousands of interviews placed on the internet in each city requesting responses from car drivers. Although the sample size is very large in this case, the respondents are self-selecting which can lead to bias in the results: a point addressed by the authors. The data are subjected to quantitative statistical analyses to try to determine significant statistical correlations, for example between age or gender and driving behaviour. The ultimate aim of the authors is to contribute to improving educational programmes to improve driver safety.

Sub-catchment or shoreline unit level

Two cases from the project's conceptual approaches represent methodologies used at this scale. The first is Winchester's (2000) study of agriculturalists in a delta-island in south India. Winchester's perspective is that the vulnerability of these people to floods can be explained by the inter-play of closely linked political and economic circumstances which have their roots in historical and present day land ownership and resource access inequities. He employs a *"Structural and policy analysis"' methodology* which focuses upon the alliances which have dominated the local political economy and which controls access to land and resources. His aim is to demonstrate how empowering organizations (such as a non-conventional bank) can be incorporated into flood mitigation to overcome these ingrained structural disadvantages afflicting the poor. Winchester's data is largely qualitative, being derived from living and working amongst the poor and progressively interviewing them, and also partly quantitative (e.g. estimates of flood losses, distribution of land ownership and other assets). The strength of the study is that it powerfully demonstrates that vulnerability can be helpfully approached by a study of power alliances and their impacts. There is no obvious shortcoming with the possible exception of the subjectivity brought to the study by Winchester's world view, but this is also a strength. Outputs are in the form of qualitative policy prescriptions.

The second case in Tunstall et al (1991, 2007) studies of the socio-economic impact of flooding in England and Wales undertaken in a variety of sub-catchments and subsequently assembled into a "national study" for the FLOODsite project (although the national study is simply the aggregation of the individual sub-catchment studies). Tunstall et al. employ a *"Social survey" methodology* which comprises lengthy and detailed interviewer-administered questionnaires targeting those who have been recently flooded or who are at risk from flooding. The anticipated benefit of these studies has been that they inform flood risk management policy-making in the UK by illuminating the social, economic and other impacts of flooding upon people's lives. Thousands of questionnaires were collected from a range of different surveys. Data inputs are socio-economic characteristics of respondents, and data on their flood perception and knowledge, impacts of floods on them and their household etc. A shortcoming in aggregating the data is that the survey instruments evolved over time and are not always entirely compatible or consistent from one study to another presenting some aggregation and interpretation problems. In addition, the results are not displayed through a GIS. The strength of the methodology is that it canvasses the views of those at the sharp end of flooding – individual flood victims – breathing "reality" into flood management policy. Data are analysed using SPSS software and are presented in output form as tabulations and correlations.

Floodplain community/floodplain management unit level

One of the project's conceptual approaches represents the methodology used at this level. Wisner's (2000) analysis of the African township called Alexandra Township uses a very similar methodology to that employed by Winchester above: a *"Structural and policy analysis" methodology*. Alexandra is a small part of Johannesburg and partly occupies the floodplain of the Juksei River. Wisner uses essentially the same data collection strategies as Winchester and the pros and cons of his approach are as those for Winchester, as are the other aspects of this methodology.

Individual household, business and floodplain occupant

Two of the project's conceptual approaches exemplify the individual, basic building-block, level. The first is the series of health vulnerability studies by Tapsell and colleagues (e.g. Tapsell et al., 1999). The methodology is a "Social survey methodology" (12) although *"Focus group interviews"* and a *"Self-report health questionnaire"* and a *"General Health Questionnaire"* were also administered. The intended benefit of using these methods was to reveal hitherto poorly understood impacts of floods on individual householders, and an important part of the study was comparison of effects over a period of several years. The identification of health effects relies upon a self-reporting approach by those affected by floods, rather than upon a research using a flooded group of individuals and a similar non-flooded control group. Data collected include socio-economic characteristics of respondents, their experience and perception of floods, and the economic, social and health impacts of floods. Data are both quantitative and qualitative. Outputs are extracts from interview transcripts and tabulated data. The second case comprises the research of De Marchi et al. (2007) and Steinfuhrer and Kulicke (2007) in the Italian Alps and in the Elbe catchment of Germany. Again *"Social survey" methods* were employed with interviews focusing upon local villagers and individual householders in the main, but the research is cast within a socio-economic profile of these settlements including data from secondary sources on population, income and education characteristics.

The present section indicated that there are various points of view and assessment possibilities as regards territorial vulnerability. The parameters and indicators used vary to a large extent. The query that is raised is whether these parameters and indicators are representative, measurable, stable and reliable. These are the issues involved in the discussion that follows.

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