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Models and methodologies for socio-economic vulnerability assessment

A theoretic and research perspective

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See References in ENSURE Deliverable 1.1.3

Numerous models and methodologies exist for assessing economic and social vulnerability. One theoretical model, designed by Green et al. (1994) as part of the Euroflood project, is aimed at understanding both the social and economic vulnerability of households to flood hazards. This methodology adopted a formula in which household vulnerability is a complex function of many variables, including: socio-economic variables, property and infrastructure variables, flood event characteristics, flood warning and response variables.

However, most approaches in the past have tended to focus on either economic or social vulnerability assessment, as often different approaches and methods are needed for each. Besides different models and approaches have been adopted at different scales, i.e. the micro/project, meso/regional and the macro scale. Therefore, for the purposes of this report the various assessment models and methodologies will be discussed separately.

1 From damage loss assessment to economic systems vulnerability assessment

Although damage and loss assessment methodologies are certainly not the same as models and methodologies for socio-economic vulnerability assessment, they are strongly related.

Lessons, conceptual and methodological issues in the field of damage assessment have certainly a bearing on the further development of models and methodologies for assessing economic and social vulnerability.

That's why in what follows reference is made to a number of damage and loss assessment methodologies complemented by assessment frameworks for the vulnerability and resilience of economic systems.

Van der Veen et al. (2003b) presented a number of papers that reflect current methodologies in damage estimation. They conclude that the field is now covering a full range of micro, meso, and macroeconomic approaches.

The following topics are relevant:

1. Cochrane (2004) discusses pitfalls in the development of a methodology for estimating flood damage. Those pitfalls include double counting of value added and direct damage to buildings, ignoring post-disaster liabilities and questions how indirect losses might be modelled. Cochrane categorises techniques for calculating and estimating indirect damage in one of six categories: linear programming models, surveys, econometric models, input-output models, general equilibrium models, and hybrid models. He is critical on the use of Computable General Equilibrium (CGE) Models: looking at actual events relative price changes are conspicuously absent, which robs CGE of one of its chief advantages. Cochrane discusses new issues in loss estimation asking attention for forms of indirect losses often neglected: non-market losses. Here, he relates to the European research on non-market losses by Flood Hazard Research Center at Middlesex

University, UK. Based on the empirical case of the attack on the World Trade Center, he defines a number of critical issues, which are relevant for damage and loss assessment in general: i. Baselines for estimating loss are inconsistent and misleading; ii. Failure to account for the reconstruction stimulus; iii. Failure to distinguish between losses sustained from the disaster versus the cost of adjusting to the disaster; iv. The possible existence of post disaster systemic losses.

2. Green (2004) takes a *macro and a micro* point of view in evaluating vulnerability to flooding. He argues that vulnerability has to be discussed in its entire systems context. Scale issues are central to the assessment of vulnerability. Floods may be a negligible hazard when compared to other hazards that exist. And, at the other hand, a household may be vulnerable to an event when neither the local community nor the country as a whole is vulnerable. Green concludes that a systems' approach in defining vulnerability eventually will have far-reaching implications as vulnerability is path-dependent; vulnerability thus is time-dependent; and vulnerability has to be understood as being constructed rather than being innate.
3. Mechler (in Van der Veen et al., 2003b) takes a different stance: he stresses the macro economic consequences of a disaster. Especially he and his co-authors calculate the macro-economic effects of diverted funds and foreign funds for relief and reconstruction. Direct stock losses due to a disaster are an input in a macro model that uses a flow-of funds accounting methodology to ensure consistency between the sources and uses of funds in a national accounting framework. He distinguishes between the public sector, the monetary sector, the foreign sector and the private sector. In an empirical study, Mechler applies the model to Honduras, computing the effects of a catastrophe on GDP. He concludes that it is important to understand the probable size of losses compared to resources available to meet reconstruction and relief needs. At the International Institute for Applied Systems Analysis (IIASA), a methodology was developed to integrate direct losses to capital stock as calculated using analysis tools of Swiss Re with macroeconomic planning tools of the World Bank in order to study the macroeconomic effects of natural disasters and be able to plan accordingly so as to reduce the adverse impacts. The authors undertook a series of case studies on Argentina, Honduras, and Nicaragua. The methodology allows estimating the potential aggregate effects of natural disasters before they occur and take respective coping measures by reducing or sharing risk (Freeman et al., 2004).
4. Rose (2004) puts the discussion on resiliency with respect to its scope: micro-economic, meso-economic and macro-economic. According to Rose, resiliency has a behavioral emphasis: individuals and firms do not simply react passively in the face of a disaster. He distinguishes three difficulties: firstly, on the conceptual level, where actions may violate established norms, such as rational behaviour; secondly, the operational level, where it is difficult to model individual and community behavior in one single framework; and thirdly, the empirical level where it is difficult to gather data. He then turns to the resiliency of markets: prices do act as invisible hands that guide resources to their best allocation. Computable General Equilibrium Models are state-of-the-art in regional economic modelling, but he acknowledges the fact that CGE models emphasize equilibrium, whereas after a disaster, disequilibrium ensues. These disequilibria can be researched by analyzing the underlying closure rules. Rose applies this type of

disequilibrium model to simulate the impacts of water disruption in a regional economy. Finally, Rose is able to make a distinction between inherent resiliency and adaptive resiliency within a CGE model; inherent resiliency is the ability or capacity of a system to absorb or cushion against damage, and adaptive resiliency is the ability to cope due to ingenuity or extra effort.

Recently, Rose (2007) further develops operational definitions of economic resilience. He argues that the effectiveness of economic resilience as a major way to reduce losses from disasters would be further enhanced if it could be precisely defined and measured. There, he distinguishes static economic resilience (efficient allocation of existing resources) from dynamic economic resilience (speeding recovery through repair and reconstruction of the capital stock).

5. Bockarjova, Steenge and Van der Veen (2004), Cole (2004) and Okuyama (2004) strive at structuring resiliency within an Input-Output accounting framework. Cole (2004) extends the IO system with a Social Accounting Matrix in order to capture adaptations of societies to lifeline disruptions. Societies are structured and adapt over time to balance performance and its protection. The question Cole raises is how society deals with the balance between the level of protection and accompanying costs, based on output losses. Moreover, how are these losses divided over all actors in the system? He illustrates his theoretical model with empirical material for a sub-regional economy in the US. The Niagara Power Project is the example for a lifeline disruption of power supply that hits a regional economy. Cole shows in his work how costs of protection vary with the size and frequency of events over time and the relative importance of direct and knock-on effects for the well-being of economic actors.
6. Okuyama (2004) applies an IO framework to model damages due to earthquakes. He illustrates his work with the Great Hanshin Earthquake in Japan. Okuyama bases his model on Miyazawa's Extended Framework of conventional IO models. This extension has the advantage of structuring production generation and income distribution and linking location of production and location of consumption. Temporal impacts of a disaster are captured in a Sequential Interindustry model. Okuyama distinguishes between a just-in-time production mode, an anticipatory production mode and a responsive production mode. Each economic sector is then assigned to one of the three modes. A simulation of the Sequential Interindustry model produces a production chronology that reveals how an economic structure deals with a disaster. Okuyama concludes that recovery and reconstruction activities after a disaster need to be planned and phased so that no significant supply constraints occur; secondly, detection of temporal key sectors are crucial for economy-wide recovery.
7. Bockarjova, Steenge and Van der Veen (2004) formulate *a new view on structural changes* in a regional economy after a disaster. Starting from Input-Output analysis their basic question is 'where to start from'. The reason being that a catastrophe by definition affects the existing networks and connections in a fundamental way. Certain elements in the structure may be lost, some possibly forever, while others may survive. From the literature, they apply the concept of an 'Event Matrix'. It traces the development of the situation at selected intervals after the catastrophe and during reconstruction. The problem with the concept, however, is that it is still in the developing phase. By introducing the notion of a 'Basic Equation' that structures the

insight in production capacities that remain active, they make an important step forward.

8. Thissen (2004) investigates the effects of *a lifeline transport infrastructure disruption* on a regional economy. He formulates a Spatial Applied General Equilibrium Model where a transport disruption affects production and labour allocation between regions. The effect on labour markets is seen as a major improvement towards previous models where commuting and migration patterns were omitted. Search behaviour of commuters and migrants is such that in the end utility is equal for labourers among regions taking local price differences such as housing prices into account. Secondly, an important element of the model is that the effect of transport infrastructure takes agglomeration effects in consideration.

For Latin America and the Caribbean, ECLAC (2003) presented an example of an initiative where a uniform and consistent methodology has been developed to assess the social, economic and environmental effects of disasters, breaking them down into direct damages and indirect losses and into overall and macroeconomic effects. Macro-economic effects in this respect include: Gross GDP; sectoral production; current account balance; indebtedness and monetary reserves; public finances and gross investment; and prices and inflation.

Further methodological issues in the methods for the assessment of economic damage and vulnerability, but to a large extent addressed in the economic literature – also in relation to standard cost-benefit analysis approaches, include: the financial (private) versus the economic (public, societal) perspective; scale issues; stack versus flow estimation; estimation of direct and indirect damage; and the valuation of tangible versus intangible losses.

Because of these development at various scales (macro, meso and micro), for the different continents we see now more or less standardized approaches to measure damages:

For Europe a number of different assessment methodologies have been developed to calculate flood losses. Methodologies in England and Wales, especially detailed researched flood damage data, are probably still the most developed (Penning-Rowsell and Chatterton, 1977; Parker et al., 1987; Penning-Rowsell et al., 2005). Data and methodologies have also now been developed in Germany (Kreibich et al., 2005; Merz et al., 2004), the Netherlands (van der Veen et al., 2003; Vrouwenvelder et. al. 2003), the Czech Republic (Sartrapa et al., 2005) and France (Water Agency Artois-Picardie, 2006; Water Agency Loire-Bretagne, 1999). Similar damage assessment methodologies have been devised by the US Army Corps of Engineers (Hydrologic Engineering Center in Davis, California (2008), Canada (e.g. Schultz and Kejelland, 2002) and Australia (cf. Zerger, undated).

In England, since the 1970s, a system of modelling flood damages at different spatial scales has evolved, including a national high level method, a regional level method, an intermediate level method for Catchment Flood Management Plans and a local level. At almost all levels standard flood damage data developed by the Flood Hazard Research Centre at Middlesex University are used (Penning-Rowsell and Chatterton 1977; Parker et al., 1987, Penning-Rowsell et al., 1992; Penning-Rowsell et al., 2005). Standard damage data are available, for example, for residential buildings (with a breakdown by type and age of building), and for different types of non-residential property (e.g. offices, manufacturing plants, retail units etc.).

Indirect loss values are also available for all building types, for traffic disruption, emergency service costs and agricultural production. Intangible loss values (some quantitative, other qualitative) are available for people, health, environmental impacts, and recreational impacts. Flood damages are also calculated for different depths and durations of flooding.

In Germany slightly different approaches have been developed in different Bundesländern or regions. For example, in North Rhine-Westphalia a state level, meso-scale damage and risk analysis has been carried out, and a more detailed level analysis has been used at river basin level. A micro-scale damage evaluation method has also been developed there (Meyer and Messner, 2005).

The Czech Technical University in Prague has developed a system of three methods of flood damage evaluation with different levels of accuracy, and all methods are based on the same approach which is an estimation of the value of assets at risk per metre or cubic metre, mainly based on data from official statistics (Satrapa et al., 2005). The three methods relate to three different scales of analysis: national, regional and local.

The flood damage assessment methodologies currently used in European Union member states have been recently reviewed in Meyer and Messner (2005), Messner et al., (2006b) and in Parker et al. (2008). Meyer and Messner (2005) have compared the flood damage evaluation methods of England, the Netherlands, the Czech Republic and Germany. These countries have different histories of flood protection policy and different institutional settings, but all use sophisticated methods of flood damage evaluation.

In principle these methods all follow the same idea of trying to place economic values to elements of flood risk in order to estimate the benefits of measures designed to prevent flood damage. Although the methods exhibit different approaches, such as the categories of land uses chosen, in the degree of detail, the scale of analysis and the application of principles relating to replacement or depreciated costs, are broadly similar.

2 Methods for assessing social vulnerability

Warner (2007) examines the state of research and emerging perspectives on social vulnerability by addressing general frameworks for thinking about social vulnerability to multiple stressors and examining some of the factors that contribute to social vulnerability. The review underscores the importance of examining social vulnerability when designing and implementing policy.

Research on social vulnerability has traditionally focused on characteristics that contribute to specific aspects of social vulnerability in a subgroup of the total population at risk from a hazard rather than an all inconclusive investigation of the relevant factors in the total population. Moreover, the focus of this research has been on how to assess characteristics of vulnerability rather than how to *integrate* social vulnerability into the broader context of vulnerability and risk equations. Consequently, the findings are fragmentary and there is no consensus on a) the primary factors that influence social vulnerability, b) the methodology to assess social vulnerability, or c) an equation that incorporates quantitative estimates of social vulnerability into either overall vulnerability assessment or risk. Nevertheless, several methods for assessing social vulnerability have been proposed. We present a few recent ones here, without specifying the type of hazard.

Cutter et al., (2003) used 1990 US Census data from all 3,141 counties in the USA as the unit of analysis. These data were free and available through the internet via the US Census Bureau portal. Using the Census data, variables that represented the broader dimensions and constructs of social vulnerability were identified. Originally some 250 variables were selected and then reduced to 85 raw and computed variables. Factor analysis (principle component analysis) reduced the data to eleven factors, which explained some 76% of the variance in vulnerability among all counties. The methodology used in developing this Social Vulnerability Index (SOVI) model allows for a robust and consistent set of variables that can be monitored through time to assess changes in vulnerability. A major strength of the model is that the data are obtained from standard census studies performed by governments rather than expensive one-off surveys such as those often funded through scientific research. The shortcoming of the model is that it is not linked into a model of risk, but as the authors explained, a logical next step is to integrate the model findings or outputs (GIS maps of vulnerable areas) with physical hazard maps.

In a separate study, Dwyer et al. (2004) describe a methodology for measuring aspects of social vulnerability and its role in contributing to risk from natural hazards in Australia. A limitation of this study is that it is specific to individuals in households. In yet other studies, Paton (2002) has developed a social-cognitive model that predicts the factors that influence individuals' decision-making process in the context of preparing for natural hazards. Key variables in this model are self-efficacy and outcome expectancy (Paton et al., 2008). Key strengths of this model are that it has been tested across multiple hazards and in both individualist and collectivist cultures. A limitation of its use in social vulnerability studies is that the model has not been integrated into risk equations. Yet another limit to its application to social vulnerability studies is that the model focuses on understanding the factors that predict why people do or do not undertake preparedness actions rather than how effective specific preparedness actions taken might be in reducing vulnerability. Attention in recent hazard and disaster research studies has focused on describing 'social capital' and 'collective efficacy'. These relate to the collective intellectual and physical strength of individuals in communities who are able to reduce individual and group vulnerability.

With the growing awareness of, and emphasis on, the social aspects of flooding in the last decade, particularly in Europe, more and more research is now focusing on assessing the social vulnerability of individuals, households and communities to flood risk and impacts. Many quantitative surveys have been undertaken focusing on household impacts (including health impacts) and responses to floods (e.g. Tapsell et al., 1999, 2002; 2003; Skertchly and Skertchly, 2000; RPA, FHRC et al., 2004; Steinfuhrer et al., 2007b; De Marchi et al., 2007, Tunstall et al., 2007; Werrity et al., 2007).

Analytical approaches for assessing vulnerability tend to closely follow research paradigms from historical narratives, contextual analyses, case studies, to statistical analyses, GIS and mapping techniques.

Much social research involves qualitative approaches and methods such as in-depth interviews, focus groups, oral histories, etc. (e.g. Thrush, 2002) although quantitative techniques such as structured surveys and collection of statistical data are also frequently employed.

Social impact and response are often measured by threats to lifelines or infrastructure to support basic needs, special needs of populations, poverty or wealth indicators, gender, age etc. The geographical scale poses difficulties in measurement as applications range from local to global scales. For flood risk the most detailed vulnerability assessments are conducted at the local level, often of individuals or households. Methodological decisions often mean sacrificing localised detailed case study approaches for more broadly based patterns and distributions (Cutter, 1996). Sophisticated tools for health risk assessment exist but these are largely aimed at providing aggregate measures or focus on description of impacts and response capacities. Techniques such as the General Health Questionnaire (Goldberg and Hillier, 1979) and the Post Traumatic Stress Scale (Scott and Dua, 1999) have been used in England and Wales to assess health impacts following flooding (RPA et al., 2004).

There is a growing range of literature on the health impacts of flooding (Hobbs, 1995; Ohl and Tapsell, 2000; Hajat et al., 2005; Few and Matties, 2006; Ahern and Kovats, 2006), much of which has been used to suggest the parameters and indicators of vulnerability outlined in Section 7 below.

Much of the literature focuses on post-disaster responses and on how to determine physical and psychological impacts on health and well-being. In developed countries floods may potentially impact upon human health in a number of ways, the most serious being by death from drowning or serious injury (HR Wallingford, 2003; Ahern and Kovats, 2006; Tunstall et al., 2006). The risk to life from flood hazards has been modelled by various authors (Brown and Graham, 1988; Waarts, 1992; Vrounwemvelder and Steenhuis, 1997; Graham, 1999; Wallingford, 2003, 2005; Jonkman, 2007; Zhai et al., 2006; Priest et al., 2007). These models differ in the types of flood risk being assessed, from river flooding to dyke breaches and dam failures, and include a range of different variables. Many focus on the key variables influencing risk to life e.g. area characteristics (topography, nature of housing and propensity to collapse, institutional responses such as flood warnings), flood characteristics (depth, velocity, etc.) and population characteristics (age, health, etc.). Some models are based on the analysis of just one flood event (e.g. Waarts, 1999 on the 1953 flood), while others focus on analysing data from a number of flood events (HR Wallingford, 2003, 2005; Jonkman, 2007; Priest et al., 2007). The models also vary in whether they attempt to predict actual numbers of fatalities or merely indicate levels of risk e.g. low to extreme. Some models (e.g. Priest et al., 2007) have also developed simple GIS mapping of the risk to life to provide vulnerability maps of study areas.

More frequently than deaths, common health effects in developed countries from flooding result from minor injuries (Schmidt et al., 1993; Manuel, 2006), diarrhoeal episodes, (Wade et al., 2004; Reacher et al., 2004), respiratory disease (Franklin et al., 2000) and psychological impacts (Bennet, 1970; Phifer and Norris, 1989; WHO, 2003). The risk to public health from communicable diseases is still a problem in many developing countries but is relatively infrequent in developed countries due to good sanitation and water supplies and lack of overcrowding (Malilay, 1997; Meusel and Kirch, 2005; Ahern and Kovats, 2006), although the risk could increase in the future with global warming. Toxicants in sediment and air may also pose a problem as evidenced following Hurricane Katrina (Manuel, 2006).

Most studies agree that the psychological impacts are by far the most significant (Tunstall et al., 2006). Beck and Franke (1996) report that 15-20% of people studied following natural disasters are reported to have symptoms of Post Traumatic Stress Disorder (PTSD). Moreover, there is growing evidence that disaster victims may continue to experience psychological health symptoms long after the event (Steinglass and Gerrity, 1990; Tunstall et al., 2006). Thirty-eight percent of those interviewed following the 1993 Midwest floods in the US met criteria for post-flood psychiatric disorder (McMillen et al., 2002). Moreover, those who are diagnosed with PTSD or psychiatric problems are more likely to have a greater number of physical health problems than those who are not diagnosed (Stoudemire, 1995). Chronic problems identified by Norris et al., (2001) in their review of 177 articles comprising over 50,000 individuals who experienced 80 different types of disasters (62% of which were natural disasters, mostly in the US), include: troubled family and interpersonal relationships, social disruption, occupational and financial stress, concerns about general living conditions and the wider community, and obligations to provide support to others.

Health Impact Assessment (HIA) is a relatively new multidisciplinary process and its potential as a tool for assessing disaster risk or vulnerability has not yet been fully explored. HIA views a range of evidence within a structured framework through a variety of procedures and methods, often integrated with Environmental Impact Assessment (EIA) and Social Impact Assessment early in the planning cycle. It uses checklists of determinants as indicators of changes in health risks. Health inequality is a central issue and identification of the most vulnerable groups is very important.

In order to deepen understanding of the processes that shape how vulnerability to health impacts varies, an intermediary research tool has been suggested by Few (2007) that narrows analysis to specific hazards (in this case floods) and health outcomes and disentangles the points at which aspects of vulnerability and response actions come into play. This ‘health impact pathway’ model for flooding depicts the potential progression of impacts of flood hazard events and possible response mechanisms (Appendix XI).

There have been few studies comparing social vulnerability in differing cultural contexts. One example is that conducted as part of the EC FLOODsite project which analysed social vulnerability of flooded and at risk populations in Germany, Italy, England and Wales (see Steinführer et al., 2007a). Many similarities were found across the four countries regarding social vulnerability, however, local culture and context was a key influencing factor. Institutional arrangements, previous flood-experience, frequency of floods, location, community size etc. all matter and can be summarised under the umbrella-term ‘risk cultur’”, which differs between and among regions. Several additional aspects also need to be considered when assessing social vulnerability, these include people’s behaviour, assumptions, knowledge and ignorance (Gross 2007; Kuhlicke 2007) as well as processes of sense-making.