

Session No. 4

Course Title: Disaster Planning and Policies

Session 4: Measuring and Mapping Vulnerability

Time: 3 hrs

Learning Objectives:

- 4.1 Define and discuss vulnerability
 - 4.2 Enumerate indicators of vulnerability
 - 4.3 Data sources
 - 4.4 Vulnerability assessment as one level of hazard assessment
 - 4.5 Use of GIS technology as part of the vulnerability assessment process
 - 4.6 Demos or review of vulnerability assessment methodologies
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Scope:

This final session of the Disaster Mitigation module focuses on hazard and vulnerability assessment and applications. It provides important context for the next module which covers social and economic vulnerability in more depth. By the end of the session, students should understand the factors that give rise to vulnerability and the potential for disasters to compound these vulnerabilities.

Student Readings (also referred to in the subsections below):

- Lindell M., C. Prater, R.W. Perry with W.C. Nicholson (2006). Chapter 6, “Hazard, Vulnerability and Risk Analysis” in *Fundamentals of Emergency Management* pages 155-179 <http://training.fema.gov/EMIWeb/edu/fem.asp>
 - Deyle, R.E., S.P. French, R.B. Olshansky, and R.G. Patterson (1998). Chapter 5 “Hazard Assessment: The Factual Basis for Planning and Mitigation” in R. Burby (Ed.) *Cooperating with Nature*. Washington, DC: Joseph Henry Press.
 - Esnard, A-M. (2007). Chapter 5, “The Nexus of Hazard Assessment, GeoSpatial Technologies, and Holistic Community Planning Strategies “. In J.R. Nolon and D.B. Rodriguez (Eds.). *Losing Ground: Nation on Edge*. Washington, DC: Environmental Law Institute.
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General Requirements:

The materials for this session are on the syllabus and the instructor should remind students that the materials should be read and reflected upon before class. The information about the readings materials should also be placed on an appropriate course website.

Instructional Methodologies: The instructor can choose to employ a mixture of tools for presenting the materials. The materials presented here can be summarized into a PowerPoint presentation.

4.1 Define and discuss vulnerability

Refer to Readings:

- Lindell M., C. Prater, R.W. Perry with W.C. Nicholson (2006). Chapter 6, “Hazard, Vulnerability and Risk Analysis” in *Fundamentals of Emergency Management* <http://training.fema.gov/EMIWeb/edu/fem.asp>
- Deyle, R.E., S.P. French, R.B. Olshansky, and R.G. Patterson (1998). Chapter 5 “Hazard Assessment: The Factual Basis for Planning and Mitigation” in Burby, Raymond (ed.). *Cooperating with Nature*. Washington, DC: Joseph Henry Press.

4.1.1. Refer to Session 3’s discussion of natural and technological hazards, but for purposes of measuring and mapping vulnerability, we will focus on “natural hazards”. Segue to a discussion on vulnerability by reminding students that planners cannot avoid all natural hazards, and that hazard mitigation planners require an understanding of vulnerability. Refer to the Lindell et al (2006) required reading, and their discussion (on page 153, and in Figure 6-1) on the effects of a disaster being determined by three pre-impact conditions—hazard exposure, physical vulnerability, and social vulnerability.

What is vulnerability?

Sample answer:

- Vulnerability is the susceptibility of human settlements to the harmful impacts of natural hazards. Impacts of concern include: (i) injuries and death to human populations; (ii) damage to personal property, housing, public facilities, equipment, and infrastructure; (iii) lost jobs, business earnings, tax revenues, as well as indirect losses caused by interruption of business and production; and (iv) public costs of planning, preparedness, mitigation, response and recovery (Deyle et al., 1998, p. 121)

- Vulnerability is usually categorized using two main components: physical vulnerability and social vulnerability. However, they are very much inter-related. Several scholars have noted that vulnerability is a function not only of the immediate physical conditions, but also of society's capacity to withstand disasters.

4.1.2. Discuss the sub-components of physical and social vulnerability. For details, see Lindell et al (2006, pages 154- 155; and 174-177).

1) What are some sub-components of physical vulnerability?

Sample Answers and Definitions:

- *Human vulnerability* – “Humans are vulnerable to environmental extremes of temperature, pressure, and chemical exposures that can cause death, injury, and illness... Typically, the most susceptible to any environmental stressor will be the very young, the very old, and those with weakened immune systems”.(Lindell et al., 2006, p. 154-155)
- *Agricultural vulnerability* – “Like humans, agricultural plants and animals are also vulnerable to environmental extremes of temperature, pressure, chemicals, radiation, and infectious agents. However, agricultural vulnerability is more complex than human vulnerability because there is a greater number of species to be assessed, each of which has its own characteristic response to each environmental stressor.” (Lindell et al., 2006 , p. 155)
- *Structural vulnerability* – “Structural vulnerability arises when buildings are constructed using designs and materials that are incapable of resisting extreme stresses (e.g., high wind, hydraulic pressures of water, seismic shaking) ... variations in structural vulnerability can increase or decrease the effect of hazard exposure on physical impacts (property damage and casualties) the construction of most buildings is governed by building codes intended to protect the life safety of building occupants from structural collapse” (Lindell et al., 2006 , p. 155)

2) What are some sub-components of social vulnerability?

Social vulnerability has been defined in terms of people's “capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard (Wisner, Blakie, Canon & Davis, 2004, p. 11 cited in Lindell et al., 2006). Lindell and his colleagues discuss many of the important sub-components from the perspective of social impacts.

Sample Answers and Definitions:

- *Psychosocial vulnerability* includes effects such as personal fragility (lack of *emotion-focused* coping skills); rigidity (lack of *problem-focused* coping skills defined by an inability to develop adaptive strategies for responding to altered conditions) and social isolation (infrequency and superficiality of social contacts with peers such as kin (extended family), neighbors, and coworkers). (See Lindell et al. (2006, p. 175) for more details.

- *Demographic vulnerability*: this component of social vulnerability can be predicted by demographic characteristics such as gender, age, education, income, and ethnicity”
These demographic predictors of social vulnerability are frequently associated with hazard exposure because the population segments with the fewest psychological, social, economic, and political resources often disproportionately occupy the most hazardous geographical areas.
- *Household vulnerability*: “ *demographic predictors of social vulnerability are often associated with structural vulnerability because those same population segments disproportionately occupy the oldest, most poorly maintained buildings. Thus, those who are most socially vulnerable are also likely to experience the greatest physical impacts such as casualties and property loss*” . (p. 177)
- *Economic Vulnerability*: Wealth (which includes income and assets) is a major component of economic vulnerability. “*Tangible assets such as buildings, equipment, furniture, and vehicles that are located in the disaster impact area are more vulnerable than financial assets such as bank accounts, stocks, and bonds that are recorded electronically. Households and businesses both have tangible and financial assets, so both are vulnerable to the loss of their tangible assets and both have financial assets that can be used to support disaster recovery. There are substantial variations among households in their assets and the same is true for businesses. One noteworthy difference between households and businesses is that the latter also has operational vulnerability arising from dependency upon those who supply its inputs (suppliers and labor) as well as those who purchase its outputs (distributors and customers).*” (p. 176)
- *Political vulnerability*: “*political impacts of disasters often arise from conflicts over the management of the emergency response and disaster recovery. Accordingly, political vulnerability arises from inadequate emergency management interventions—which create situations that pit one group of stakeholders against another—and inadequate mechanisms for managing this conflict when it does arise.*” (p. 176)

4.2 Enumerate indicators of vulnerability and related data sets

Refer to Readings:

- Lindell M., C. Prater, R.W. Perry with W.C. Nicholson (2006). **Chapter 6**, “Hazard, Vulnerability and Risk Analysis” in *Fundamentals of Emergency Management* <http://training.fema.gov/EMIWeb/edu/fem.asp>
- Deyle, R.E., S.P. French, R.B. Olshansky, and R.G. Patterson (1998). **Chapter 5** “Hazard Assessment: The Factual Basis for Planning and Mitigation” in Burby, Raymond (ed.). *Cooperating with Nature*. Washington, DC: Joseph Henry Press.

Instructors should discuss indicators of physical and social vulnerability, but ask students to be mindful that:

- vulnerability (especially social vulnerability) varies across communities and also across households within communities. It is this variability in vulnerability that is likely to be of greatest concern to local emergency management officials, and disaster planners and policy-makers because it requires that they identify the areas within their communities that have population segments with the highest levels or clusters of socially vulnerable residents.

Sample physical/locational vulnerability indicators include:

- hazard zones (e.g. flood zones/ percent urbanized area in flood zone; earthquake fault lines; soils that are highly erodible and prone to landslides; barrier islands; and mature stands of natural vegetation prone to wildfires)
- built environment
 - o Building inventory – type, location, occupancy, and age (as it relates to conformance with building codes),
 - o Structural integrity (e.g. % of manufactured housing) and structural type (wood frame, steel frame, unreinforced masonry) especially for earthquake vulnerability assessments
 - o Critical infrastructure (roads, bridges, water supply, sewerage, electric-power systems, telecommunications) – type, location, structural integrity

Sample social vulnerability indicators include:

- Income (e.g. low income/high poverty, housing affordability);
- economy (e.g. occupations with focus on single sector economic dependence, employment gain/loss);
- age (e.g. elderly, children/youth);
- disadvantaged (e.g. single head of households; government-assisted households);
- race/ethnicity (e.g. ethnic/racial/language minorities); and
- education (e.g. educational attainment)

Segue to the next section

Remind students that listing indicators is an easy step and that one ongoing challenge remains the fact that some of these indicators do not have “direct” measures. For example, psychosocial vulnerability has to be measured indirectly through expensive customized surveys for representative samples of community members. The use of age, socioeconomic status, and ethnicity is therefore commonly used as proxy measures of psychosocial vulnerability. The following section explores some of the common data sources.

See Table 6-5 from Lindell et al. (2006, page 178) which lists some of the specific normalized variables (e.g. percent of households below poverty level) that also inform data collection from various sources.

4.3 Data sources

Refer to Readings:

- Esnard, A-M. (2007). The Nexus of Hazard Assessment, GeoSpatial Technologies, and Holistic Community Planning Strategies (Chapter 5). In “Losing Ground: Nation on Edge” Environmental Law Institute (on Bb).

Discuss with students the variety of data resources disseminated by federal government agencies (such as Federal Emergency Management Agency (FEMA), U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (EPA), the Natural Resource Conservation Service (NRCS), National Oceanic and Atmospheric Agency (NOAA) and the U.S. Census Bureau); state government (via GIS clearinghouses); and private sector vendors.

You can refer students to Figure 1 from pages 185-186 of Esnard (2007) which categorizes “potential data providers” into: (i) State and local government; (ii) businesses; (iii) institutions; (iv) federal government and related independent agencies; (v) others.

Let students know that the most commonly used resource (for social vulnerability assessments) is the U.S. Census Bureau which has developed various products and interactive on-line services that allow users to display different thematic maps using data from the decennial and economic censuses.

See also NOAA’s suggested geospatial data checklist as part of coastal risk assessment <http://csc.noaa.gov/digitalcoast/training/roadmap/pdf/geospatial-data-checklist.pdf>

4.4 Vulnerability assessment as one level of hazard assessment

Refer to Reading(s):

- Deyle, R.E., S.P. French, R.B. Olshansky, and R.G. Patterson (1998). **Chapter 5** “Hazard Assessment: The Factual Basis for Planning and Mitigation” in R. Burby (Ed.). Cooperating with Nature. Washington, DC: Joseph Henry Press.

Start this subsection by highlighting the following:

- (i) vulnerability is a complex issue with multiple facets. It is therefore important for agencies to adopt a systematic process to assess both physical and social vulnerability.
- (ii) vulnerability assessment is the intermediary level in the hazard assessment process, and the focus of sections 4.5 and 4.6. The content and details are partially influenced by agency capacity. Some agencies hire consultants to conduct such assessments.
- (iii) output from such assessments can highlight the spatial extent of vulnerability and potential impact of disasters on people and infrastructure; and provide useful information for mitigation and recovery plan development and for more efficient resource allocation.

Refer students to the Deyle et al (1998, 121) required reading which states that “hazard assessment can be conducted at three levels of sophistication:

- (Level 1) hazard identification- defines the magnitudes (intensities) and associated probabilities (likelihoods) of natural hazards that pose threats to human interests in specific geographic areas” (Deyle et al., 1998, p. 121). One example of an output is a hazard map which delineates and labels flood zones based on the use of digital Flood Insurance Rate Map data. Another example/application is informing designation of hazardous area overlay zones and specification of hazard setbacks in subdivision ordinances (p. 122).
- (Level 2) vulnerability assessment – “characterizes the exposed populations and property and the extent of injury and damage that may result from a natural hazard event of a given intensity in a given area” (Deyle et al., 1998, p. 121). Vulnerability assessment “combines the information from hazard identification with an inventory of the existing (or planned) property and population exposed to a hazard. It provides information on who and what are vulnerable to a natural hazard within the geographic areas defined by hazard identification. Vulnerability assessment can also estimate damage and casualties that will result from various intensities of the hazard” (Deyle et al., 1998, p. 129). “Vulnerability assessments attempt to predict how different types of property and population groups will be affected by a hazard” (Deyle et al., 1998, p. 131).
- (Level 3) risk analysis – “incorporates estimates of probability of various levels of injury and damage to provide a more complete description of the risk from the full range of possible hazard events in the area” (Deyle et al., 1998, 121-122)

Refer students to:

- Table 5-1 “Use of Hazard Assessment in Land Use Planning and Management” on page 123 of DEyle et al. (1998) and point out that hazard identification is the most common hazard assessment practice, and that vulnerability assessments are used to build support for hazard management policies and programs (e.g. building relocation; acquisition of damaged buildings).
- Deyle et al’s discussion of assessment of specific natural hazards – floods, earthquakes, landslides, hurricanes and coastal erosion, and wildfire (see pages 148-164)

4.5 Use of GIS technology as part of the vulnerability assessment process

Preamble for Instructor: Vulnerability assessment can be facilitated by using geospatial techniques (including geographic information systems (GIS)).

Ask the students whether any of them have taken a GIS class or have used GIS before. Remind them that students will not be expected to be able to use the GIS at the end of the session, but he/she will be expected to know what a GIS is and its capabilities. Tell them that some basic definitions and applications will be reviewed during the remaining class time.

1) What is GIS and why use it?

Answer:

- GIS is the acronym for geographic information system. A GIS *“lets us visualize, question, analyze, interpret, and understand data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts”* (ESRI, <http://www.esri.com/what-is-gis/index.html>).
- For our purposes, GIS provides an efficient way to identify natural hazard-prone areas, critical natural resource areas and vulnerable populations, structures, and resources. This is done by combining/layering planimetric/engineering data (such as tax parcels and roads), physical science data (such as flood zones), natural resource and environmental data (such as steep slopes and soil types), and other data (such as distribution of low income households and community facilities).

The resulting maps, tables and charts reveal patterns or trends that might otherwise be difficult to associate using other means, and can be used by planners. Policy makers and emergency management professionals to:

- Disseminate information to heighten public awareness of site, local, and regional hazards
- Identify hazard-prone areas and hazard hot spots
- Map geographic distribution of hazards
- Derive information on vulnerable populations, economic vulnerability infrastructure vulnerability, and damage losses
- Forecast damage estimates
- Evaluate and plan evacuation routes
- Identify gaps in services and shelters
- Assess structural alternatives for flood control
- Predict demand for emergency response services, public disaster assistance, and insurance losses
- Target landowners and homeowners for disaster education programs

Note to instructors: Walk your students through a sample application where GIS was applied in the policy/planning context. An example is provided below, but you may choose to use other examples of more relevance to your region (e.g. earthquake or wildfire).

Sample application: Barrier Island Vulnerability Assessment for Nags Head, North Carolina

Source: Esnard, 2007, pp. 182-183

GIS technology was used in the late nineties to assess:

- 1. The built environment and the extent of development and tax base in the danger zones (floods, oceanfront hazard zone, incipient inlets);*
- 2. The status of pre-Flood Insurance Rate Mapping (pre-FIRM) structures on developed parcels; structures built prior to Nags Head's regular participation in the Flood Insurance Rate Mapping program, i.e., 1978, were termed pre-FIRM.*
- 3. Vacant land in relation to current zoning; and*
- 4. Properties and land uses within the Ocean Erodible Area of Environmental Concerns.*

The assessment showed (among other things) that in the late nineties (1) 72% of Nags Head was developed, with close to one-third of the developed parcels within the oceanfront hazard zone, and (2) a relatively high percentage of structures built prior to Nags Head's regular participation in the FIRM program lay within incipient inlets and VE flood zones.

The results of the assessment were used as part of a broad spectrum of mitigation, response, recovery, and redevelopment proposals and activities, to assess the locations of public infrastructure and critical facilities, and to determine where future development should and should not take place. Planners had a basis for more effectively steering growth and development away from hazard areas and other environmentally sensitive areas such as streams, wetlands,

4.6 Demos or review of vulnerability assessment methodologies

Note to Instructors: Depending on your comfort level with GIS, the background of your students, and the remaining class time, you can consider one or more of the following options given myriad approaches to vulnerability assessments.

Option 4.6.1: Your own GIS example or HAZUS demo

4.6.1.1 If possible, open ArcGIS or other software and show students the various datasets and GIS spatial queries. An example was the “*Barrier Island Vulnerability Assessment for Nags Head, North Carolina*” presented in a previous section

4.6.1.2 If possible, introduce students to other GIS-based tools such as the MH-HAZUS software program which was developed by FEMA to (1) model and estimate potential losses from earthquakes, floods, and hurricane winds, (2) map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure, and (3) estimate impacts of hazards on populations. For more details and ideas, see <http://www.fema.gov/plan/prevent/hazus/index.shtm>; http://www.fema.gov/plan/prevent/hazus/hz_app.shtm

Option 4.6.2: NOAA’s coastal vulnerability assessment (Roadmap for Adapting to Coastal Risk)

<http://csc.noaa.gov/digitalcoast/training/roadmap/index.html> (accessed March 2012)

Walk students through the various stages, from Overview -> Process -> Training -> Resources -> In Action.

An example exercise using this resource to engage students in discussion can be accessed by clicking on “example assessment maps” to discuss the potential value of such maps: <http://csc.noaa.gov/digitalcoast/training/roadmap/resources.html>

Option 4.6.3: Review the vulnerability assessment methodology of an accessible hazard mitigation plan or local mitigation strategy.

Example: Sutter County (California) Multi-Hazard Mitigation Plan Vulnerability assessment, http://www.co.sutter.ca.us/pdf/cs/es/Section_4-2_Vulnerability.pdf

In this case, you can use these examples to engage in discussions about: critical facilities, assets; inventories; the built environment, housing and land development trends; categories of flood zones; source of GIS flood data; reporting vulnerability and impact in written, tabular and map form; application of HAZUS-MH for earthquake vulnerability assessment; and HAZUS scenario results.