Constructing Urban Vulnerability Index (UVI) for U.S. Coastal Cities
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This project is developing urban vulnerability index to incorporate the social and economic vulnerability assessment into counterterrorism measures.

Modeling Area: DC, Baltimore, New Orleans, Chicago, Houston and Miami
Case Studies Supported: Hurricanes Katrina and Andrew
Other Investigators: Mika Kato, Ph.D.-Howard University

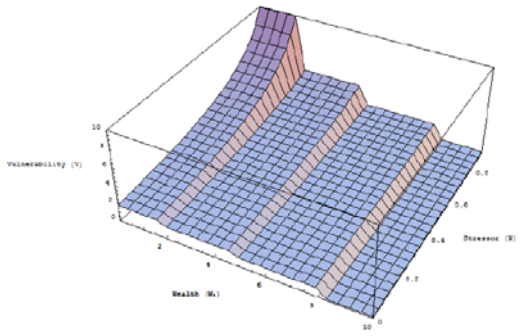


Figure 1: Ex. 1 Vulnerability by Wealth and Stressor

Brief Description:
The purpose of this research is to integrate the social and economic vulnerability assessment into counterterrorism measures. The main goal is to improve methods for risk-based allocation of resources to counterterrorism measures. This work builds on CREATE efforts to develop Urban Vulnerability Index (UVI) to evaluate the social and economic vulnerability of U.S. coastal cities. Vulnerability is defined as the likelihood of falling below the minimum in case of natural or man-made disaster. This definition is consistent with the risk-averse social welfare function which assumes that consumers prefer a society where the basic minimum protection should be provided for everyone. The UVI takes into account poverty levels, degree of racial segregation, industry mix, crime levels, and overall city fiscal capacity, as well as several characteristics of government fiscal capacity and elements of the built environment. This index will help the DHS optimally allocate its limited resources based on the relative vulnerability rankings. This project provides sound analytical and empirical guidance to decision makers regarding the most effective and efficient way to allocate resources among the cities to minimize the social and economic vulnerability.

Objectives:
This research will: (a) develop Urban Vulnerability Index that uses vulnerability as a key concept in understanding the extent of the damage caused by extreme events (natural or man-induced) and people's ability to bounce back; (b) study the economic, demographic and social factors that are key to the ability of the city, state, and Federal Government to minimize and contain human, economic and social costs; (c) relate recovery rates for various population groups to their pre-disaster private and social capacity based on actual insurance loss data and recovery-related public spending data; (d) assess vulnerability rates for population groups under the conditions where both the strength of the disaster and pre-disaster level private and social capacity vary; (e) provide cost estimates and recovery rates for extreme events under various scenarios, where local economic conditions, social and demographic conditions vary across time and place; (f) enable the DHS to quantify social and economic risks and allocate resources among the cities by the most effective and efficient way.

Interfaces to other Center Projects:

This work will maintain a close interface with the Dr. Rae Zimmerman's risk analysis of urban infrastructure project and Dr. Adam Rose's natural hazard loss estimation project.

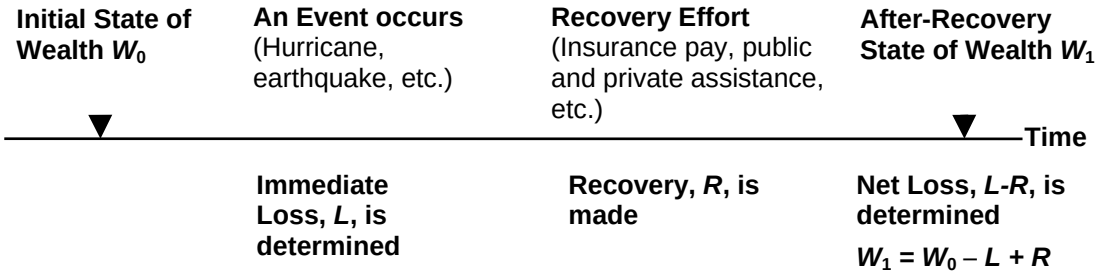
Interfaces to non-Center Projects:
We plan to work with the District of Columbia government and City of New Orleans to quantify and communicate risks of extreme events for low income and minority neighborhoods. We also plan to collaborate with the DHS to use their RAMCAP methodology for prioritizing risks.

Major Products and Customers:
This research will: (a) develop Urban Vulnerability Index that uses vulnerability as a key concept in understanding the extent of the damage caused by extreme events (natural or man-induced) and people's ability to bounce back; (b) study the economic, demographic and social factors that are key to the ability of the city, state, and Federal Government to minimize and contain human, economic and social costs; (c) relate recovery rates for various population groups to their pre-disaster private and social capacity based on actual insurance loss data and recovery-related public spending data; (d) assess vulnerability rates for population groups under the conditions where both the strength of the disaster and pre-disaster level private and social capacity vary; (e) provide cost estimates and recovery rates for extreme events under various scenarios, where local economic conditions, social and demographic conditions vary across time and place; (f) assess and measure vulnerability based utility maximization and risk-averse social welfare function so that policy preferences are consistent with public perceptions.

Customers: DHS – IP; DHS – ORD; D.C. Government.
Products: Urban Vulnerability assessment methodology for determining optimal disaster assistance and for measuring the cost/effectiveness of spending in vulnerability reductions; research publications and reports.

Technical Approach:
The methods developed will build on previous research on reliability analysis and impact analysis methods for ranking contingencies to minimize social and economic vulnerabilities. Vulnerability assessment will be consistent with utility-maximizing consumer behavior and risk-averse public perceptions.

<u>Assessing Vulnerability</u>
To assess a particular area's vulnerability due to a natural disaster, we first simplify a series of events as follows:



Initial Wealth W_0 – It is the area's total initial wealth before any event occurs. The area's structure value (e.g., housing value and other private and public property value) can be used for this.

Size of an event X – It measures the strength of a natural disaster. We can use readily available indices such as the Carvill Hurricane Index for hurricanes and Richter magnitude scale for earthquakes.

Immediate Loss L – After an event occurs, immediate loss is determined. It is the total damage to the area's structure. The amount of loss is proportional to the initial wealth W_0 and the rate of loss θ depends on the size of an event X,

$$L = \theta(X) W_0$$

where

$$\partial\theta(X)/\partial X > 0.$$

Recovery R – A part or all of the loss L can be restored by private or/and public efforts. A large part of the recovery process is affected by insurance coverage and it varies by wealth, i.e., wealthier families afford insurance that pays more. Thus we may assume that the rate of recovery ρ depends on initial wealth W_0,

$$R = \rho(W_0) L$$

where

$$\partial\rho(W_0)/W_0 > 0.$$

Post-Recovery Wealth W_1 – After recovery, the net loss due to an event is determined, $L - R$. Then, the after-recovery state of wealth is

$$\begin{aligned} W_1 &= W_0 - L + R \\ &= [1 - \theta(X) + \rho(W_0)\theta(X)] W_0. \end{aligned}$$

Vulnerability Index

Vulnerability Index attempts to capture both potential damages from a natural disaster and the afterward resilience for a particular area.

First, we compute an increase in potential loss due to an additional shock by taking the first derivative of W_1 with respect to X

$$|\partial W_1/\partial X| = (1 - \rho(W_0))\theta'(X) W_0$$

Let's define a minimum wealth $\underline{W}$ which is a sort of poverty line or minimum wealth. Policymakers may want to emphasize vulnerability of those that fall behind the minimum wealth and discount vulnerability of those that are able to come above the minimum wealth.

$W_1 / \underline{W} < 1 \rightarrow$ Amplify vulnerability
$W_1 / \underline{W} > 1 \rightarrow$ Discount vulnerability

Taking this into account, we can define the following Vulnerability Index:

$$\begin{aligned} V &= \frac{|\partial W_1/\partial X|}{W_1/\underline{W}} \\ &= \frac{(1 - \rho(W_0))\theta'(X) W_0}{[1 - \theta(X) + \rho(W_0)\theta(X)] W_0/\underline{W}}. \end{aligned}$$

Methods for incorporating losses, disaster strength, recovery rates and pre-disaster private and social capital stock are grounded in the theory and methods of risk analysis, economic impact

analysis, social choice theory, and public finance. The overall urban vulnerability analysis uses case studies, data on insurance losses, local social and economic conditions to identify the key economic, demographic and social factors enable the city, state, and Federal Government to minimize and contain human, economic and social costs. The case studies on the past three blackouts in New York City have documented that, among other things, local social and economic conditions, such as crime rate, racial tensions, and unemployment rate were the main reasons why the public reacted so differently during these events. The total losses were compounded by the local social and economic conditions during economic and social downturns. Similarly, a local government with weak fiscal capacity will have difficulty in communicating the risk to the lower income population during and after an extreme event (Katrina).

We have already compiled data sets on losses (public and private) caused by the major named hurricanes since 1990. Our challenge has been to create data sets that incorporate geographical and socio-economic vulnerability for disasters of different magnitudes. By the end of this grant period, we plan to complete constructing urban vulnerability index for various population groups in New Orleans and Miami. Our final will provide comprehensive results, including sensitivity tests to check the robustness of the analytical and empirical methodology.

We propose to construct UVI index in other major coastal cities, including DC, Baltimore, Chicago, and Houston. Once the basic parameters of the UVI are estimated by utilizing private and public loss data, pre-disaster private and public capacity and recovery rates for an impact area, we can easily apply the same methodology to different cities or impact areas.
This proposal will enable the DHS to quantify social and economic risks and allocate resources among the cities by the most effective and efficient way.

Major Milestones and Dates:

1. Review the case studies and the loss literature on past disasters in DC, Baltimore, Chicago, and Houston– October 2008.
2. Estimate the weights for the social and economic variables and identify the functional form of the UVI -- December 2008.
3. Develop the Urban Vulnerability Index for these cities – February 2009.
4. Run simulations to decide on appropriate level of disaster spending on each social and economic variable that will minimize the UVI—April 2009.
5. Conduct rigorous comparisons and tests of various allocation models to compare costs and benefits of distribution of the DHS funds based on the Urban Vulnerability Index -- August 2008.
6. Submit the final report- September 2009