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Constructing Urban Vulnerability Index for Major U.S. Cities

Haydar Kurban
Howard University, HKURBAN@HOWARD.EDU

Mika Kato
Howard University, mkato@howard.edu

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Constructing Urban Vulnerability Index for Major U.S. Cities
Haydar Kurban, Howard University
Mika Kato, Howard University
hkurban@howard.edu

1. Executive Summary

The primary focus of the research at Howard University has been to integrate the social and economic vulnerability assessment into counterterrorism measures. Specifically, this research develops an empirical method to measure the vulnerability of various population groups during a disaster. This work builds on CREATE efforts to develop Urban Vulnerability Index (UVI) to evaluate the social and economic vulnerability of major U.S. cities.

The research at Howard University has developed a novel approach to quantify and rank the vulnerability in terms of uninsured losses that may delay the recovery. The degree of vulnerability depends on the nature of the disaster, i.e., its severity, duration and scope, and the household’s ability to insure against their losses. For the majority of population home ownership is the most important source of wealth. Thus access to home owner insurance and the coverage rate on losses during a disaster become key factors in disaster recovery. Given that natural catastrophes have been occurring with greater frequency and severity in the last decade, this project’s aim is to provide sound analytical and empirical guidance to decision makers regarding the most effective and efficient way to allocate resources among the cities in order to minimize social and economic vulnerability.

Currently, methods are lacking for assessing and ranking vulnerabilities in a systematic and integrated manner. The model parameters were estimated based on the socioeconomic and loss data compiled from public and private sources. The urban vulnerability index project at Howard University contributes to the vulnerability literature by developing a vulnerability measure that is consistent with utility maximizing consumer behavior and risk-averse public perceptions. As seen during Hurricane Katrina, a lack of such models can lead to tremendous costs and suffering for vulnerable populations and national economy. The inverse relationship between vulnerability and household wealth becomes stronger when local area’s poverty level is taken into account because lower income properties are underinsured.

The empirical method developed and applied to Hurricane Katrina can easily be extended to other types of disasters in the states other than Alabama, Louisiana, and Mississippi. The model parameters were

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October 15, 2009
estimated based on national level information on insurance coverage level, tenure, homeowners insurance premium and whether homeowners have insurance coverage or not. The empirical methodology developed for urban vulnerability index can be extended to other areas face Hurricanes or other types of natural disasters. Given information on pre-disaster level wealth, the type of disaster, its impact area and its severity, one can estimate the vulnerability for various population groups in coastal and non-coastal communities.

Another objective of this study is to provide 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. This index will help the DHS optimally allocate its limited resources based on the relative vulnerability rankings. Once the urban vulnerability index model is tested and calibrated, it can be very useful in allocation of resources in a much more systematic manner. A prototype of model building and simulations for evaluating urban vulnerability under various scenarios has been developed, and once completed; it will be transferred to CREATE.

2. Research Accomplishments

The Howard University research team has developed an empirical methodology to quantify and rank vulnerability. The model parameters were estimated based on the socio-economic and loss data compiled from public and private sources. The PI (Haydar Kurban) and Co-PI (Mika Kato) presented their research on urban vulnerability at professional conferences. Based on the feedback they received from their colleagues they updated their working paper numerous times. The final version of the paper entitled “Measuring Vulnerability: An Application to Hurricane Katrina” was submitted to Global Environmental Change, a leading journal in environmental and disaster studies, for publication.

This project measures vulnerability based on the pace of recovery. Given pre-disaster wealth data and loss data, the model parameters return one value to be used for setting policy priorities. Different parameters for coastal counties and non-coastal counties are estimated. The estimated parameters are reliable and can be very useful to guide policy makers. Because they are estimated by using real-world disaster data compiled by FEMA, NOAA and HUD. The socio-economic variables were derived from American Housing Survey (AHS) and U.S. Bureau’s Public Use Micro Samples (PUMS).

A generalized measure of vulnerability should be able to:

- Identify the proportion of the population that are vulnerable
- Be sensitive to distribution of vulnerability within the population
- the severity of vulnerability (distance from threshold)
- Distinguish between variability and vulnerability.

The proposed vulnerability index \( V_{ij} \) measures the adjusted marginal wealth loss for income group i in location j under stress X.
adjustment coefficient

$\sigma = \text{degree of emphasis on vulnerability of below-poverty-line groups}$

A greater $\sigma$ implies that a policymaker puts higher priority on those who fall below $\bar{\$}$ bar. Notice that the vulnerability depends only on the wind speed $\bar{\omega}$ and the pre-disaster wealth $\bar{\$}_0$. 

$$W_1 = W_0 - L + R$$
The loss rate $\theta_i(X)$ of group I is estimated based on real loss data compiled by HUD and SBA. The loss structure of coastal counties is significantly different from that of non-coastal counties. This is so as damages in coastal counties are not only from strong wind but also from hurricane tidal surge flooding. Therefore, the 88 impacted counties are divided into two groups, 72 non-coastal counties and 16 coastal counties, and the loss rate function for non-coastal counties and the loss rate function for coastal counties are estimated separately.

3. Applied Relevance

Research on risk and vulnerability assessment of disasters for various population groups has direct implications for risk-based resource allocation. The policy makers can make informed decisions on how to allocate scarce public sources to minimize the risks. Figure 2 graphically shows our empirical model and Figure 4 presents the estimated urban vulnerability index for different vulnerable groups in a disaster. The empirical methodology developed by this project can be used to construct map of vulnerability for every locality which can be shared with local and state government to coordinate and guide recovery efforts. These maps are very helpful to identify and rank vulnerabilities.
Figure 3: Estimated Vulnerability
Figure 4: Uninsured losses of vulnerable populations when maximum windspeed= 120mph
The vulnerability measure developed at Howard University emphasizes the differences in resiliency across communities and socio-economic groups. Note that resilience is defined as “the capability of an asset, system, or network to maintain its function or recover from a terrorist attack or any other incident” (National Infrastructure Protection Program, 2006). In fact, when the policy measure is set equals to 1 and the relative distance from the minimum level of well-being is ignored, the vulnerability simply becomes a measure of resiliency. The vulnerability measure developed by this project stresses two aspects of vulnerability: vulnerability as exposure (condition that make people or places vulnerable to hazards) and vulnerability as social condition (measure of resilience to hazard). This measure integrates potential exposures and societal resilience with a specific focus on places or regions. Thus this project complements the studies that investigated the resilience of local economies during and after a disaster by Adam Rose and others at CREATE.

4. Collaborative Projects

In general terms vulnerability is defined as:

\[ \text{Vulnerability} = \frac{\text{sensitivity to stress}}{(\text{state relative to threshold} \times \text{probability to exposure})} \]

This project concentrated on measuring vulnerability when a region is hit by a disaster. The probability to exposure is related to physical closeness to public health risks or other environmental risks (asthma, lead paint, flooding or living close to dump sites). The location theory of urban and regional economics suggests that the most undesirable locations will be filtered down to the lower income populations who happened to be the most vulnerable group during or after a disaster. Howard University group will concentrate on the probability to exposure aspects of vulnerability in the 6th year of this project. Again, the focus will be on vulnerable populations in disaster prone urban areas such as New Orleans, Houston and Miami.

The PI and CO-PI plans to work with Adam Rose and other researchers to integrate vulnerability studies with resilience and sustainability studies at CREATE. The research team plans to present the research papers developed in this project to researchers at Department of Housing and Urban Development for feedback and possible future collaboration.

5. Research Products

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<tr>
<td>5a # of peer-reviewed journal reports accepted for publication</td>
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</tr>
<tr>
<td>5a # of non-peer reviewed publications and reports</td>
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</tr>
<tr>
<td>5b # of scholarly presentations (conferences, workshops, seminars)</td>
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<tr>
<td>5b # of outreach presentations (non-technical groups, general public)</td>
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5.1. Publications and Reports

<table>
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<td><strong>Kurban, Haydar - Howard University</strong></td>
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5.2. Presentations - Conferences


5.3. Presentations - Outreach

2. Kurban, H., “Using GIS for Developing Indicators of Urban Vulnerability,” presentation to graduate students in *Urban Economics* course, Howard University, Fall 2009

5.4. Models, Databases, and Software Tools and Products

Prototype software for urban vulnerability index methodology will be transferred to CREATE once completed. The estimated model parameters and research output, papers, maps and graphs will be shared
with CREATE and DHS. The P.I. (Haydar Kurban) will presented the Urban Vulnerability Index methodology at Southern Economic Association Meetings in DC (November 22, 2008) and at Allied Social Science Meetings in San Francisco in January 2009. *The final version of the paper entitled “Measuring Vulnerability: An Application to Hurricane Katrina” was submitted to Global Environmental Change, a leading journal in environmental and disaster studies, for publication.

6. Education and Outreach Products

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<tr>
<td># of students involved (funded by CREATE + any other programs)</td>
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<td># of students graduated</td>
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<td># of existing courses modified with new material</td>
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</tr>
<tr>
<td># of new courses developed</td>
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Judy Mulusa who is a Ph.D student in Economics, was supported by this project this summer. She is working with the PI and the research team to develop UVI for major U.S. cities. Judy Mulusa is expected to graduate in May 2010 with Ph.D in economics. Alexis Miller, an MA student in economics at Howard University was supported by this project in summer 2008 semester. She graduated with MA in economics degree in May 2009.

In the fall 2008 semester and fall 2009 the PI (Haydar Kurban) has incorporated some aspects of developing Urban Vulnerability Index into his Introduction to Urban Economics course. Three students wrote papers on differential effects of disasters on inner city and minority population. They used GIS and U.S. Census data for their analyses. Four students are writing term papers on vulnerable population this semester (Fall 2009).

In the spring 2008, two graduate students constructed vulnerability indices for various population groups in Baltimore and Atlanta. Their papers focused on physical housing conditions, such as structure and elevation. They also used GIS and regression analysis.