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A Web-based Application for Estimation of Personal Vulnerability in Disasters

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A Web-based Application for Estimation of Personal Vulnerability in Disasters

October 2011 to September 2012

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Cooperative Agreement No. 2010-ST-061-RE0001
Department of Homeland Security

December 31, 2011
ABOUT CREATE

The National Center for Risk and Economic Analysis of Terrorism Events (CREATE) was the first university-based Center of Excellence (COE) funded by University Programs of the Science and Technology (S&T) Directorate of the Department of Homeland Security (DHS). CREATE started operations in March of 2004. This annual report covers the seventh year of CREATE funding from October 2010 to September 2011, the first year under Cooperative Agreement 2010-ST-061-RE0001 from DHS. While the text of this report focuses on the seventh year, all data tables, publications, lists of participants, students, and presentations and events are cumulative from the inception of CREATE.

CREATE’s research mission is to develop advanced models and tools for risk assessment, economic assessment, and risk management to counter terrorism. CREATE accomplishes this mission through an integrated program of research, education, and outreach, spanning the disciplines of economics, psychology, political science, industrial and systems engineering and information science. CREATE develops models, analytical tools, methodologies and software, and tests these tools in case analyses, representing critical homeland security investment and policy decisions.

Due to the cross-cutting nature of research in risk, economics, and risk management, CREATE serves the need of many client agencies at the DHS, including the Transportation Security Agency, Customs and Border Protection, Immigration and Customs Enforcement, FEMA and the US Coast Guard. In addition, CREATE has developed relationships with clients in the Offices of National Protection and Programs, Intelligence and Analysis, General Council, Health Affairs, and Domestic Nuclear Detection. Using a mix of fundamental and applied research, CREATE faculty and students take both the long-term view of how to reduce terrorism risk through fundamental research and the medium-term view of how to improve the cost-effectiveness of counter-terrorism policies and investments through applied research.

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A Web-based Application for Estimation of Personal Vulnerability in Disasters

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1. Executive Summary

The goals of the research project at Howard University has been to (a) develop a web-based tool that provides more accurate estimates of uncovered losses during a disaster; (b) inform and educate the public and policy makers about the disaster risks by efficiently combining personal finance, insurance and wealth information with information on disaster strength, availability of insurance, coverage limits, structure types and local economic and government conditions; (c) help and guide the households and local governments in disaster prone areas to minimize private and social costs of disasters; (d) integrate local economic, physical and social factors into overall vulnerability and resilience measures; (e) evaluate and measure the extent of uncovered losses by utilizing publicly available data and relying on user provided personal data to overcome imperfect/incomplete information problem faced by researchers and state and federal disaster relief agencies. This project builds on CREATE efforts to develop personal and community level vulnerability indices to evaluate social and economic vulnerability of the U.S. coastal communities.

The Howard University research team has developed a user friendly-and-web-based tool to estimate household level vulnerability measured by uncovered losses in a natural disaster. This work builds on efforts to incorporate disaster strength, availability of insurance, coverage limits, and personal savings and local government resources into vulnerability and resilience measures. The newly developed web-based tool is designed to be used by local residents, local agencies, and high schools and colleges to enhance disaster risk awareness and help the public to prepare against disaster risks. In particular, this project 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 recover. The newly-developed web-based tool allows the user to estimate household level uncovered losses caused by disaster by partly relying on information on personal savings, insurance coverage limits and insurance types entered by the user.

This project efficiently utilizes publicly available data from Census Bureau to create county level income distribution and house value distribution. The structure loss rates estimated by HAZUS model or damage
data from local agencies are based on replacement costs. Given the disaster strength and structure type and location conditions, our vulnerability methodology estimates the associated structure loss rates. Personal vulnerability is defined by the difference between structure losses and the sum of insurance coverage limit and personal saving. Our model utilizes coverage limit and insurance premium data received from National Insurance Commissioners (NAIC) to estimate coverage per dollar provided by property insurance premium. The index partly also utilizes information on property insurance policy and personal saving entered by the user. The input from the public helps us to mitigate imperfect/incomplete data problem faced in disaster studies. Without this private information, we have to rely on the availability and accuracy of the data samples generated by U.S. Census Bureau’s public use micro samples (PUMS) and other agencies. The new web-based tool enables the public and the policy makers to improve their assessments of disaster losses. The user can observe the level of uncovered losses under various disaster strength scenarios as well as under various property insurance coverage and personal saving scenarios.

The web-based tool provides a more accurate assessment of vulnerability without additional costs. The model also aggregates personal vulnerabilities for a given disaster type and strength to estimate community-based or place-based total uncovered losses. The web-based tool can be used by local agencies and education institutions to educate the public to better prepare for disasters and minimize disaster risks. Lack of information on personal or community vulnerability may delay the recovery from a disaster.

The PI at Howard University has tested the vulnerability methodology on two-pilot counties (Edgecombe and New Hanover) in North Carolina as a part of a contract agreement with the North Carolina Integrated Hazard Risk Management (IHRM) Program. The PI has closely worked with the researchers at IHRM to develop a web-based urban vulnerability module for a few pilot counties in North Carolina. The new module enables the user to estimate the uncovered losses and the level of personal vulnerability. When a user enter information on household characteristics, housing type, insurance coverage and disaster strength, the model returns an estimate of uncovered losses.

The PI at Howard University incorporated the urban vulnerability measure methodology into two undergraduate courses, Introduction to Urban Economics and the Economics of Black Community Development, taught in fall 2010 semester, fall 2011 semester, fall 2012 semester and spring 2010 semester. The PI has also presented the research outcome of this project in a Freshmen Seminar course in fall 2011 semester at Howard University. The PI presented the urban vulnerability measure methodology in IHRM Indirect Loss Estimation Workshop in Raleigh North Carolina (as invited speaker) in February 2012.

Finally, the proposed project involves the public in the process of data generation. When the user enters information on insurance coverage and personal saving, the new data will be incorporated into the vulnerability estimation by the web-based tool. This tool will allow the user to estimate the level of uncovered losses under various disaster strength and insurance coverage scenarios. The proposed tool will improve disaster assessments and inform the public and the local agencies to better prepare for future disasters and improve the pace of recovery.

Keyword 1: urban vulnerability
Keyword 2: natural disaster
Keyword 3: web-based vulnerability module
2. Research Accomplishments

2.1. Measuring Vulnerability: Personal Vulnerability Index (PVI)

The research at Howard University builds on the previous urban vulnerability model (Kurban and Kato, 2009) which measures vulnerability in terms of uninsured losses. The model incorporates housing structural types, household characteristics, disaster strength, local economic conditions, insurance coverage limits and exposure to disasters. FEMA’s HAZUS Hurricane model is used to estimate physical structure loss rates based on real-world data. Insurance coverage limit data are collected from private insurance agencies and local governments. The newly developed empirical methodology is flexible enough to be extended to the disasters other than hurricanes. The basic model compares a household’s pre-disaster wealth \( W_0 \) with post-disaster wealth, \( W_1 \). The uncovered losses are defined as the difference between the losses to physical structure and the insurance coverage limit purchased by the householder. The following diagram presents the model.

![Diagram of Wealth Change Over Time]

\[ W_1 = W_0 - L + R \]

2.2. Estimation of Uninsured Losses

This project estimates the residential-structure loss rates by using the HAZUS hurricane model. The HAZUS model enables us to construct loss rate functions for various types of building structures. The structural loss rate functions estimated by HAZUS model are based on sound engineering principles. Given the disaster strength one can more accurately estimates the loss rates and the dollar value of losses. The loss rate functions presented in Figure 1 are based on HAZUS model loss rate functions. The estimated loss rate functions in Figure 1 can easily be incorporated into the estimation of vulnerability at the household level as well as at the community level. There are five steps involved.

From HAZUS to urban vulnerability measure:

Step1: Derive HAZUS loss rate functions for an area under a specified disaster.
Step 2: Estimate structural and content damage in dollar terms.

Step 3: To what extent these damages are covered by insurance? Recovery pace is determined by insurance coverage rate and the assistance from federal, state and local governments. Combine structural damage data with the data on household characteristics, i.e., income, savings, and insurance coverage.

Step 4: Estimate the rate of uncovered losses for different income and house values.
Personal Vulnerability = Uncovered losses/Household income.

Step 5: Estimate Community Level Vulnerability = Community level Uncovered Losses/Community Level Income

![Graph](image1)

**Figure 1**: Loss rate for WSF1 (top) and WSF2 (bottom)
2.3. Estimating Structure Loss Rates for Housing Types

The structural loss rates are estimated based on HAZUS model. For example, Figure 1 shows the estimated structural loss rates for one-story single family detached house (WSF1) and for two-story single family house (WSF2). We searched for the best-fitting functions that fit the HAZUS data for WSF1 and WSF2. Figure 1 establishes a functional relationship between housing structure type and the disaster strength. Since FEMA HAZUS model is based on sound engineering method, the estimated loss rates are more accurate than the loss rate estimates of physical structure obtained from local private and public sources.

2.4. Estimation of Personal and Community Level Vulnerability in a Group of Counties in North Carolina

Estimation of Personal Vulnerability Index (PVI)

We estimate PVI in five steps:

1. **Estimate insurance premium based on structure value in the county.** American Community Survey (ACS) and 5% Public Use Micro Samples (PUMS) provide household level data on property insurance, property characteristics and household characteristics. For the pilot counties in North Carolina, the PI used property assessment data provided by the IHRM program.

2. **Estimate coverage limit per dollar of insurance premium.**
   The most common residential insurance policy HO-3 comprised over 85 percent of all owner-occupied homeowners’ policies (NAIC Research Quarterly, spring 2005). HO-3 coverage includes dwelling, other structures, personal property and loss of use. If the homeowner chooses m dwelling coverage limit, her other structure coverage is 10% of dwelling coverage limit (0.1m), her personal property coverage is 50% of dwelling coverage limit (0.5m) and loss of use coverage is 20% of dwelling coverage limit (0.2m) (see http://www.insureuonline.org/consumer_guide_home.pdf). Table 1 shows the dollar value of coverage purchased per $1 of insurance premium. Given structure value, household income, insurance premium and coverage per dollar of premium, one can decide whether a household buys sufficient coverage limit to cover all structural and personal losses.
Table 1: Coverage per Dollar of Premium

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<td>1,860.9</td>
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</tbody>
</table>

Source Turk (2005)

3. Determine disaster strength and therefore damage level bus using HAZUS model.

4. Estimate uncovered losses:
   \[ \text{Uncovered Losses} = \text{Structure Value} - \text{Coverage Limit} \]

5. Estimate Personal Vulnerability for a given household income
   \[ \text{PVI} = \frac{\text{Household Income} - \text{Uncovered Losses}}{\text{Poverty Level Income}} \]
   Identify structures with Low, Medium and High PVI.

U.S. Census Bureau defines poverty area (see Hollar and Usowski (2007) as family income equals to 60 percent of area median income (AMI). When household income is less than 60 percent of the area median income that household will be considered “poor”.

Therefore,
If \( \frac{\text{Household Income} - \text{Uncovered Losses}}{\text{Poverty Level Income}} < 0.6 \times \frac{\text{Area Median Income}}{\text{Poverty Level Income}} \)
this household will be designated as “High PVI”.

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If \((\text{Household Income} - \text{Uncovered Losses})/\text{Poverty Level Income}\) is in the range of \(0.6 \times (\text{Area Median Income}/ \text{Poverty Level Income})\) to \((\text{Area Median Income}/ \text{Poverty Level Income})\), this household will be designated as “Medium PVI”.

If \((\text{Household Income} - \text{Uncovered Losses})/\text{Poverty Level Income} > (\text{Area Median Income}/ \text{Poverty Level Income})\), this household will be designated as “Low PVI”.

3. **Applied Relevance**

3.1. **Measuring Personal Vulnerability: A Web-based Application for two Pilot Counties in North Carolina**

The PI has collaborated with the IHRM program in North Carolina to develop a PVI module to be incorporated into the overall risk assessment into the iRISK project. The PVI is estimated for two pilot counties, i.e., Edgecombe County and New Hanover County in North Carolina.

- \(\text{PVI} = (\text{Household Income} - \text{Uncovered Losses})/\text{Poverty Level Income}\)

It is assumed that uncovered losses reduce household income. Hence, as \((\text{Household Income} - \text{Uncovered Losses})\) decreases, the household gets closer to poverty level income. The \((\text{Household Income} - \text{Uncovered Losses})/\text{Poverty Level Income}\) ratio measures the degree of vulnerability. A standalone web-based application is already built for the pilot counties. The user can estimate her PVI by entering information on house value, property insurance, and household income. The web-based application uses underlying property insurance premium and coverage rate equations to estimate the PVI. For each pilot county, the Howard University research team estimated insurance premium and coverage rate equations by using micro samples obtained from U.S. Census Bureau and other public sources. Insurance premium equation predicts the insurance premium for a given structure value and coverage rate equation predicts the coverage amount for given insurance premium.

The web-based PVI application enables the user to estimate the level of uncovered losses. This application tries to provide an answer to the following question: “If a household loses her property at 100 percent in a disaster, how much uncovered losses will she incur?”

The level of uncovered losses will determine the recovery rate. Table 2 shows that about 56% of residential buildings are rated “high” PVI in Edgecombe County NC and only 21% of buildings are rated as “high” PVI in New Hanover County NC.

Table 2 shows the distribution of residential units based on their PVI ratings. These numbers are based on the aggregation of the PVI for individual housing units.
Table 2: PVI Ratings in Edgecombe and New Hanover

<table>
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<tr>
<th>County</th>
<th>Number of Buildings</th>
<th>PVI Rating</th>
<th>Share</th>
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<tr>
<td>Edgecombe</td>
<td>14228</td>
<td>High</td>
<td>55.97%</td>
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<td>Edgecombe</td>
<td>5201</td>
<td>Medium</td>
<td>20.46%</td>
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<tr>
<td>Edgecombe</td>
<td>5812</td>
<td>Low</td>
<td>22.86%</td>
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<tr>
<td>New Hanover</td>
<td>17076</td>
<td>High</td>
<td>20.91%</td>
</tr>
<tr>
<td>New Hanover</td>
<td>9966</td>
<td>Medium</td>
<td>12.21%</td>
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<tr>
<td>New Hanover</td>
<td>54608</td>
<td>Low</td>
<td>66.88%</td>
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</table>

Figure 2 shows PVI module within the iRISK pilot model. The iRISK pilot model is currently tested by the public and the stakeholders in North Carolina. The user can evaluate her PVI by entering her personal data on household income, insurance coverage limit, savings, wealth, and property value. The web-based PVI tool is used for risk assessment of personal and community level vulnerability caused by disasters. This user-friendly and web-based application can be used by DHS, education institutions and local agencies.
Figure 2: The PVI module as part of iRISK pilot

Collaborative Projects

The project on structure losses and disaster strength was greatly assisted by FEMA HAZUS model, which provides engineering based structure loss data. HAZUS loss data was used to fit structure loss rates for various housing types. Insurance coverage data from private sources, U.S. Census Bureau, Socio-economic data from U.S. Census, and structure share of house value from the Lincoln Institute improved our vulnerability measure. Using HAZUS model has also prevented us from duplications and wasting our research time and resources. The Howard University research team has obtained property assessment data from a test county in North Carolina. The assessment data provides more accurate and up-to-date information on property values. More importantly we can separate structure value from the land value.

The PI has collaborated with the researchers involved in North Carolina Integrated Hazard Risk Management (IHRM) Project through a contract agreement to integrate the vulnerability methodology within the general economic modeling framework for risk management. This project has developed a web-based module tool to be integrated into the iRISK model for North Carolina. The web-based module for two pilot counties in North Carolina is at the trial stage.
Howard University team plans to develop a similar web-based module for educational purposes if additional funding becomes available.

a) The PI has partnered with Integrated Hazard Risk Management (IHRM) project in NC to develop web-based PI module for four counties in NC; b) the PI module will help the public to publically access the vulnerability to disasters measured by uncovered losses as share of income

### COLLABORATIVE PROJECTS

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### 4. Research Products

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### 5.1. Publications and Reports

**CREATE PUBLICATIONS**

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CREATE PUBLICATIONS

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Presentations

PRESENTATIONS – CONFERENCES

Haydar Kurban, Howard University

5.3. Models, Databases, and Software Tools and Products

Prototype web-based application of Personal Vulnerability Index for pilot counties in North Carolina is currently under development. The PI has completed the PVI module for IHRM Loss Estimation project in Raleigh North Carolina. The intended users are general public and local and state stake holders. The user will enter information on household characteristics, housing type and disaster strength and estimate uncovered structure losses both in terms of dollars and loss rates.

SOFTWARE PRODUCTS

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6. Education and Outreach Products

Education and Outreach Initiatives (Please detail below) #
# of students supported (funded by CREATE) | 3
---|---
# of students involved (funded by CREATE + any other programs) | |
# of students graduated | 2
# of contacts with DHS, other Federal agencies, or State/Local (committees) | 1
# of existing courses modified with new material | 4
# of new courses developed | |
# of new certificate programs developed | |
# of new degree programs developed | |

## CREATE STUDENTS

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## PRESENTATIONS - OUTREACH EVENTS

**Kurban, Haydar - Howard University**

1. Kurban, Haydar, “Constructing Urban Vulnerability Index,” Interdisciplinary Undergraduate Research Group, College of Arts and Sciences, Howard University, Spring 2010, Fall 2010, Fall 2011.


3. Kurban, Haydar, “How to Incorporate Socio-economic Factors in Vulnerability Measure”, A week long lecture in the Economics of Black Community Development (undergraduate), Spring 2010, Fall 2010, Fall 2011, Fall 2012

4. Kurban, Haydar, “How to Incorporate Socio-economic Factors in Vulnerability Measure”, A two week teaching to freshman students in Freshmen Seminar course (undergraduate), Howard University, Fall 2011.

## References


