Assessing the Losses Avoided from the Adoption of Building Codes: A Multi-Hazard Nationwide Study

FEMA Resilience Lunch and Learn

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Disclaimer

• FEMA does not endorse any non-government entities, organizations, or services.

• This slide deck has been amended as of August 26, 2019
Introduction

Brief History of Project

NMIS Goal 3, Recommendation 3.1:
• Encourage Communities to Adopt and Enforce Up-to-Date Building Codes.

Mitigation Saves 2.0
• NIBS found that designing buildings to the 2018 I-Codes results in a national benefit of $11 for every $1 invested, when compared to earlier codes and NFIP regulations.

2017 MAT Report: Hurricane Harvey in Texas
• The MAT found that in one neighborhood NFIP Regulations reduced average claim payments by almost half and including freeboard (as required in modern building codes) further reduced the average claim payments by an additional 90%.
Incentivize Community Mitigation

- Demonstrate the value of adopting and enforcing hazard-resistant building codes nationwide
- Incentivize building code adoption to reduce disaster losses
- Inform local investment decisions to increase resilience

Quantify Disaster Risk Reduction

- Identify anticipated damages prevented during natural hazards due to provisions in modern building codes.
- PPD-8, PPD-21, Federal Flood Risk Reduction Standard, BW-12, FIMA Strategic Plan, NMIS
Code Adoption Status
Study Phases

Phase 1: Pilot Study (2012)
- SC and UT
- Issues: Structure and hazard data availability and local building code information, Hazus analysis

Phase 2: Regional Study (2014)
- FEMA Region 4
- CoreLogic data in SFHA only
- Issues: Data processing and gap filling, hazard data, building code assumption, large scale Hazus analysis

Phase 4: Nationwide Study (2020)
Phase 1 – Pilot Study

- **Purpose**: Test initial concept in city where data is available
- **When**: Conducted in 2011
- **Site selection**: Considered community ratings, hazard exposure, size, data availability and quality
- **Pilot study communities**:
  - Hurricane and flood hazards
    - Charleston County, SC
  - Seismic hazard
    - Salt Lake County, UT
## Phase 1 – Pilot Study

### Flood Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Lower Bound Depth-Damage Function ($1,000)</th>
<th>Upper Bound Depth-Damage Function ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 foot of freeboard</td>
<td>33,000</td>
<td>66,000</td>
</tr>
<tr>
<td>2 feet of freeboard</td>
<td>51,000</td>
<td>103,000</td>
</tr>
</tbody>
</table>

### Hurricane Summary

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>Losses Avoided ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-year (Category 1 Hurricane)</td>
<td>1,500</td>
</tr>
<tr>
<td>100-year (Category 2 Hurricane)</td>
<td>132,000</td>
</tr>
<tr>
<td>500-year (Category 3 Hurricane)</td>
<td>1,649,000</td>
</tr>
</tbody>
</table>

### Earthquake Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Losses Avoided ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M7.0 Salt Lake City Segment, Wasatch Fault</td>
<td>493,000</td>
</tr>
<tr>
<td>M7.2 Provo Segment, Wasatch Fault</td>
<td>228,000</td>
</tr>
<tr>
<td>M6.0 West Valley/ Taylorsville</td>
<td>145,000</td>
</tr>
</tbody>
</table>
Phase 2 – Regional Study

**Purpose:**
- Expand and refine Phase 1 method
- Apply systematically to region as demonstration study

**Site Selection:**
- All 10 FEMA Regions were evaluated
- FEMA Region IV was selected

**Scope:**
- Study area: 4.5M parcels
- Focus on SFHA & 500-year floodplain
- Flood, wind, seismic hazards
### Phase 2 – Regional Study

#### Results Summary

<table>
<thead>
<tr>
<th></th>
<th>AL</th>
<th>FL</th>
<th>GA</th>
<th>KY</th>
<th>MS</th>
<th>NC</th>
<th>SC</th>
<th>TN</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seismic Losses Avoided</strong> (x $1,000,000)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.03</td>
<td>0.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.85</td>
<td>0.06</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Hurricane Losses Avoided</strong> (x $1,000,000)</td>
<td>2.90</td>
<td>376.30</td>
<td></td>
<td></td>
<td>3.60</td>
<td>5.60</td>
<td>12.80</td>
<td></td>
<td>402.16</td>
</tr>
<tr>
<td><strong>Flood Losses Avoided</strong> (x $1,000,000)</td>
<td>0.83</td>
<td>87.63</td>
<td>10.10</td>
<td>0.42</td>
<td>1.30</td>
<td>7.30</td>
<td>10.08</td>
<td>0.94</td>
<td>118.60</td>
</tr>
</tbody>
</table>
Incentivize adoption and enforcement of hazard-resistant building codes nationally

Relative Impact to States for Adopting Model Building Codes

Saves a billion?

Probably - Based on the FIMA-led Losses Avoided Study, Region IV's average annual losses avoided from adopting building codes is $532 M.¹

What might it save us nationally?
Combining the states' hazard risk and building code adoption and enforcement, we determine how Region IV compares to the rest of the country and estimate losses avoided of:
$1.25 B-$2.06 B annually.²

¹ Based on FIMA's 2012 Losses Avoided Study, adjusted to 2015 dollars. This estimate does not include lives saved, decreased business interruption or other unaccounted for benefits. The value is expected to increase over time as more of the building stock transitions to model codes and older structures are removed.

² State Building Code Enforcement Grading Schedule (BCEGS) scores combined with Average Annual Loss estimates to create a relative impact index. States with low impact values will still benefit from codes.

³ Average annual losses avoided nationwide. This number is an estimate. A nationwide losses avoided study is needed to get a more precise figure.
Phase 3 – National Methodology

- **Step 1** – Perform data collection and screening
  - BCEGS, State Fact Sheets, Parcel, CRS, SFHA, NFHL, Bing Footprint, ASCE-7 & USGS Hazard Maps

- **Step 2** – Input data into Hazus (or equivalent analysis)

- **Step 3** – Adapt damage curves

- **Step 4** – Compute and analyze losses avoided
  - Flood within SFHA
  - 22 Hazus Hurricane States
  - 6 western seismic states
Phase 3 – National Methodology, Cont’d

- **Step 5** – Evaluate findings (sensitivity analysis)
- **Step 6** – Perform QA

**Screening Focus**
- Areas of growth and exposure
- Buildings constructed after I-Code adoption
Phase 3 – National Methodology
CoreLogic Parcel Data Filtering

**Parcel Characteristics**

- **Primary parcel information needed**
  - Location (e.g., State, Community, Census Tract)
  - Latitude/Longitude
  - FIPS Code/ZIP Code
  - Universal Land Use Codes
  - Universal Square Footage
  - Stories Number
  - Stories Code
  - Effective Year Built
  - Year Built

**Level 1**
Total Parcels in Region IV with a Year Built or an Effective Year Built >1999

**Level 2**
Square footage ≥ 500

**Level 3**
Remove parcels in counties with <10 parcels

**Level 4**
Removed Year Built <2000 and No Year Built (except in counties where No Year Built make up >90% of the parcel data)

**Level 5**
Parcels with questionable sqft, stories, or occupancy data are evaluated and fixed or deleted

- CoreLogic Building Code
- Mobile Home Indicator Flag
- Units Number
- Hazus Occupancy Class
- Derived Stories Number
- Derived Year Built

**Data Sources**
- CoreLogic Data
- Derived Data
- Outside Source Data
Parcels by Year
Calculating Losses

(Pre-I-Code damage) – (Post I–Code adoption damage) = Losses Avoided

<table>
<thead>
<tr>
<th>Input Loss Parameters</th>
<th>Hazus Damage Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flood Loss Parameters</strong></td>
<td>Compare pre- and post-I-code flood depths</td>
</tr>
<tr>
<td>Foundation type</td>
<td></td>
</tr>
<tr>
<td>Base flood elevation</td>
<td></td>
</tr>
<tr>
<td>Freeboard</td>
<td></td>
</tr>
<tr>
<td><strong>Wind Building Characteristics</strong></td>
<td>Compares code-era wind speed and regional practices</td>
</tr>
<tr>
<td>Roof</td>
<td></td>
</tr>
<tr>
<td>Opening protection</td>
<td></td>
</tr>
<tr>
<td>Connections</td>
<td></td>
</tr>
<tr>
<td><strong>Seismic Building Characteristics</strong></td>
<td>Compare construction quality levels assigned to pre- and post-I-Code conditions</td>
</tr>
<tr>
<td>Model Building Type</td>
<td></td>
</tr>
<tr>
<td>Design Level</td>
<td></td>
</tr>
</tbody>
</table>
Data Development Goals

• To create a nationwide property inventory that accurately aggregates parcel-level data attributes to allow further LAS analysis.
What is Our Base Unit?

- 203M parcel point records
- 144M parcel polygon records
- 98% of parcels in over 3k counties
- 88 total attributes

Key attributes
- Universal Square Footage
- Effective Year Built
- Land Use
- Structure characteristics (construction type, roof type, frame type, etc.)
Parcel Strategy

Utilizing Bing Building Footprints

Stacked Parcel Attribution Methodologies

- 1 parcel and 1 building
- 2+ parcels and 1 building
- 1 parcel and 2+ buildings
- 2+ parcels and 2+ parcels
Leveraging Cloud Infrastructure

- Use multiple software tools and languages to account for each specific need or tailored solution
- Allows team to focus more on front end
- Provides additional security
  - Physical security of data centers
  - Encryption of data in transit
  - Access/identity control
LAS Seismic - General Approach

• Analyze individual “buildings”, derived from CoreLogic parcel data using Hazus Earthquake Advanced Engineering Building Module (AEBM)
  • Additional required data:
    • Model building type (structure type)
    • Hazus design level (~code-required strength)
    • Seismic code adoption history
• Run Average Annualized Loss (AAL) (requires modification to Hazus code) using 2014 National Seismic Hazard Map data built into Hazus
Hazus AAL AEBM Optimization

• Hazus earthquake currently includes AAL calcs for general building stock economic loss and casualties only.

• Automate AAL process for AEBM fields to reduce manual labor-intensive loss calculations

• Planned approach – replicate GBS AAL process

• Radio button will be added to the AAL run menu:

Any resulting code will be shared back with the FEMA Hazus team for review and potential implementation.
Design Level (DL) Determination

- New DLs were required (Very High and Severe), since Hazus standard DLs were developed from max strength required in UBC94 Zone 4
- The current “High Code” DL served as the starting point for two new DLs: Very High Code and Severe Code
- AEBM Profiles for the new DLs will be added Hazus and shared with the FEMA Hazus team

<table>
<thead>
<tr>
<th>Parameter Change</th>
<th>Very High Code</th>
<th>Severe Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Curve – Adjust Design Strength &amp; Yield/Ultimate Capacity</td>
<td>Increase by a factor of 1.5</td>
<td>Increase by a factor of 2.0</td>
</tr>
<tr>
<td>Structural Fragility Curve – Adjust Median Spectral Displacement Values (beta unchanged)</td>
<td>Increase by a factor of 1.15</td>
<td>Increase by a factor of 1.25</td>
</tr>
<tr>
<td>Nonstructural Acceleration-Sensitive Fragility Curve – Adjust Median Spectral Accelerations (beta unchanged)</td>
<td>Increase by a factor of 1.3</td>
<td>Increase by a factor of 1.5</td>
</tr>
<tr>
<td>Nonstructural Drift-Sensitive Fragility Curve</td>
<td>No change</td>
<td>No Change</td>
</tr>
</tbody>
</table>
Standalone Hazus Hurricane Tool to Model Losses by Parcel for LAS

- Objective: Estimate hurricane wind losses avoided for all post-1999 buildings from Texas to Maine
  - Approximately 9.4 million buildings

- Approach:
  - Stand-alone application
    - Bare bones, built for bulk processing
    - Follow the Hazus methodology with enhancements
    - Building and contents losses only
  - Excludes
    - ArcGIS user interface
    - SQL database
    - Crystal Reports
## Wind Modeling Enhancements

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Prescriptive</th>
<th>Engineered to &quot;SBC (100-110 fastest mile) w/o or w/ opening protection, but no small missile above 60'&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Hazus &quot;Design&quot;:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood Frame Res</td>
<td>Masonry Res</td>
<td>Engineered</td>
</tr>
<tr>
<td>Single and Multifamily</td>
<td>Single and Multifamily</td>
<td>Commercial and Residential</td>
</tr>
<tr>
<td>Full Load Path</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Designed for internal pressure in WBDR</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Roof Cover Strength</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Gable End Failure</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Roof Deck</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Window Strength</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Non-Glazed Entry Doors</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Garage Doors</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Masonry Wall Reinforcing</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Priority</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Priority</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest Priority or N/A</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Hazus Hurricane Damage and Loss Modeling Approach

• Explicit modeling of building performance
  • Component loads
    • Wind pressures
    • Wind-borne debris
  • Resistances
    • Roof-to-wall connection
    • Roof deck attachment
    • Roof covering
    • Opening protection (e.g., engineered shutters)
  • Component failures and wind-driven rain infiltration
  • Building Loss, Contents Loss, Loss of Use as a function of peak gust wind speed in open terrain

• 100,000-year event set
  • Needed to compute regional return period losses
Hazus Hurricane Damage and Loss Modeling Approach

• Start with default Hazus mapping schemes

• Replace unknowns with knowns, where possible
  • Construction
  • Number of stories
  • Roof shape
  • Roof cover type

• Modify remaining building characteristic weights based on year built, location, and building code
  • Window impact resistance and design pressures
  • Roof-to-wall connection and full load path
  • Roof deck attachment
  • Roof cover strength and Secondary Water Resistant
Flood Data Fields

<table>
<thead>
<tr>
<th>Data Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation Type &amp; Number of Stories</td>
</tr>
<tr>
<td>Freeboard</td>
</tr>
<tr>
<td>Flood Zones</td>
</tr>
<tr>
<td>First Floor Elevation (FFE)</td>
</tr>
</tbody>
</table>

- Using building footprint for gap filling number of stories
- Determined from Community Rating System (CRS) and supplemented by BCEGS for adoption data
- Determined from NFHL with 500 ft buffer.
- FFE are assumed based upon code version
Flood-Specific Process Overview

Step 1: Freeboard Lookups (by construction date and flood zone)
   a. BCEGS
   b. State
   c. CRS
   d. Community

Step 2: Final freeboard assignment
   a. Initial value from BCEGS and State maximum
   b. CRS overrides if greater
   c. Community overrides all other values
Flood LAS Calculation

With Code = With Freeboard

Without Code = Lowest Floor Elevation (typically FFE) at BFE
Timeline Summary

Wind Model

National Data Processing
EQ Model AA/AEBM

Aug
Sep
Oct

Interim Report Development Begins

Nov
Dec
Winter 2020

Initial Results

Interim Report Development Ends

Final Report

Complete
Pending
Questions?

FEMA Building Science Branch
FEMA-Buildingsciencehelp@fema.dhs.gov