Informing Development and Retrofit Incentives with Society-wide Benefit-Cost Analysis

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Keith Porter, University of Colorado Boulder and SPA Risk LLC
“Money spent on reducing the risk of natural hazards is a sound investment. On average, a dollar spent by FEMA on hazard mitigation provides the nation about $4 in future benefits.”
Valuable, but questions remained

Private-sector retrofit

Adopt or exceed building codes

Utilities & transportation

Other perils

March 2019

Exceed: Jan 2018
Adopt: Jan 2019

October 2018

January 2018
<table>
<thead>
<tr>
<th>Peril</th>
<th>Overall Hazard Benefit-Cost Ratio</th>
<th>Exceed common code requirements</th>
<th>Meet common code requirements</th>
<th>Utilities and transportation</th>
<th>Federally funded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverine Flood</td>
<td>5:1</td>
<td>6:1</td>
<td>8:1</td>
<td>7:1</td>
<td></td>
</tr>
<tr>
<td>Hurricane Surge</td>
<td>7:1</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Too few grants</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>5:1</td>
<td>10:1</td>
<td>7:1</td>
<td>5:1</td>
<td></td>
</tr>
<tr>
<td>Earthquake</td>
<td>4:1</td>
<td>12:1</td>
<td>3:1</td>
<td>3:1</td>
<td></td>
</tr>
<tr>
<td>Wildland-Urban Interface Fire</td>
<td>4:1</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>3:1</td>
<td></td>
</tr>
</tbody>
</table>

Savings ($billion):
- Exceed common code requirements: $16/year
- Meet common code requirements: $13/year
- Utilities and transportation: $2.5/year
- Federally funded: $160/year

*BCR numbers in this study have been rounded.
Benefit categories included

- Property damage
- Business interruption
- Deaths & injuries
- PTSD
- Public service
- Insurance O&P
Some benefits too hard to estimate, so BCRs may be low.
Here, $BCR = \frac{PV\ of\ societal\ benefits}{PV\ of\ societal\ costs}$

- Incrementally efficient max = minimum lifecycle cost
- $BCR > 1.0$ means an investment gap
- $BCR > 1.0$ means that without the mitigation, other people pay more later for developers’ and initial owners’ short-term benefit
Seismic performance of stronger & stiffer buildings
Practicality: this California building could be designed to remain elastic at $\frac{2}{3} \times MCE_R$.
Affordability: 50% stronger & stiffer costs <1% more

Harris et al. (2014) designed 6 buildings to 1999 SBC & to 2003 IBC (like $I_e = 1.6$); costs 0-1% more

CUREE-Caltech Woodframe designed one building to IRC & to IO design; costs ~3% more
Affordability explained

Greater strength & stiffness increases this 2% of construction cost.

And doesn’t affect this cost at all.
More evidence of affordability

50% greater strength here

Is about the same as code level here

2 x San Diego = 1.0 x SF or LA
3 x Sacramento = 1.0 x western SF
Simmons & Kovacs 2017: “The code had no effect on either home sales or price for new homes in Moore.”

Price

Sales

Before

After
Above-code design $I_e$ reaches 3.0
**Benefit:** $4.3 billion

- 35% – Property: $1,500
- 32% – Direct business interruption: $1,400
- 18% – Deaths, injuries & PTSD: $800
- 14% – Indirect business interruption: $600
- 1% – USAR: $30

*millions 2016 USD*

**Cost:** $1.2 billion

Above-code design overall BCR = 4:1
Benefit-cost analysis of some other seismic resilience measures
Code compliance BCR reaches 32:1
Code compliance overall BCR = 12:1

**Benefit: $7 billion**
- 43% – Property: $3
- 29% – Additional living expenses and direct business interruption: $2
- 14% – Deaths, injuries, and post-traumatic stress disorder: $1
- 14% – Indirect business interruption: $1
- 0.3% – Urban search and rescue: $0.02

Billions 2018 USD

**Cost: $0.6 billion**
Stakeholder net benefits for above-code design

- Lenders
- Communities
- Tenants
- Title Holders
- Developers

- Hurricane Wind
- Earthquake
- WUI Fire
- Riverine Flood
- Hurricane Surge
Stakeholder net benefits for code compliance

- Lenders
- Communities
- Tenants
- Title Holders
- Developers

Net Benefit, $bn

- Hurricane Wind
- Earthquake
- Riverine Flood
Soft-story retrofit BCR = 12:1

**Benefit:** $190 billion

- 58% – Property: $110
- 3% – Deaths, nonfatal injuries, PTSD: $5
- 26% – Additional living expenses: $50
- 13% – Indirect business interruption: $25

Billions 2018 USD

**Cost:** $16 billion
Secure hot water heater BCR = 22:1

**Benefit:** $75 billion
53% – Property: $40
7% – Additional living expenses: $5
4% – Indirect business interruption: $3
36% – Deaths & nonfatal injuries: $27
Billions 2018 USD

**Cost:** $3.4 billion
Secure bookcases $BCR = 13:1$

*Benefit*: $28$ billion

$100\%$ – Injuries: $28$

*Cost*: $2.2$ billion

Billions 2018 USD
Other measures we are evaluating
Some limitations
BCRs is at most one among many considerations

- Preferences
- Resources
- Legal and time constraints
- Justice and equity
BCRs don’t speak to catastrophes

M7 Hayward Fault: 25% impaired

Partial solution: current minimum strength from other considerations
BCRs assume compliant construction
BCRs average over buildings & time
Funding mechanisms are needed
Conclusions
• BCRs are one way to evaluate mitigation strategies and set goals to optimize society’s interests
• Nobody actually loses when we build better or keep to with codes
• It is practical, affordable, & more efficient (with lower total cost of ownership) to building up to 3x stronger & stiffer, to keep up with new codes, and to do various common retrofit measures
• Better design & retrofit can be tailored geographically
Thanks

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The public expects and prefers better

Preferred performance for a new building after the Big One \((n = 804)\)

- Do not know: 17%
- Life safe: 22%
- Functional: 18%
- Occupiable: 41%
- Other: 2%

What would you be willing to pay for occupiable or functional?

- $0/sf: 12%
- $1/sf: 20%
- $3/sf: 31%
- $10/sf: 20%
- Do not know: 17%
City councils and mayors “absolutely do not know” about the life-safety objective & how damaged a code-compliant building stock will be in the aggregate, and are unsatisfied when they do learn of it.

-- L. Jones, pers. comm., 19 Nov 2013
“Most members of BOMA know the code is life safety but they told me they wished it was higher. They don’t want to own a building that will be a total loss, but they can’t afford to do it alone and be more expensive than their competitors.”

-- L. Jones 2015 (written commun.)
ASCE’s Code of Ethics requires public input on codes

“ASCE’s Code of Ethics requires civil engineers to make a reasonable effort to elicit and reflect the preferences of the public, whose lives and livelihoods are at stake, when setting seismic performance objectives”

M Davis
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