

Ethical and Efficient Infrastructure Resilience: The Battle for Better Building Codes

A Webinar for the Natural Hazards Center

Boulder, Colorado

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Keith Porter, University of Colorado Boulder

Intent of I-Code seismic provisions

Avoid serious injury and life loss,

Preserve means of egress,

Avoid loss of function in critical facilities, and

Reduce structural and nonstructural repair costs where practicable.

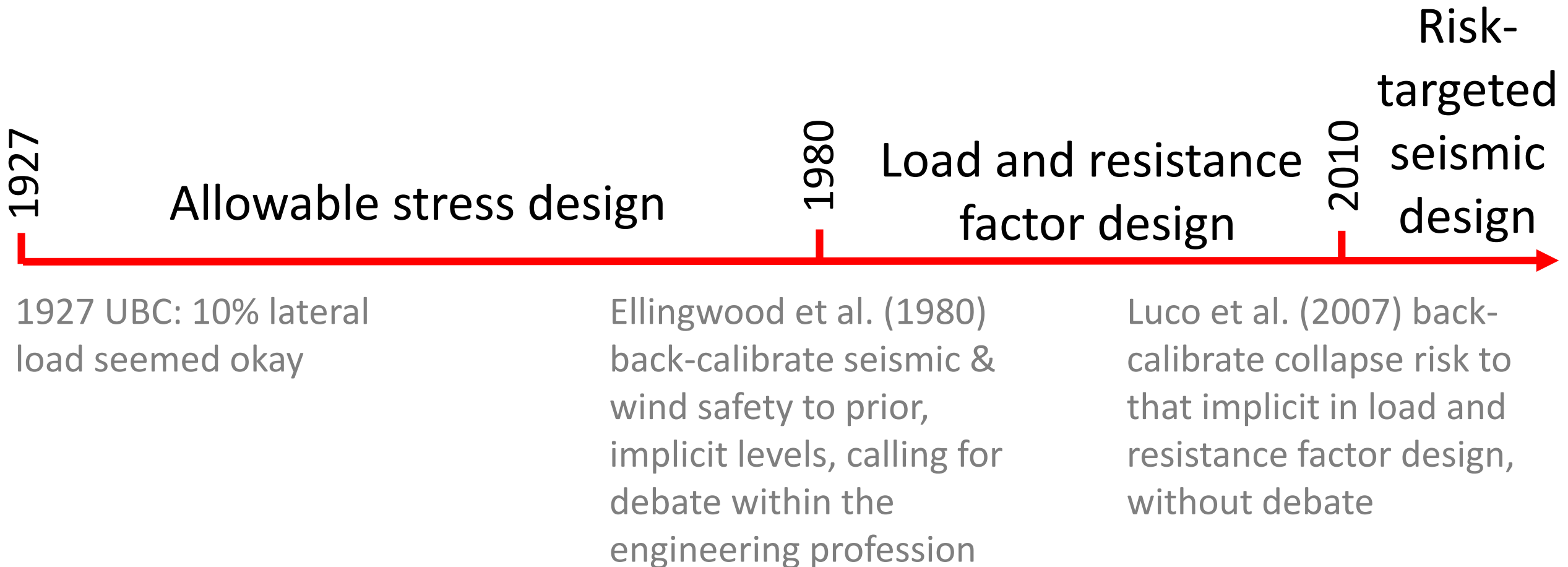
*-- NEHRP Recommended Seismic Provisions for New Buildings
and Other Structures, 2015 Edition*

I-Codes protect life safety very well

Peril	Deaths/100,000 pop/yr	Where, when
Heart disease	194	US, 2010
Occupational fatality, roofers	32	US, 2011
Auto accidents	11	US, 2009
New buildings in earthquakes	0.1	40 hours/week
CA earthquakes last 50 years	0.007	CA, 1965-2014

But are the I-Codes *ethical*?

Ethics imply deliberate choice. What choices have code-writers made?



Engineers never consciously chose resilience goals for buildings. Why?

David Hume, 1711-1776

Hume's Law



You can't get an *ought* from an *is*: you can't infer that we *ought* to have the degree of risk currently in our codes just because that risk *is* present in codes.

What branch of scholarly study
focuses on norms, shoulds, *oughts*?
What are its three approaches?



Virtue ethics: be a good person

Some of Aristotle's Nicomachean Ethics

Truthfulness with self-expression

Modesty in the face of shame or shamelessness

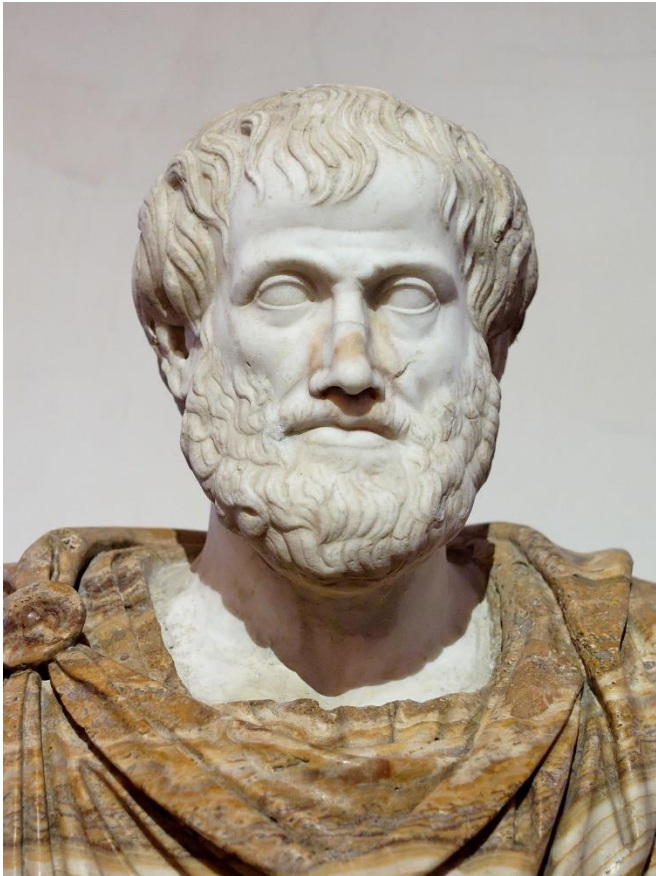
Intelligence about fundamental truths

Science and skill at inferential reasoning

Theoretical wisdom combining intelligence and science

Techne art, craftsmanship

These ethics can inform engineers' character, but are silent about desired outcomes for new buildings.



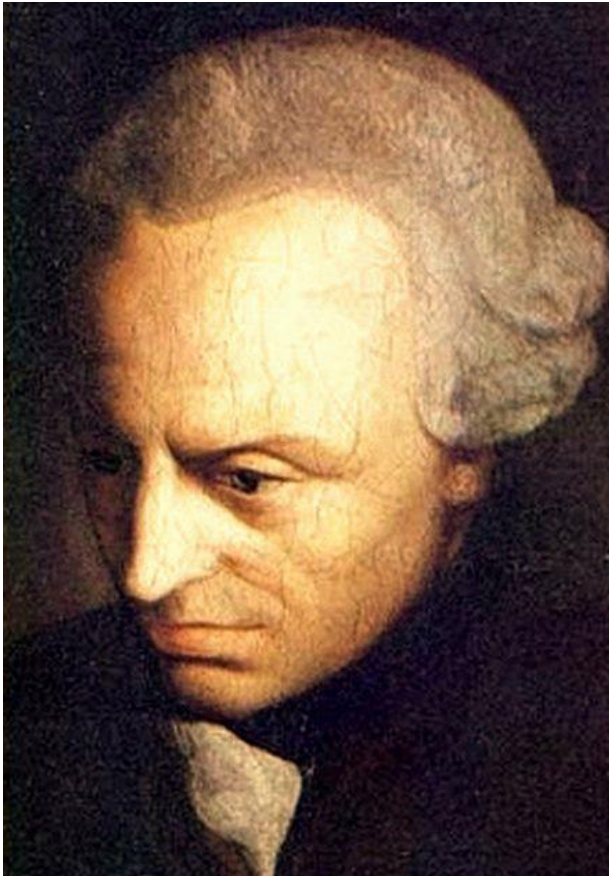
Duty ethics: act by maxims that you would have be universal laws

Immanuel Kant 1724-1804

Kant's categorical imperative

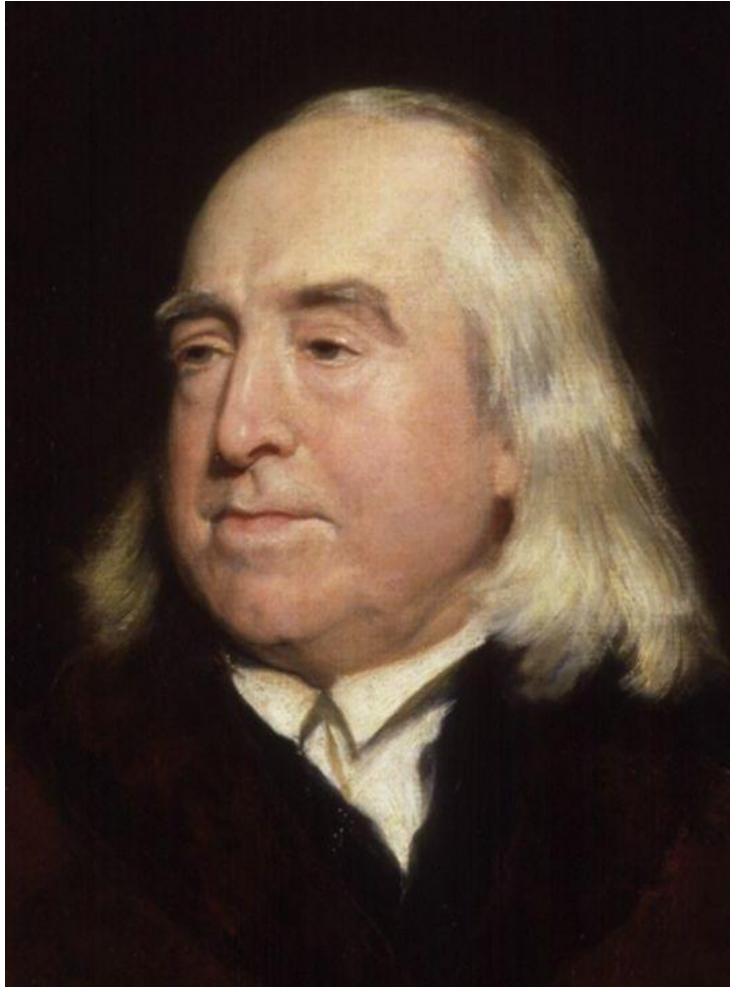
“So act, that the rule on which thou actest would admit of being adopted as a law by all rational beings.”

The building code has consistent, universal goals, but any consistent performance objectives could do so.



Utilitarian ethics: act to achieve the greatest good for the greatest number

Jeremy Bentham 1748-1832



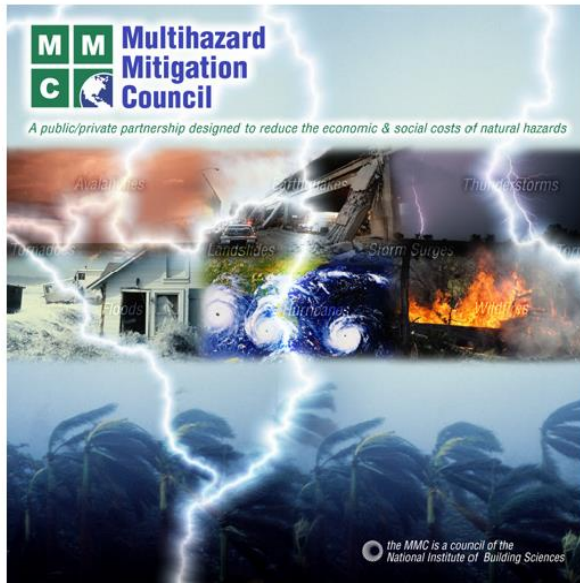
Bentham's utilitarianism

A good action is one that results in an increase in pleasure, and the best action is one that results in the most pleasure for the greatest number. "Every [person] to count for one, nobody for more than one."

The U.S. Constitution was written with utilitarian legislation in mind. Utilitarianism is an American ideal.

We can set building performance objectives mathematically once we accept this principal.

Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities (2005)



NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities

Volume 1 – Findings, Conclusions, and Recommendations

“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.”

NIBS update to *Mitigation Saves* finds the design level that maximizes the total good

$$\text{BCR} = \frac{\text{present value of avoided future losses (B, benefit)}}{\text{up-front and maintenance expenses (C, cost)}}$$

Private-sector building retrofit



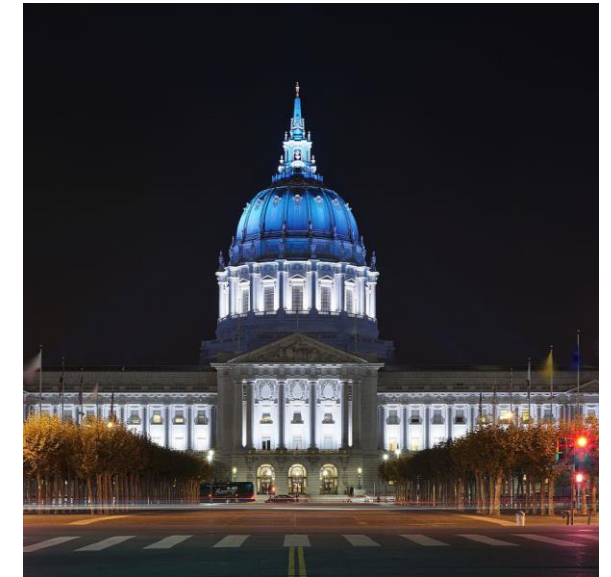
Adopt or exceed building codes



Utilities & transportation retrofit



Public-sector retrofit



Mitigation Saves counts benefits of reducing....



Property damage



DBI, IBI, & ALE



Deaths & injuries



PTSD



Insurance overhead & profit



Environmental

Also count:



Jobs



Savings to the federal treasury

Better if *Mitigation Saves* could monetize important intangibles



Elisa.rolle



Matty1378



Achieve the greatest good *how*?



Stronger & stiffer

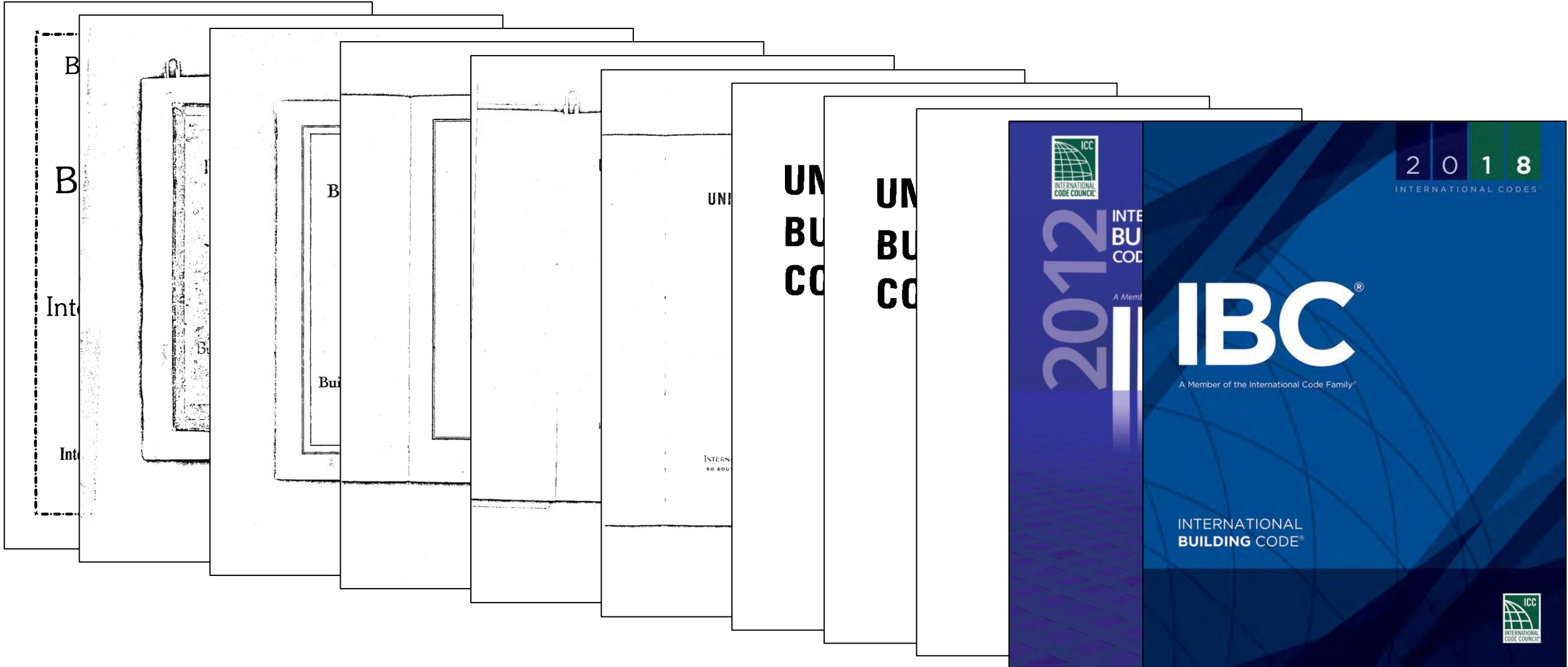


Connections, shutters

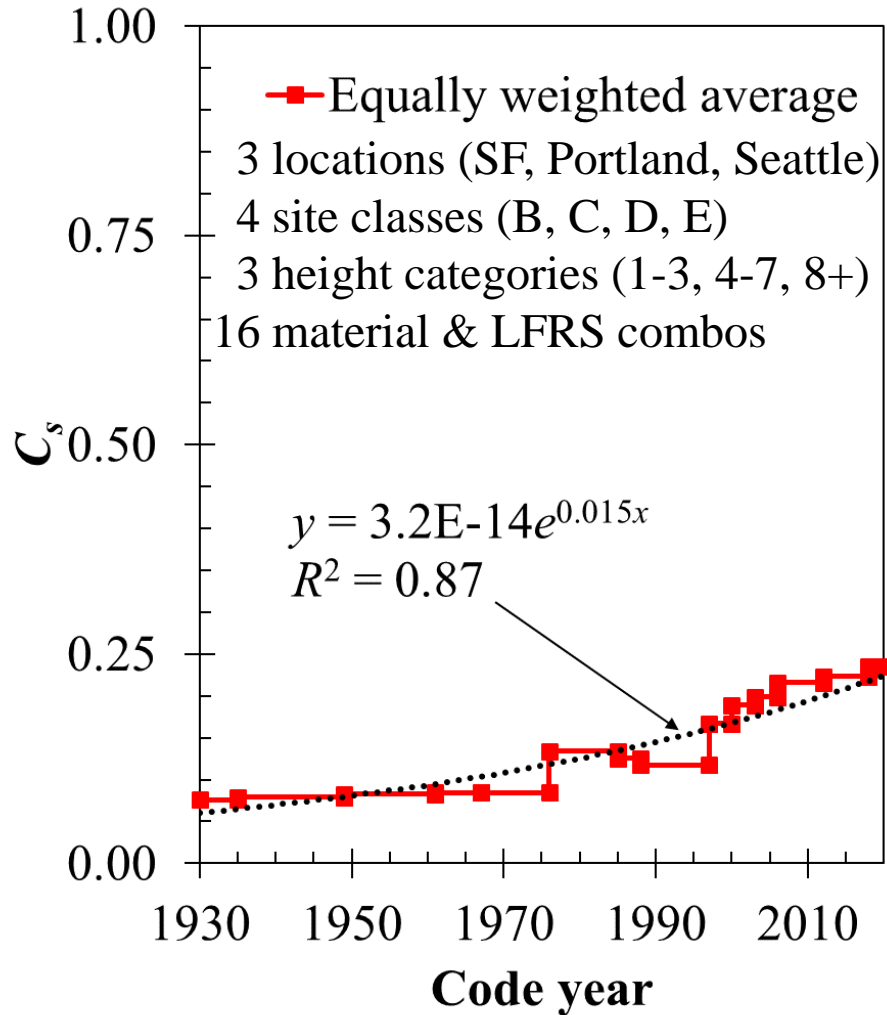
Value of I-Codes so far

Evolution of seismic & wind design

Coded seismic provisions in UBC 1927, ... 1997, IBC 2000 ... 2018 into a **big** spreadsheet



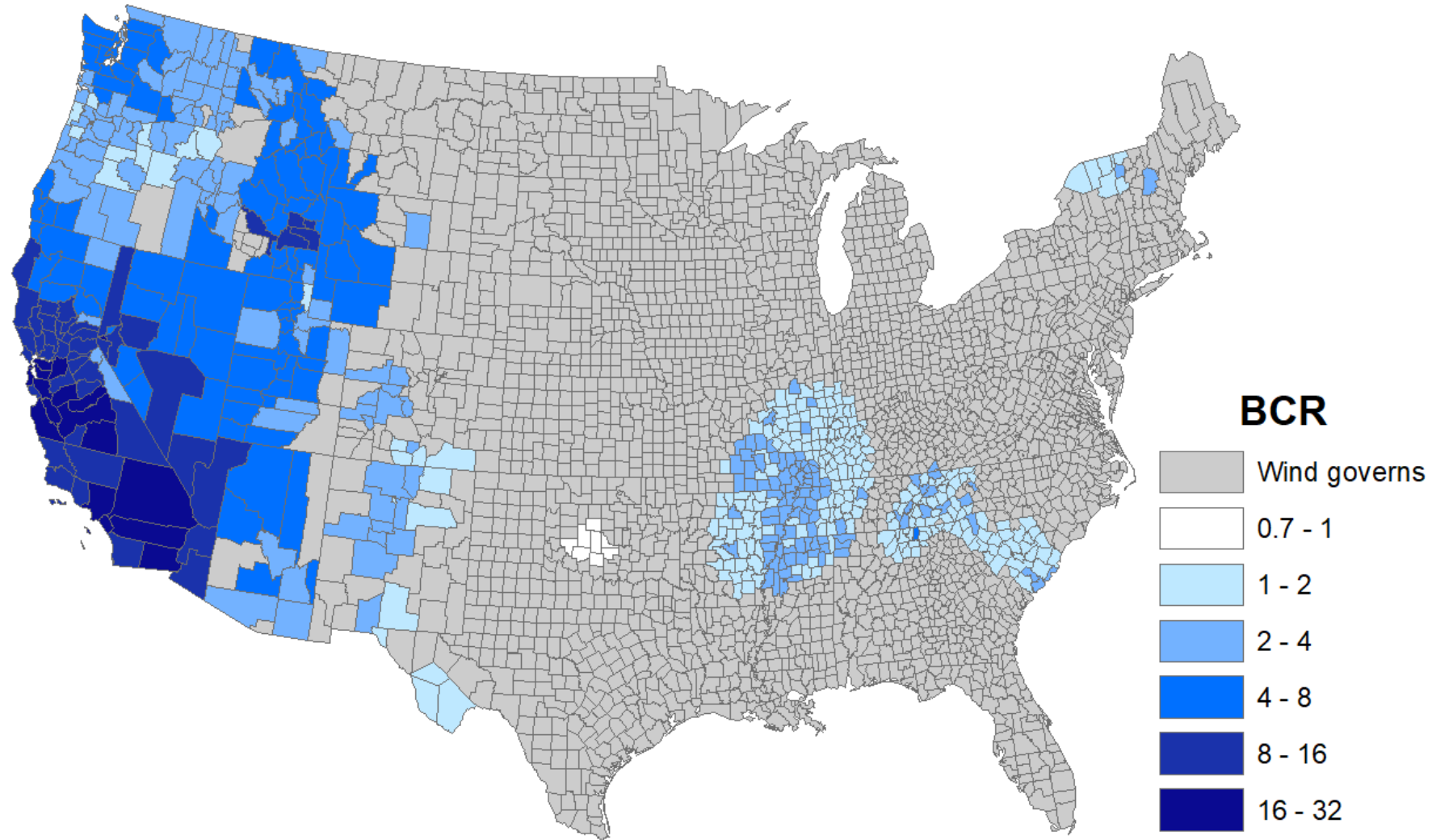
Increasing seismic design requirements



+50% strength and stiffness per 30 years

Era	Relative strength & stiffness
1930	0.30
1960	0.44
1990	0.67
Today	1.0

Earthquake code development 1990 – 2018: BCR reaches 32:1



Earthquake code dev. 1990 – 2018

Nationwide average BCR = 12:1

Benefit: \$7 billion

43% – Property: \$3

29% – Additional living expenses and direct business interruption: \$2

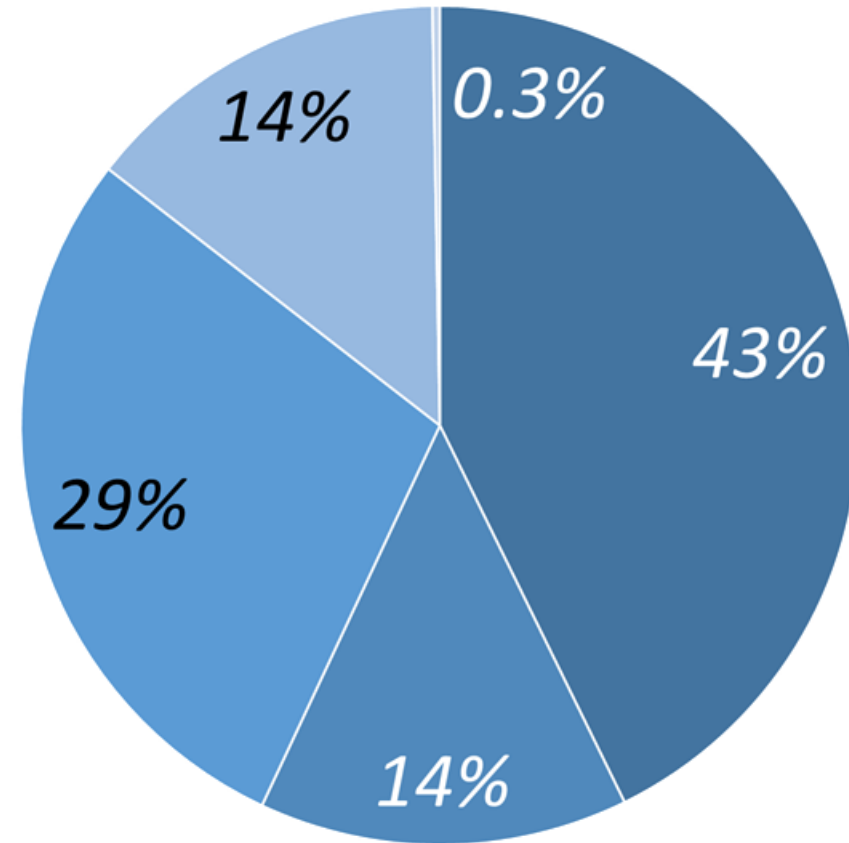
14% – Deaths, injuries, and post-traumatic stress disorder: \$1

14% – Indirect business interruption: \$1

0.3% – Urban search and rescue: \$0.02

Billions 2018 USD

Cost: \$0.6 billion

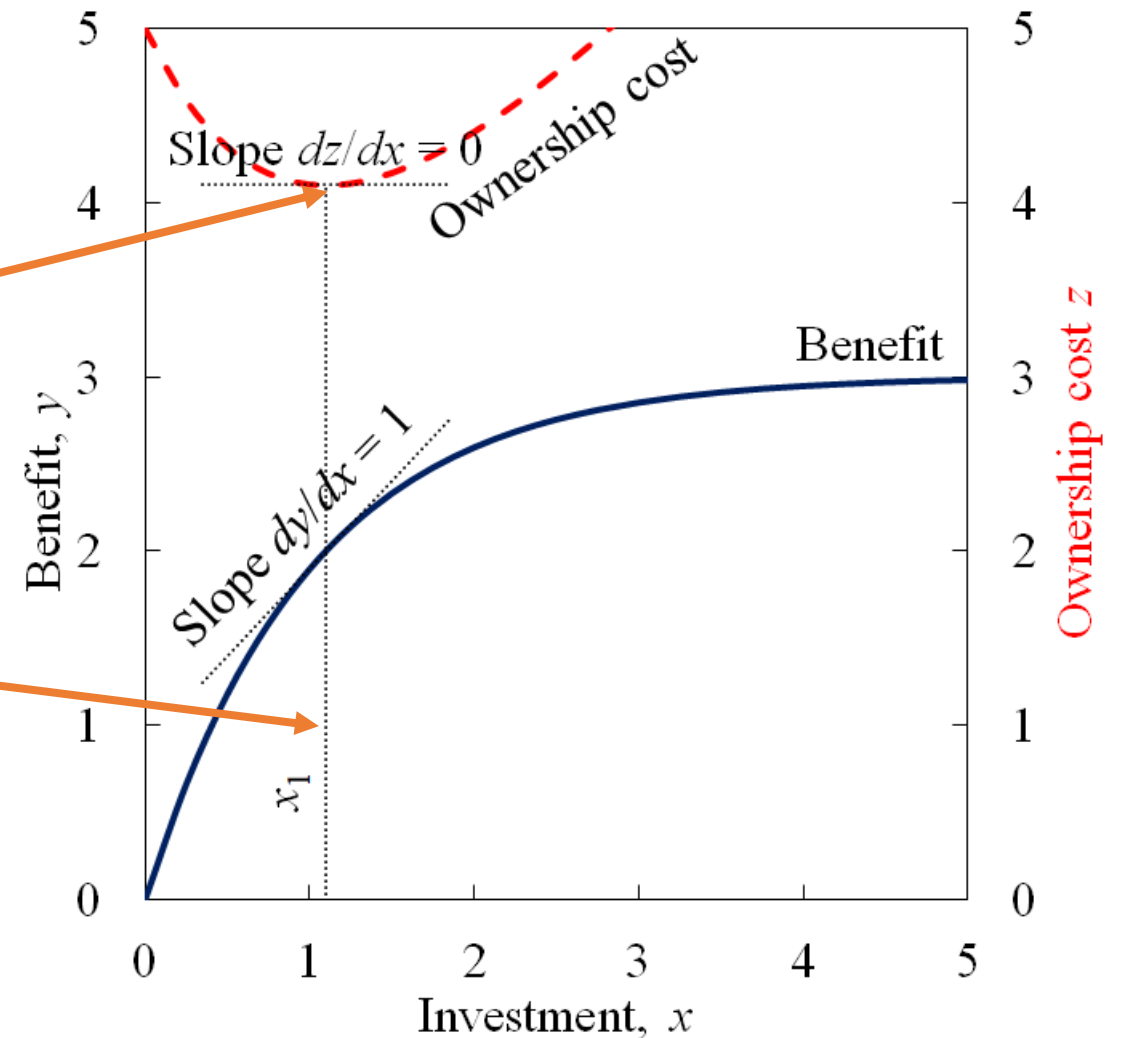


Is there an optimal level?

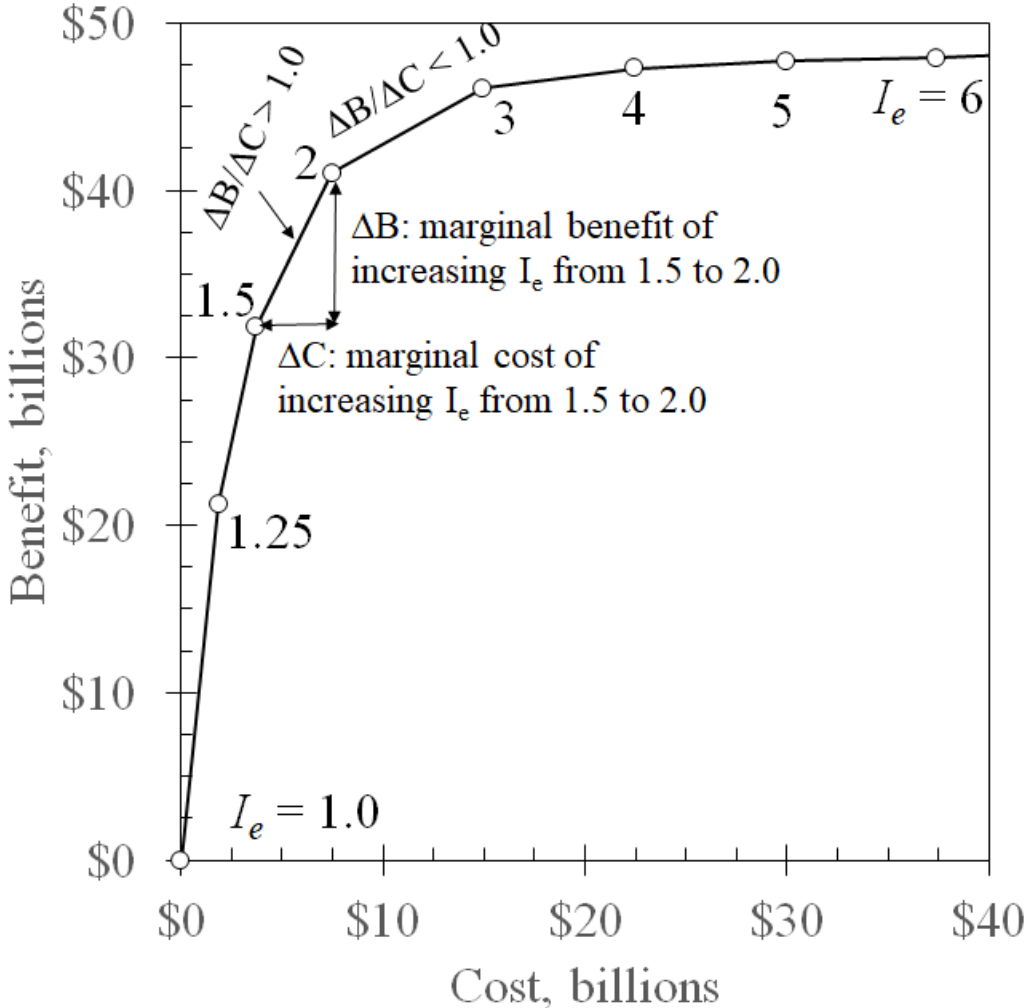
Incrementally efficient maximum investment *IEMax* minimizes societal total cost of ownership (TCO), maximizing societal benefit

Lowest (societal) total cost of ownership = the most (public) good

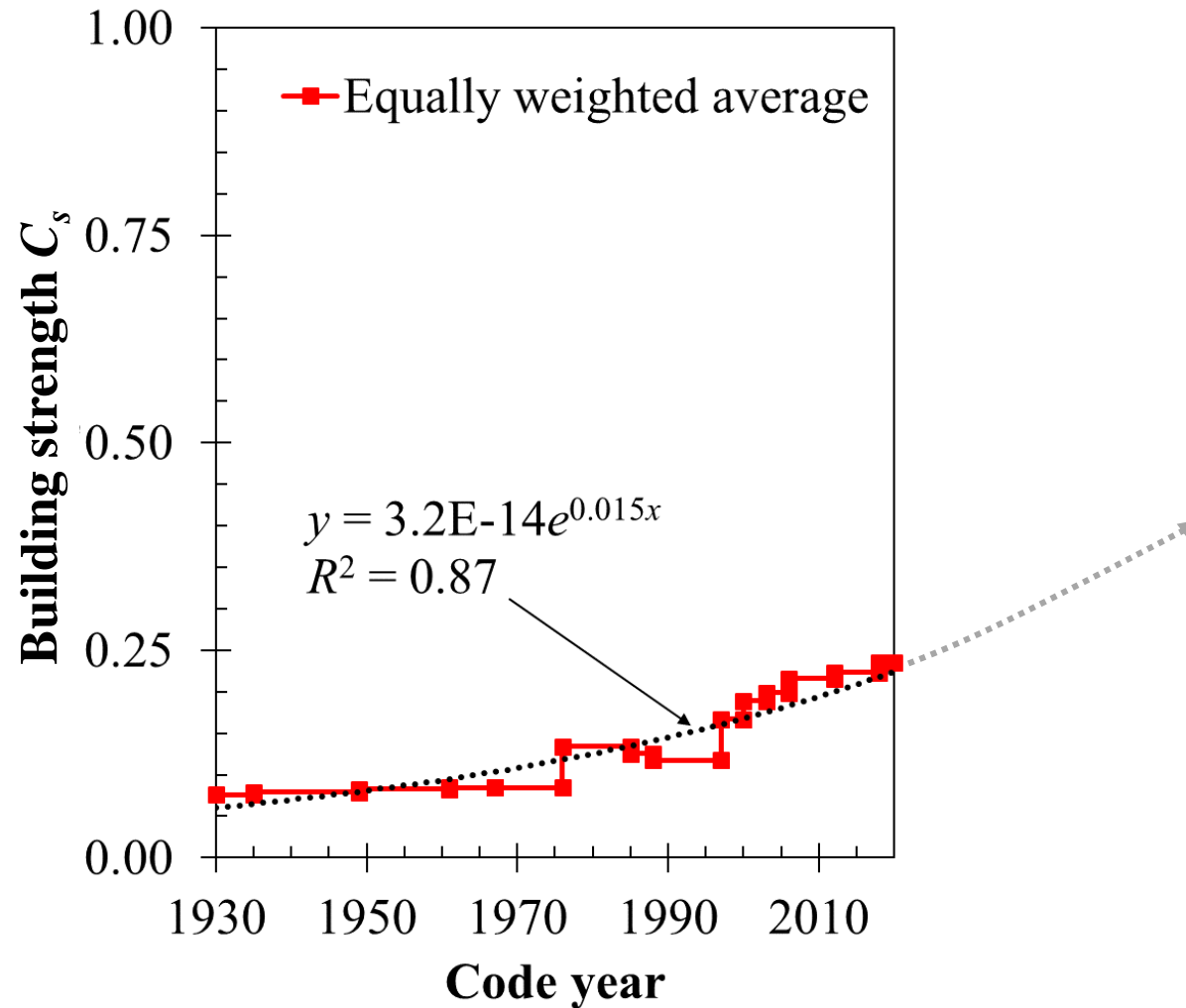
Incrementally efficient maximum investment *IEMax*



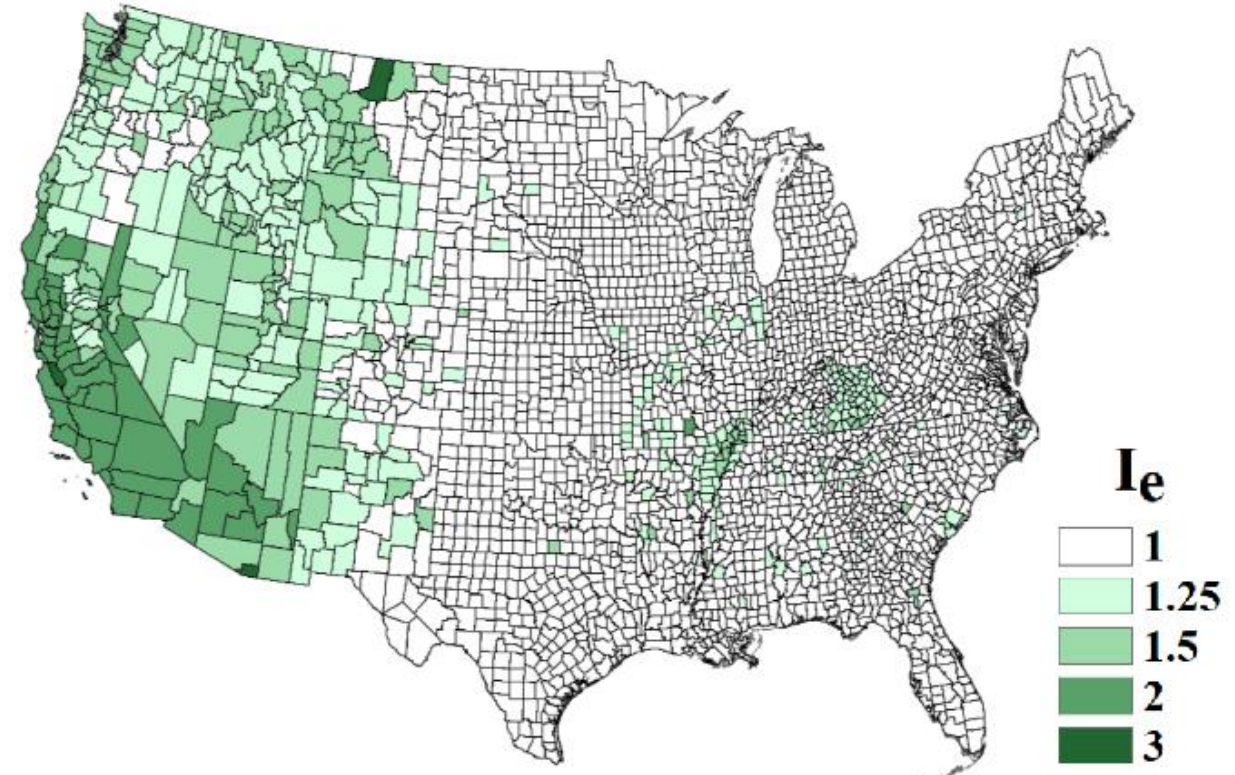
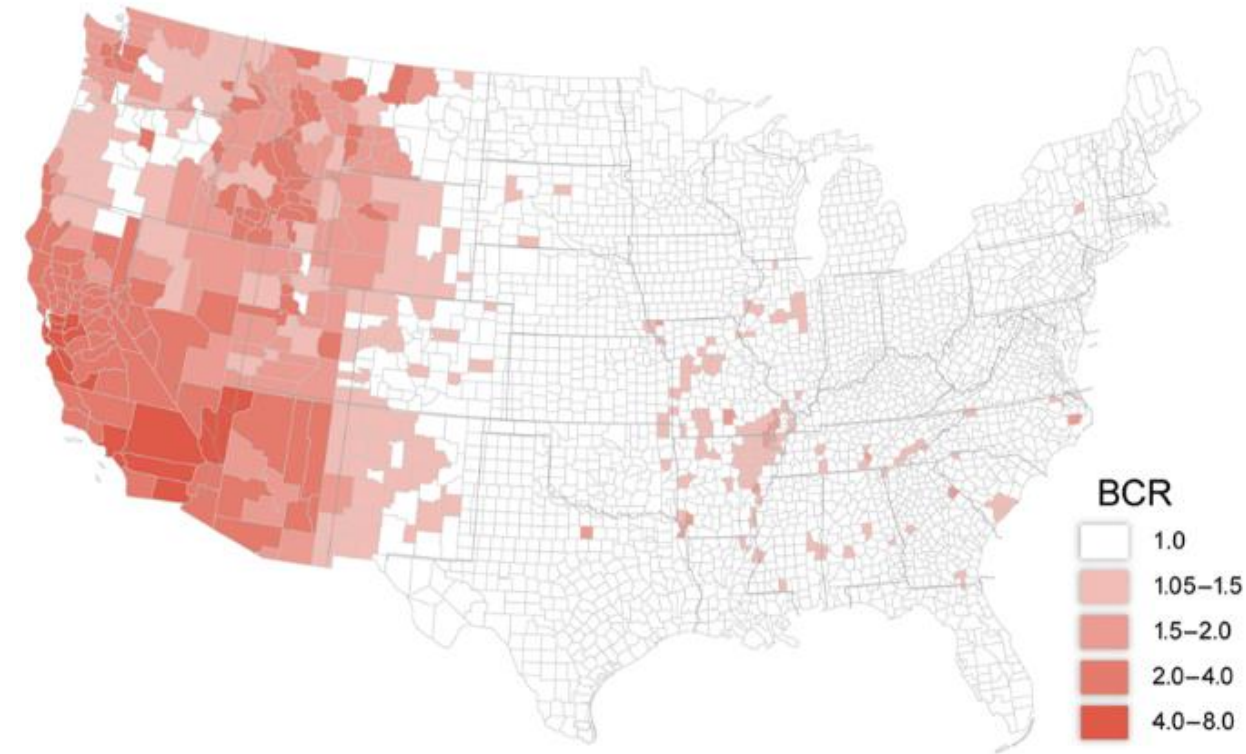
Drawing that curve for seismic loads



I-Codes are not optimally efficient yet



Utilitarian optimal earthquake design



www.nibs.org/page/mitigationsaves

Overall Benefit-Cost Ratio

**Above
code**

Cost (\$billion)

\$4/year

Benefit (\$billion)

\$16/year

**Utilitarian optima for
5 perils**

 **Riverine Flood**

5:1

BFE + 5 ft or more

 **Hurricane Surge**

7:1

BFE + 8 ft

 **Wind**

5:1

FORTIFIED Home Hurricane

 **Earthquake**

4:1

I_e up to 3x code minimum

 **WUI Fire**

4:1

IWUI Code in some places

Recap, ethics of the building code

- Current code is sub-optimal in many places
- Well accepted fundamental utilitarian and duty ethics underly the U.S. Constitution
- We found utilitarian optimal performance goals with well established engineering economics principles
- Leaving current minima in the rest of the country makes sense from a duty-ethics perspective
- Together, utilitarianism & duty ethics could provide an ethical foundation for resilience

Unfortunately, ethics is messier
than that

Utilitarianism & BCA should be part, but not all, of the building code's ethical basis

Patricia Churchland: no exceptionless moral rules



National Commission (1979—the Belmont Report): We place extra value on protecting vulnerable populations, conflicting with “Every [person] to count for one, nobody for more than one”

Slovic et al. (1981): We care about dreadedness, unknownness, & catastrophic potential (the Big One). These issues conflict with risk-neutral benefit-cost analysis, but *not* with code minima

A useful duty ethic: consider public preferences when setting objectives

A consensus of engineering ethicists conclude:

“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
Ill Inst Tech



R Hollander
NAE



J Heckert
Ariz St Univ



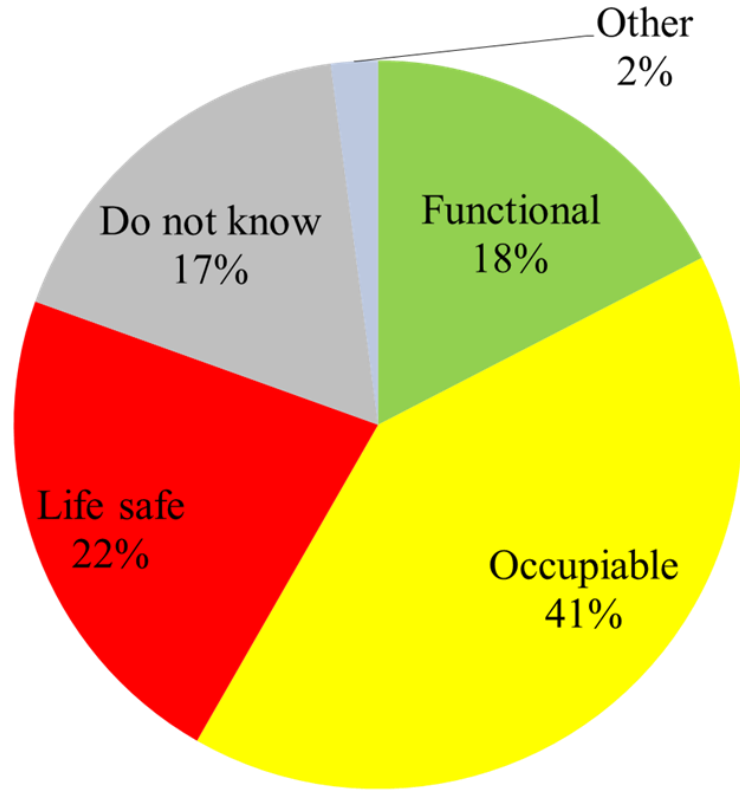
M Loui
Purdue Univ



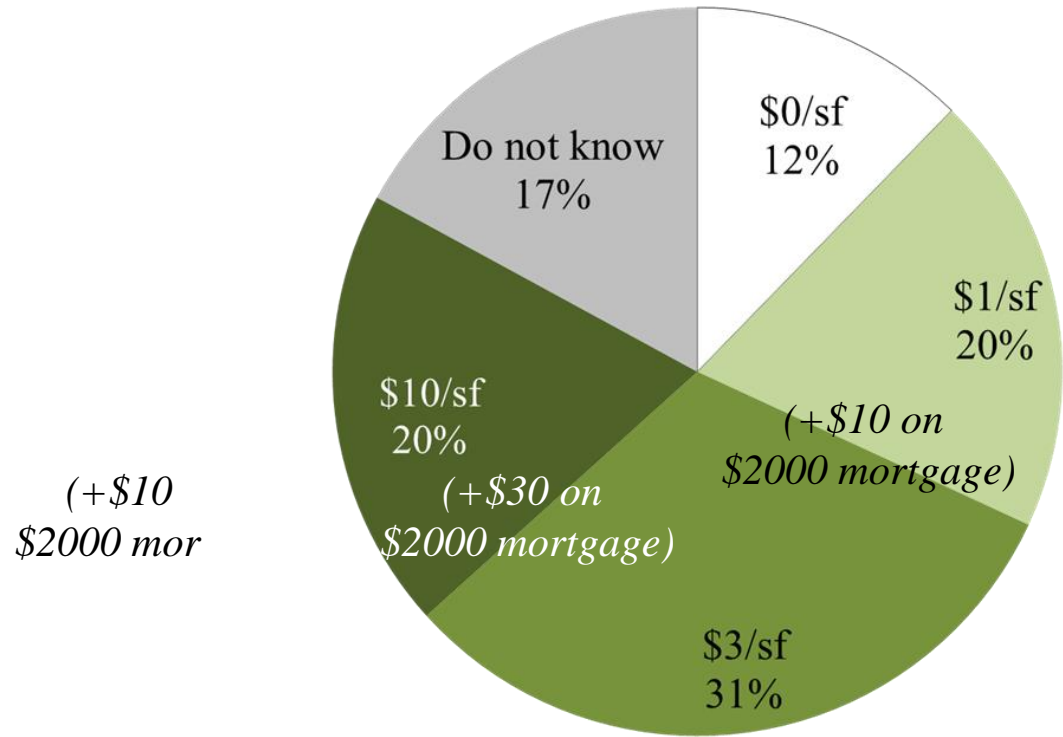
M Martin
Chapman Univ

People expect resilient infrastructure

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



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



In a heterogenous society,
perspective matters

Jobs matter

The last 30 years of code development added
30,000 long-term US jobs to produce more
construction materials

Optimal design would produce 60,000 more

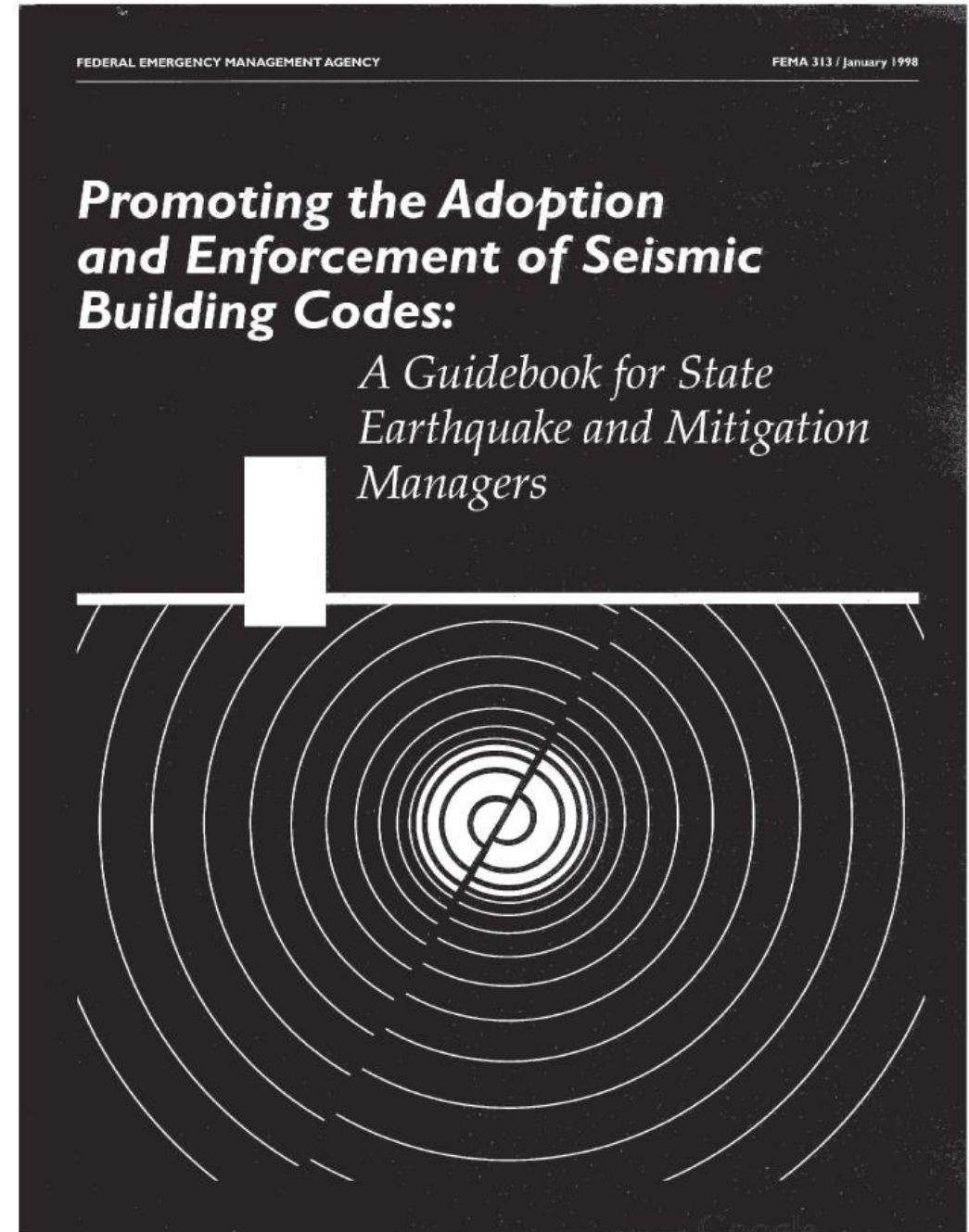
Affordability matters

“The common statement that is often made, that it is not possible to design structures to resist earthquakes, is not true. We have the technology to design earthquake resistant structures and it is an economic decision whether or not to obtain this goal.”

-- Ed Wilson, UC Berkeley, 1998

The expense

Olshansky et al. (1998)
in FEMA 313:
codes as a whole only add ~1%.



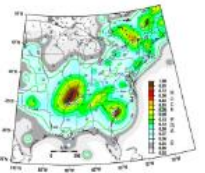
The expense

IO sheathing & nailing costs 3%





$I_e = 1.6$ costs 0-1%

NIST GCR 14-917-26

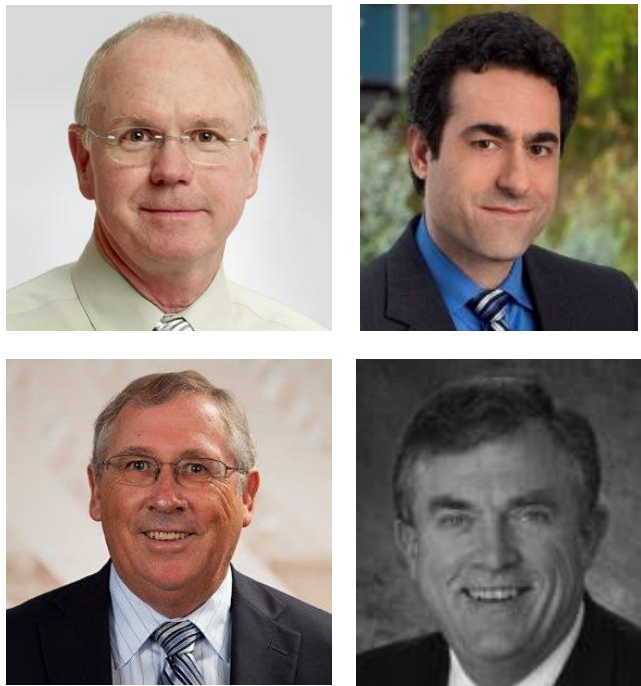


Cost Analyses and Benefit Studies for Earthquake-Resistant Construction in Memphis, Tennessee

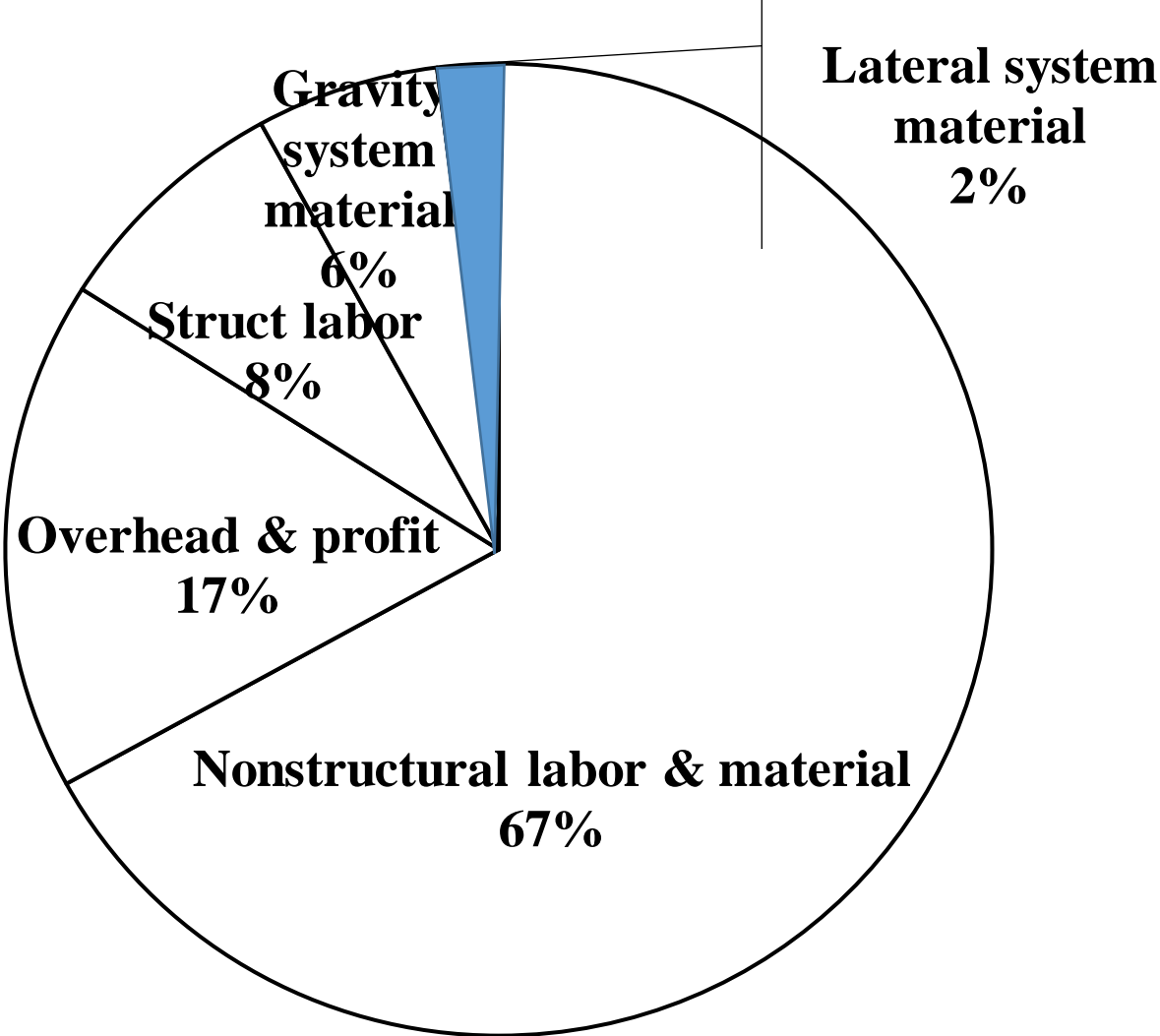
NEHRP Consultants Joint Venture
A partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering



These guys say maybe 1%

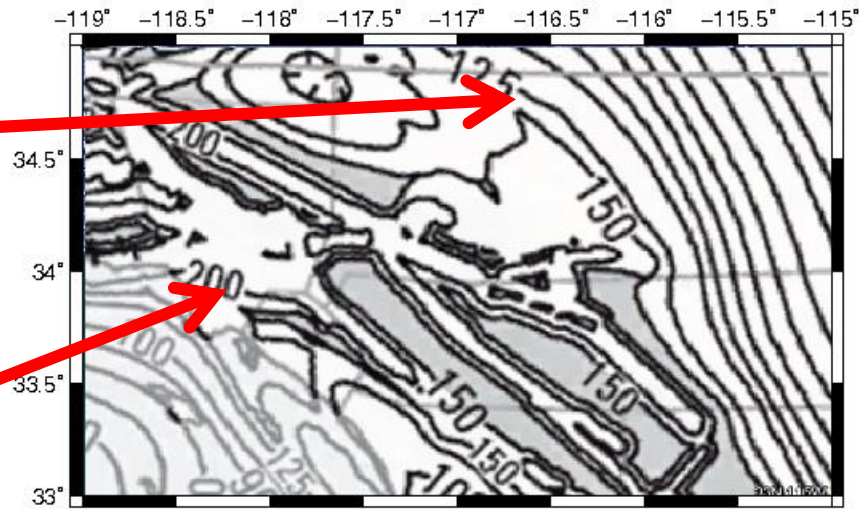


The expense



The expense

$I_e = 1.5$ here
costs less than
 $I_e = 1.0$ here



Risk-targeted SS (ASCE 7-10), %g

- 1.5 x Seattle = 1.0 x SF or LA
- 1.5 x Sacramento = 1.0 x SF or LA
- 2.0 x San Diego = 1.0 x SF or LA

The expense

“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.”

-- Lucy Jones, 2015 (written commun.)

Affordability matters

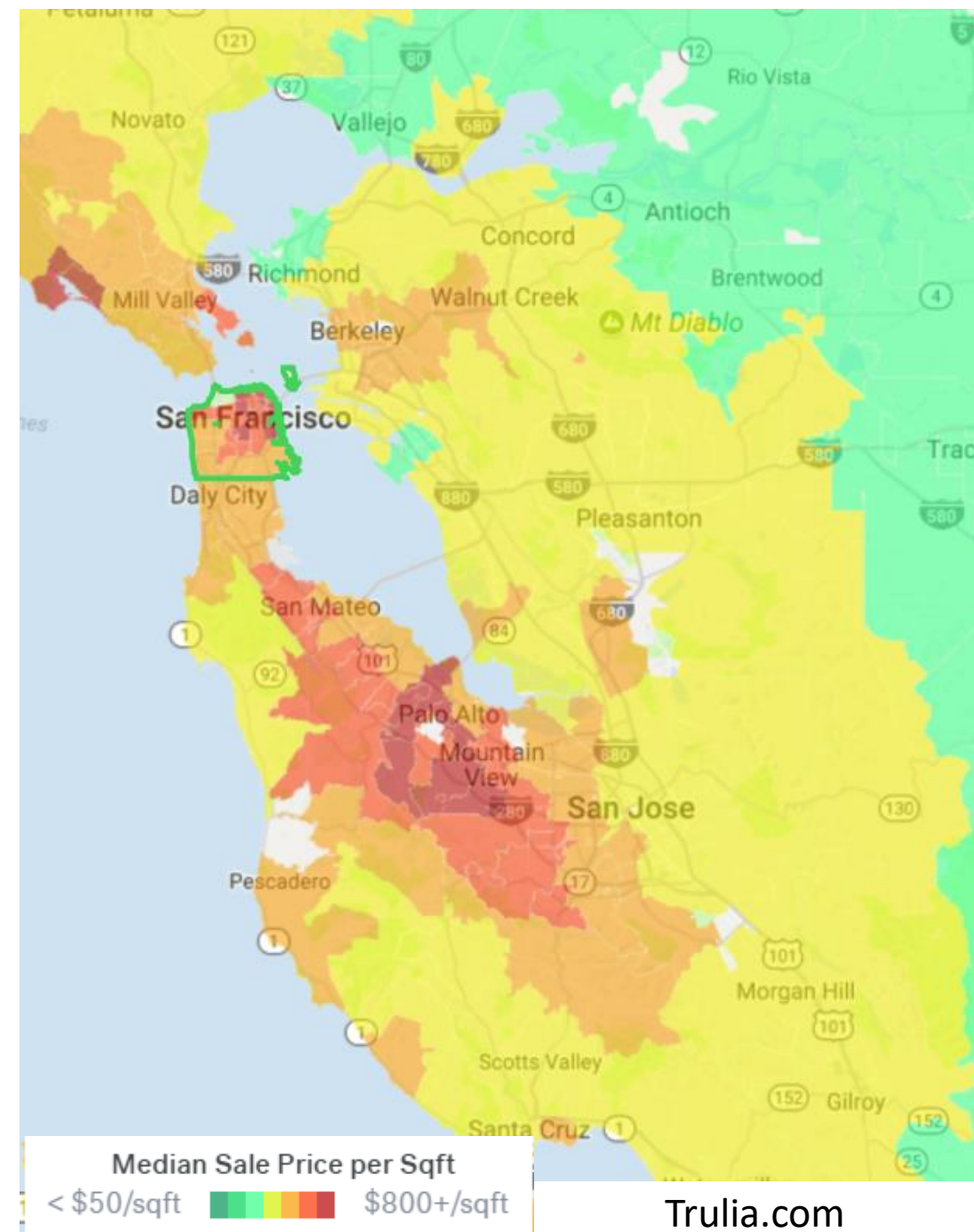
Housing is already costly: \$1000/sf in San Francisco, \$600/sf Santa Clara

~30-40% is construction \$

~0.5-1% is lateral system

~60-70% goes to developers and sellers.

Can't buyers & tenants get more resilience for their \$?



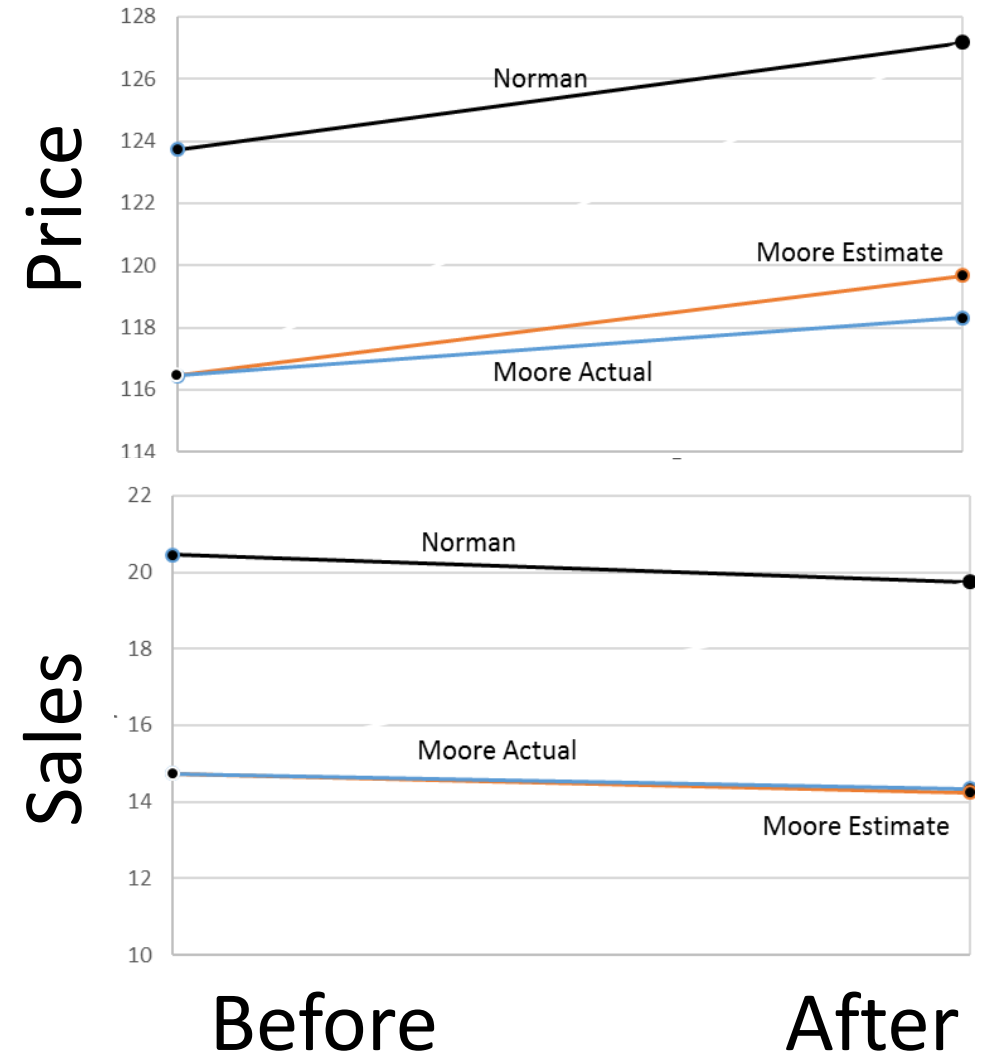
Simmons & Kovacs 2017: “The code had no effect on either home sales or price for new homes in Moore.”



Kevin Simmons, Austin College

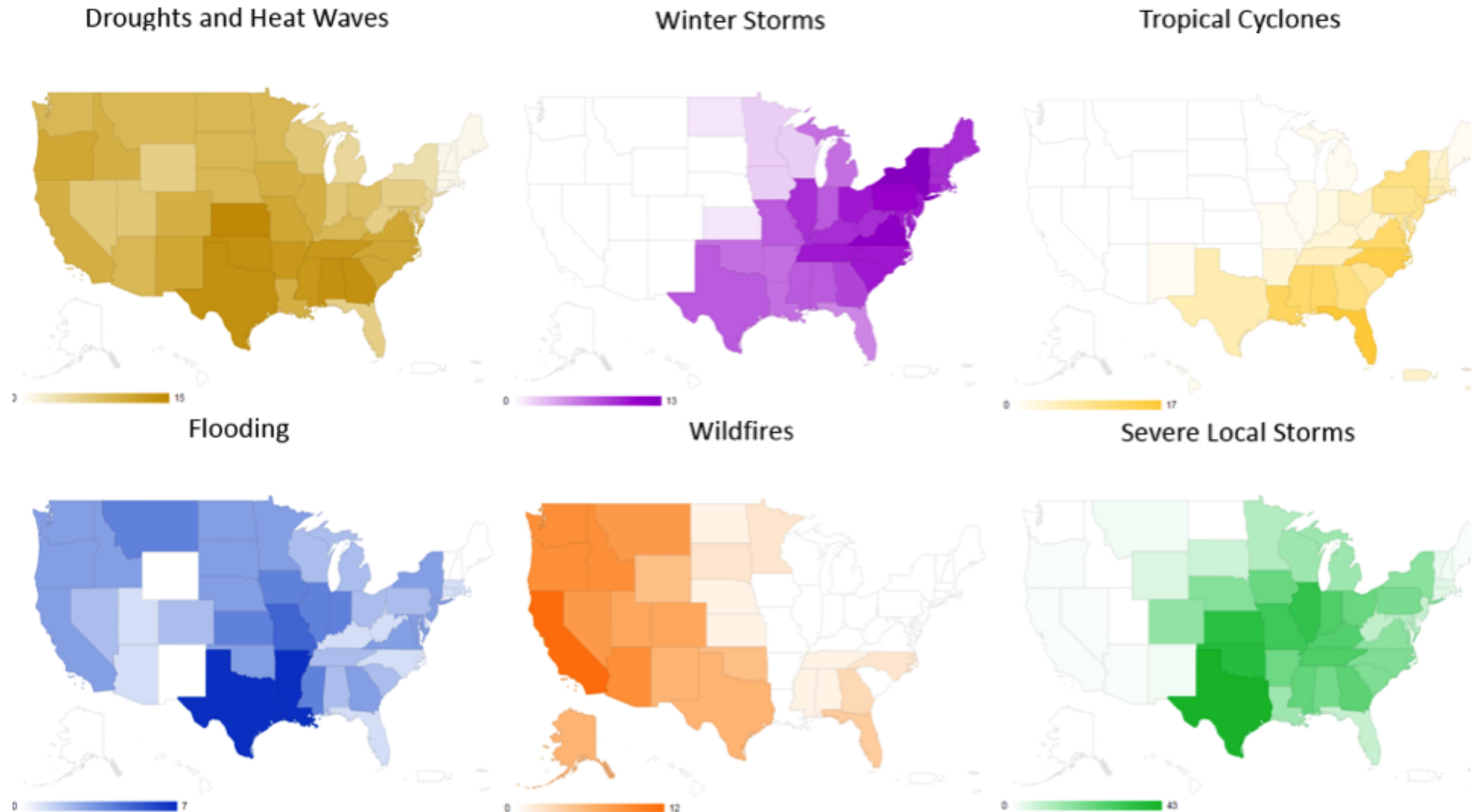


Paul Kovacs, Institute for Catastrophic Loss Reduction



Geography matters: “We don’t have [a peril] in our state.” 1. They probably do.

U.S. Billion-Dollar Weather and Climate Disasters: 1980 – 2016*

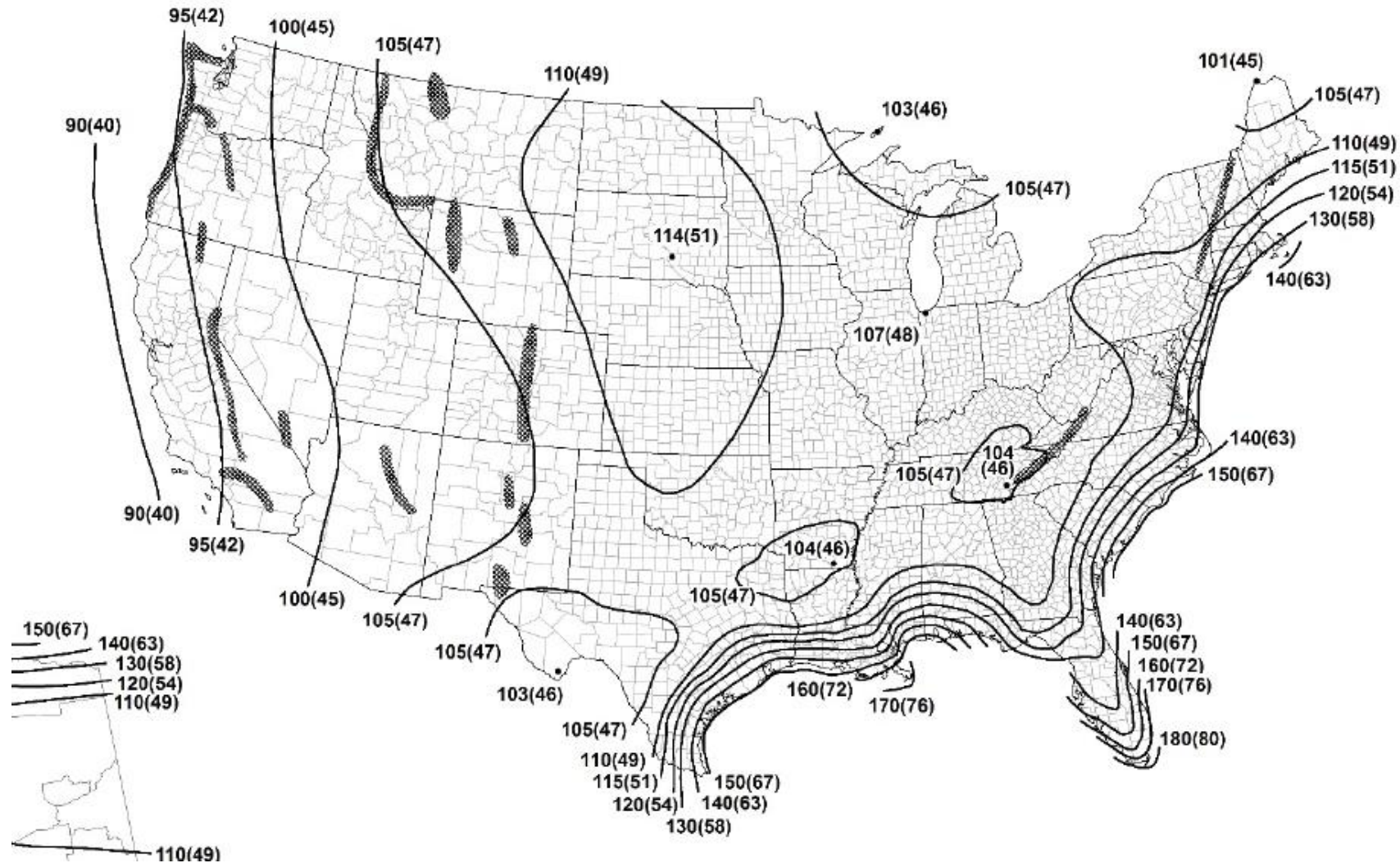


*203 weather and climate disasters reached or exceeded \$1 billion during this period (CPI-adjusted)

Please note that the map reflects a summation of billion-dollar events for each state affected (i.e., it does not mean that each state shown suffered at least \$1 billion in losses for each event).

Geography matters: “We don’t have [a peril] in our state.”

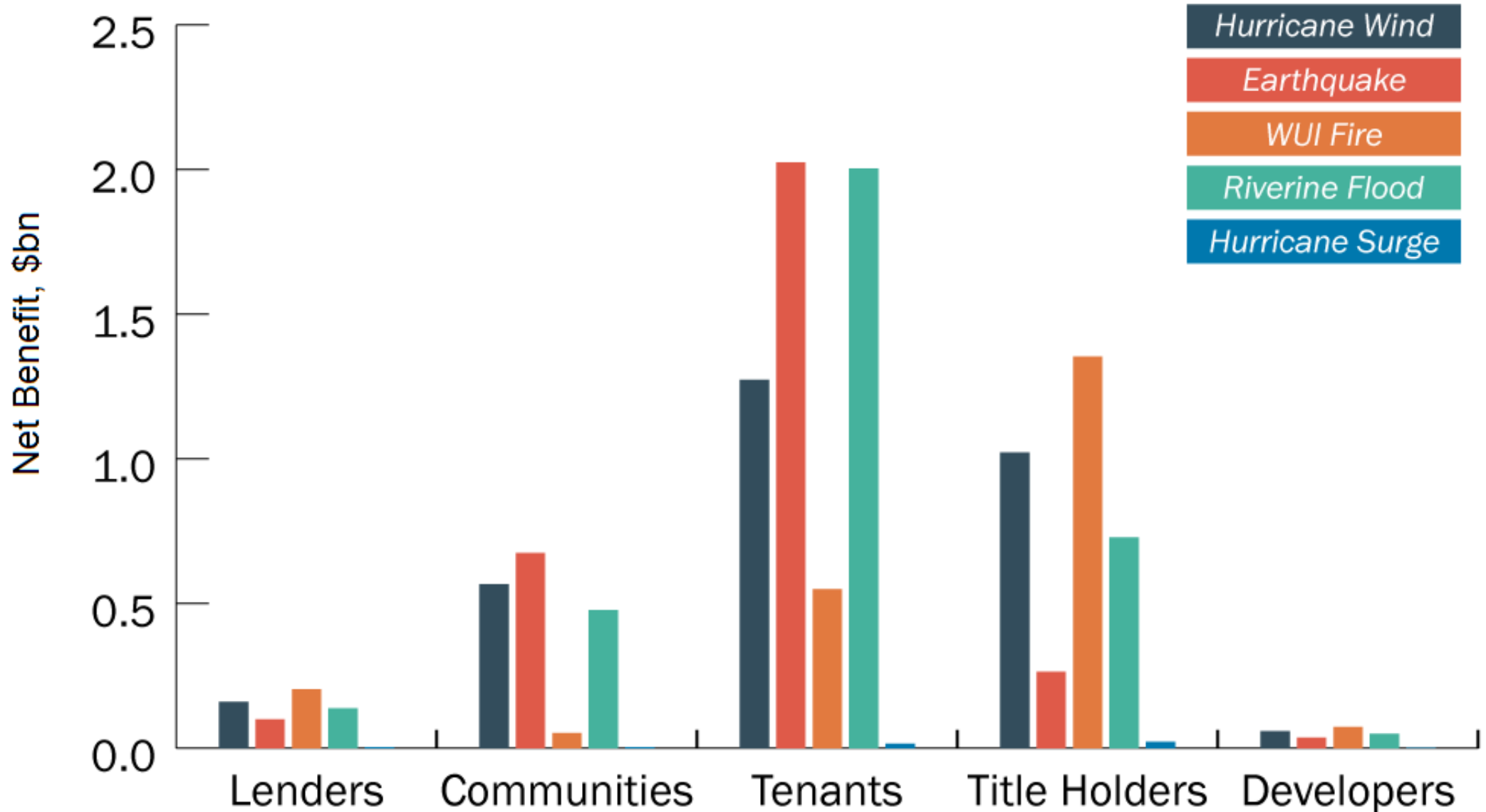
2. I-Codes are already calibrated to hazard



My disaster *is* your disaster



Role & long-term ownership costs matter



But short-term interests can diverge

U.S. construction: \$1.3T/yr; cat loss: \$100B/yr

Adopting modern codes	cost builders saved society	\$1B/yr \$13B/yr	0.3 days construction 0.13 years cat loss
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Optimal code improvement	would cost builders would save society	\$4B/yr \$16B/yr	1 day construction 0.16 years cat loss
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Enforcement matters


ASIA PACIFIC | China Admits Building Flaws in Quake

ISIS Leader in Afghanistan Is... A Young Woman's... Europe Caught in the Middle as... Pyongyang Welcomes... PAID POST: BERLIN PARTNERS Why Entrepreneurs Are Flocking to Berlin Amid Fears of Trade War...

ASIA PACIFIC

China Admits Building Flaws in Quake

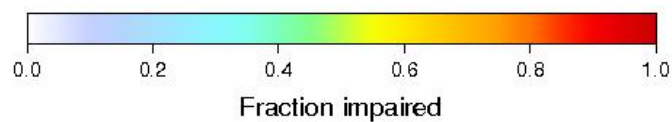
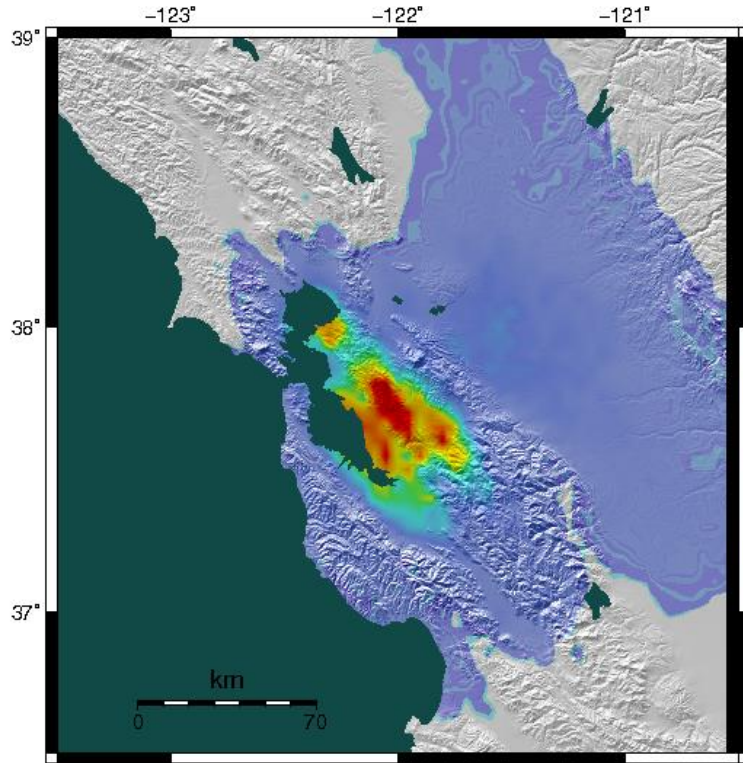
By EDWARD WONG SEPT. 4, 2008



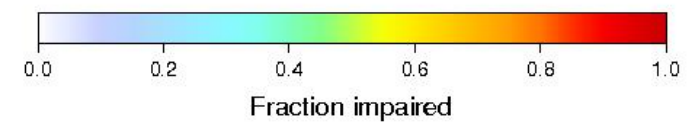
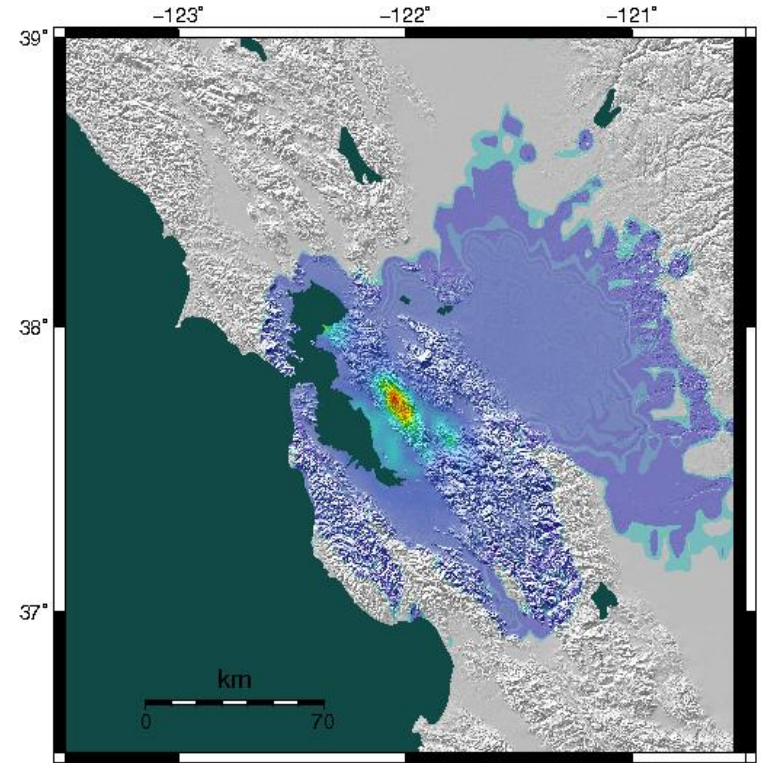
RELATED COVERAGE
TIMES TOPIC
Sichuan Earthquake

BEIJING — A Chinese government committee

Catastrophes matter



$I_e = 1.0$: 25% impaired



$I_e = 1.5$: 6% impaired

BCRs average over buildings & time



Some additional social challenges
to better buildings

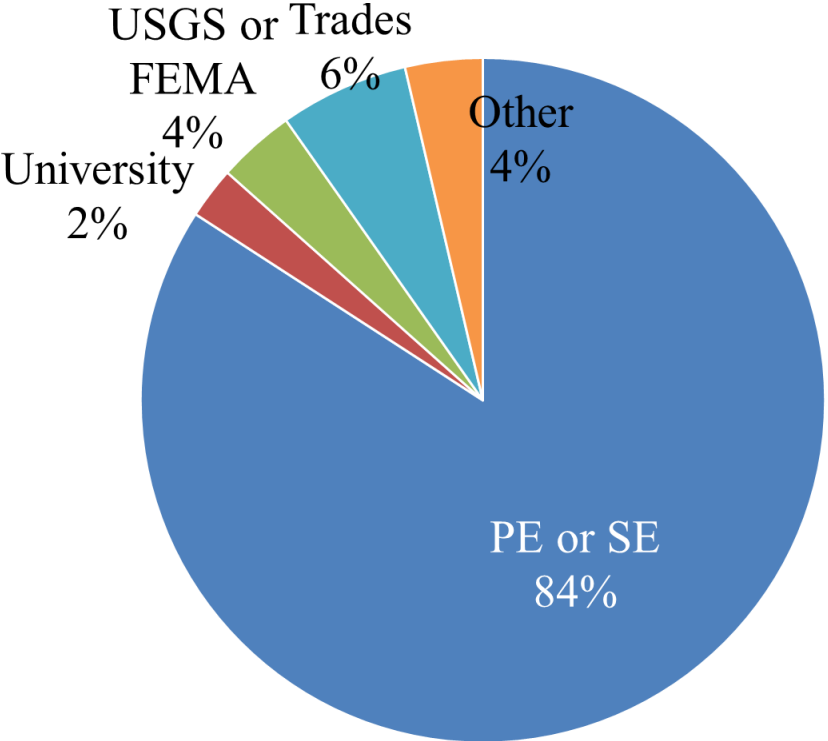
“Who better to judge than us
engineers?”

We never have judged

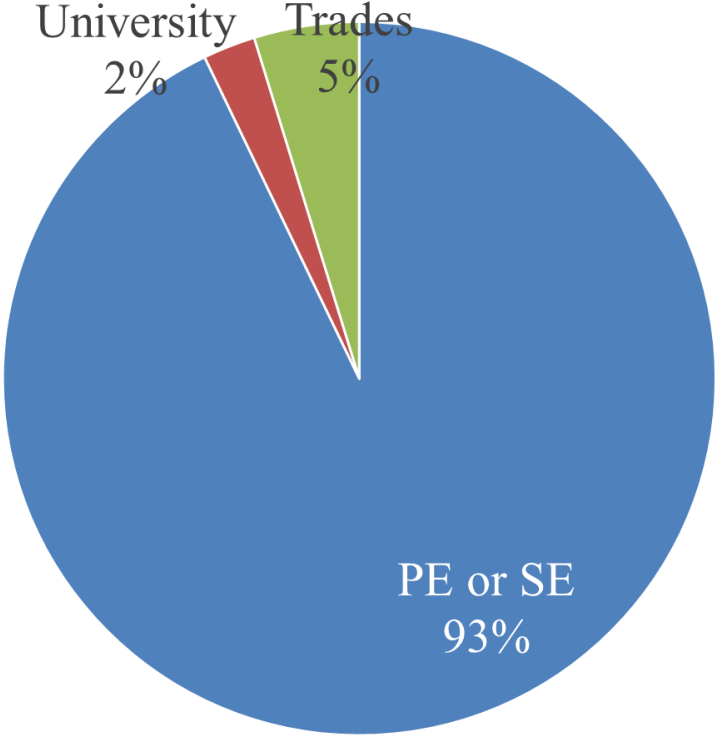
We have never asked anyone else to judge

ASCE 7 vastly diverges from public preferences

“Engineers are the public.”



Subcommittee on Seismic Loads



Main committee

“Engineers are the public.”

ASCE Code of Ethics distinguishes between 5 groups:

1. The public
2. Civil engineers' clients
3. Civil engineers' employers
4. Civil engineering profession
5. Individual civil engineers

The distinction matters. The groups' interests diverge. Only one group's interests can be held “paramount.”

“States and cities give informed consent”

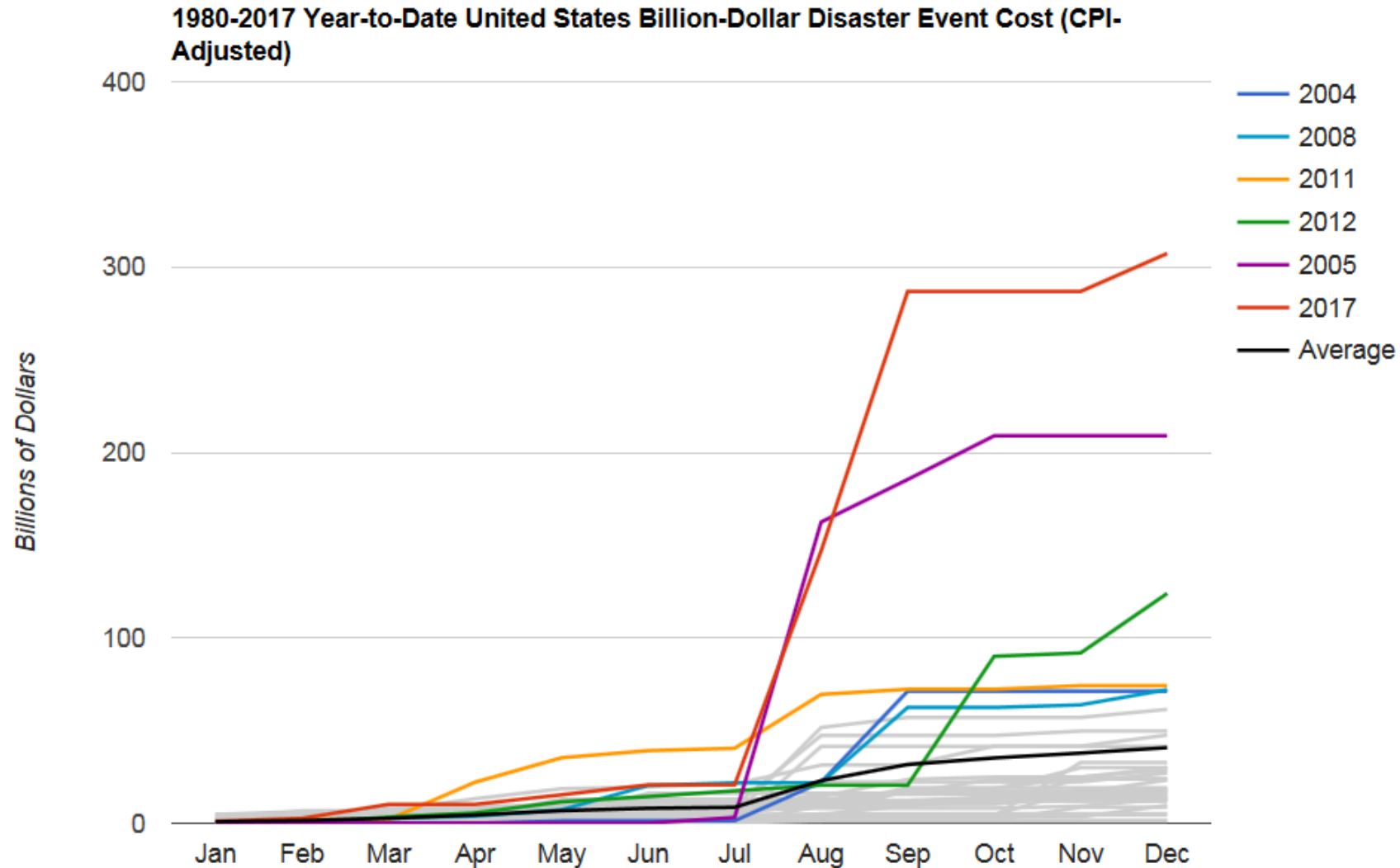
The public comprises “all persons whose lack of information, training, or time for deliberation renders them vulnerable to the powers an engineer wields on behalf of his client or employer.”

– *Michael Davis, Thinking Like an Engineer, 1991*

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.

– *Lucy Jones, pers. comm., 19 Nov 2013*

“Costlier buildings are bad for the economy.”
Earthquakes, floods, hurricanes, etc. are worse.



Short-term planning

California construction:

- \$1,000/person/yr
- ~\$35B/year
- ~\$1.4B is for lateral strength

CA quake losses: \$3.7B/yr

This is an investment gap, not an excess.

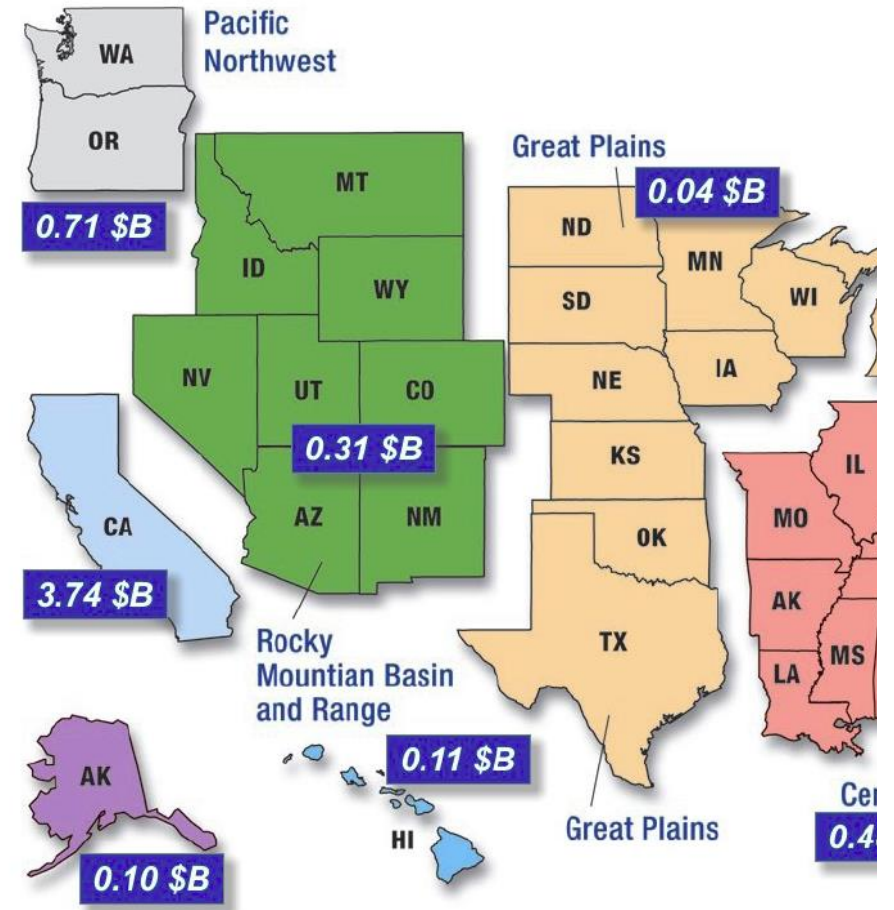


Figure E-1. Comparison of U.S. Regional Seismic Risk by Annualize

Conclusions

Conclusions

- Engineers never chose appropriate resilience because we are unequipped to do so
- Seismic provisions of the I-codes protect life, but provide a false economy, protecting developers at public expense
- The public expects and is willing to pay for resilient infrastructure
- It is practical & ethical to build more-resilient infrastructure
- Society can afford it
- We would save more than we spend, in lives, property, economic shock, and government resources
- If we think resilience is costly, just look at the bill for its lack

How shall we “hold paramount the public’s health, safety, and welfare?”



A final thought on *Mitigation Saves* & ethical, efficient infrastructure

“This is not research – it is common sense.”

– *Ed Wilson, UC Berkeley, Sept 7, 2017*

Questions

Keith.porter@colorado.edu

626-233-9758