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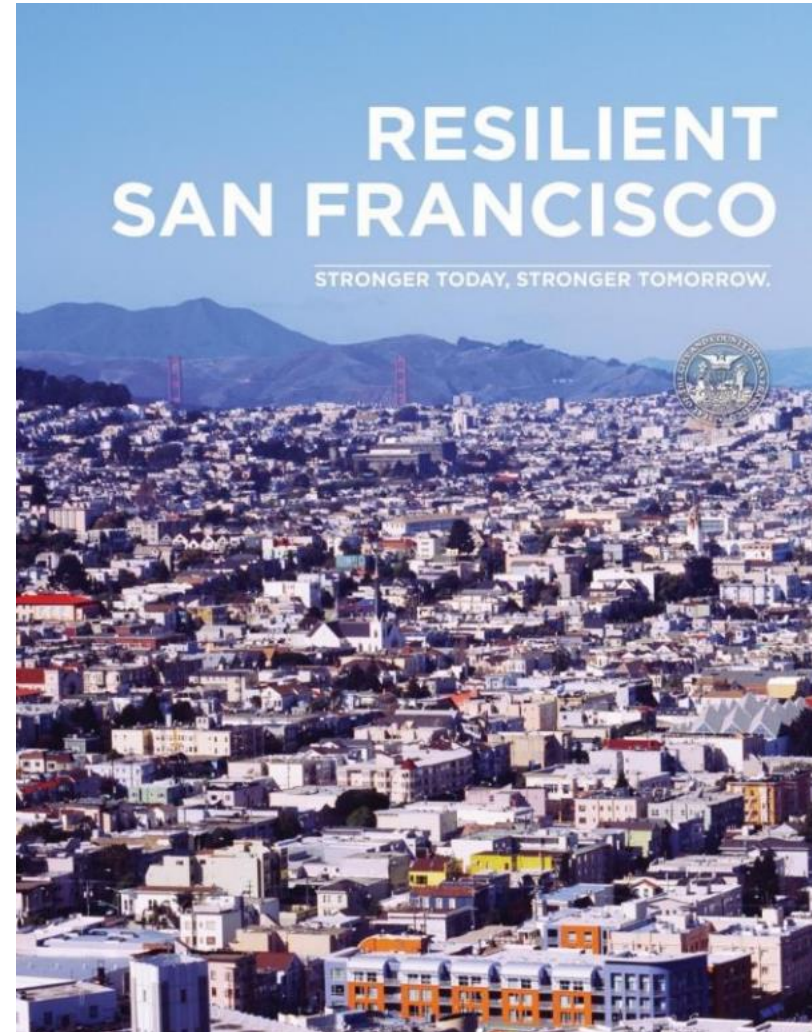
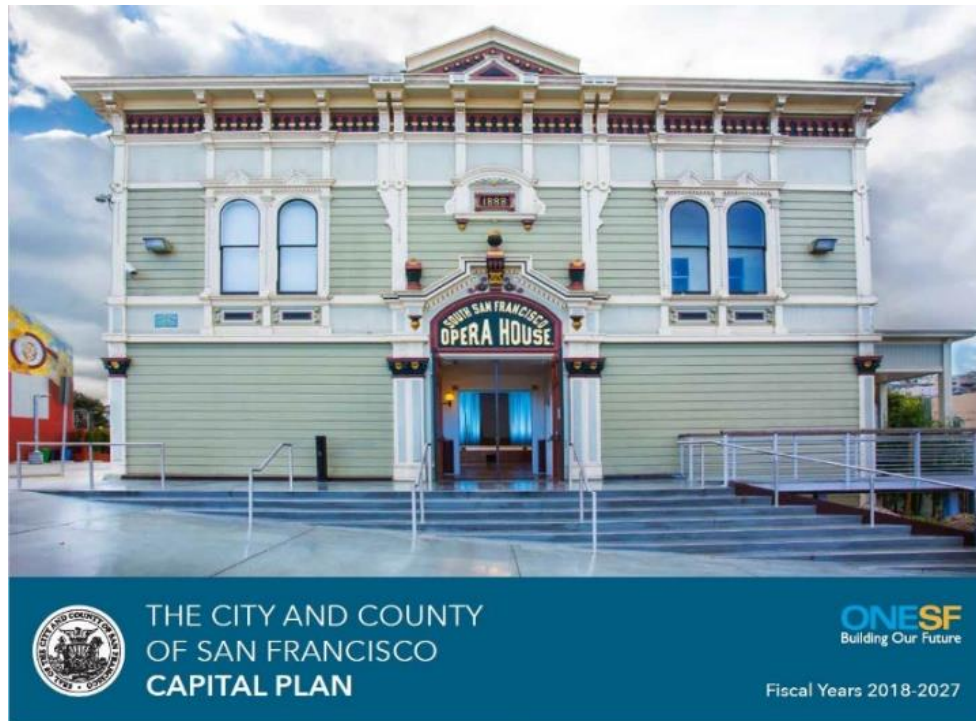


# San Francisco Tall Buildings and Earthquake Safety Implementation Program

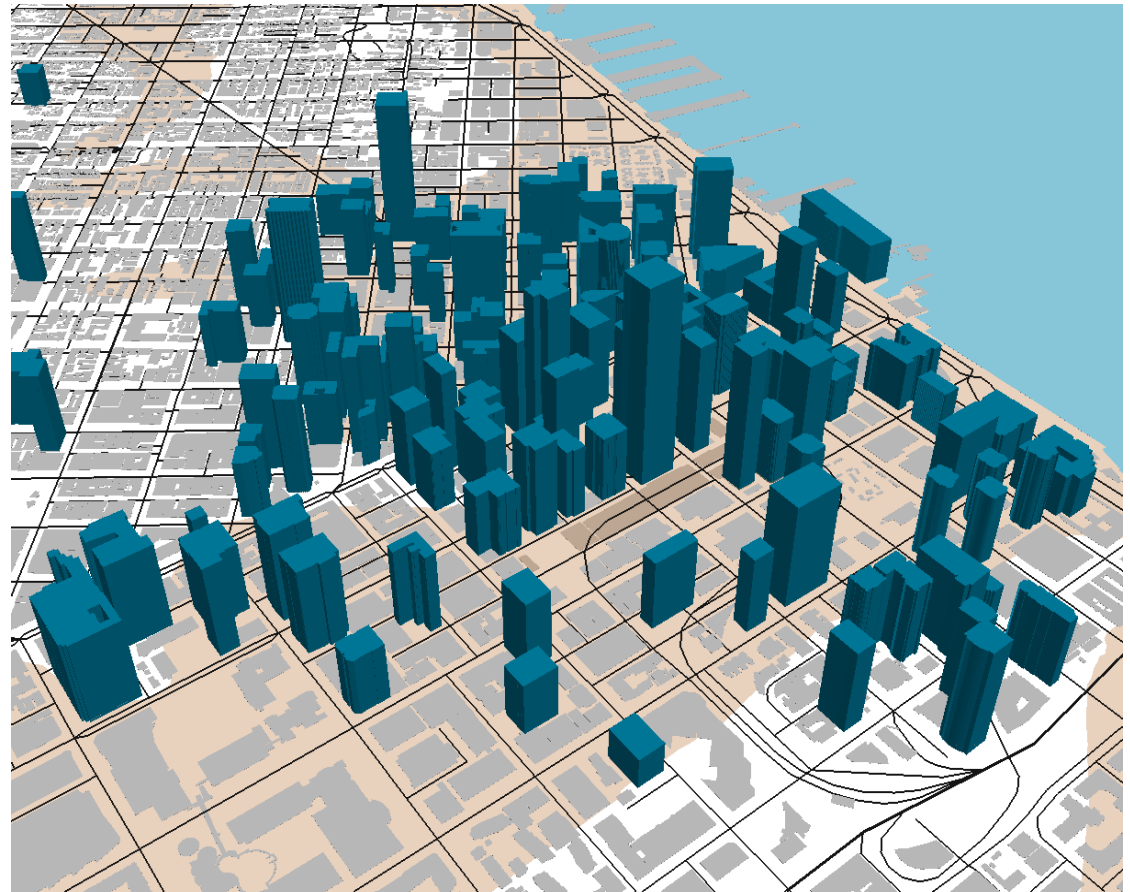
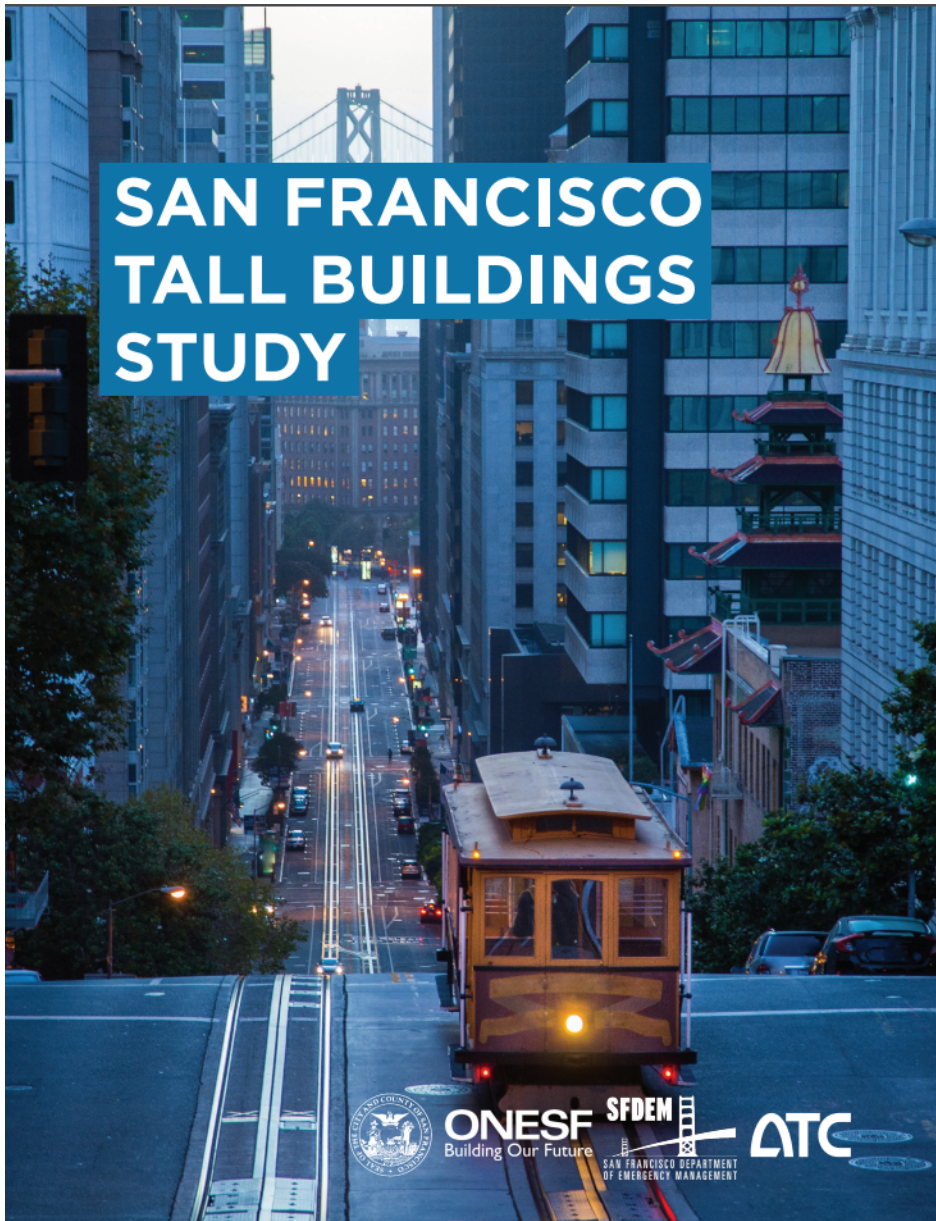
Danielle Mieler  
Office of Resilience and Capital Planning  
City and County of San Francisco  
August 20, 2019

# San Francisco Office of Resilience and Capital Planning

The mission of the Office of Resilience & Capital Planning (ORCP) is to promote the preservation and long-term sustainability of the City's capital assets and its resilience as a whole no matter the acute shocks and chronic stresses it experiences.



# SAN FRANCISCO TALL BUILDINGS STUDY

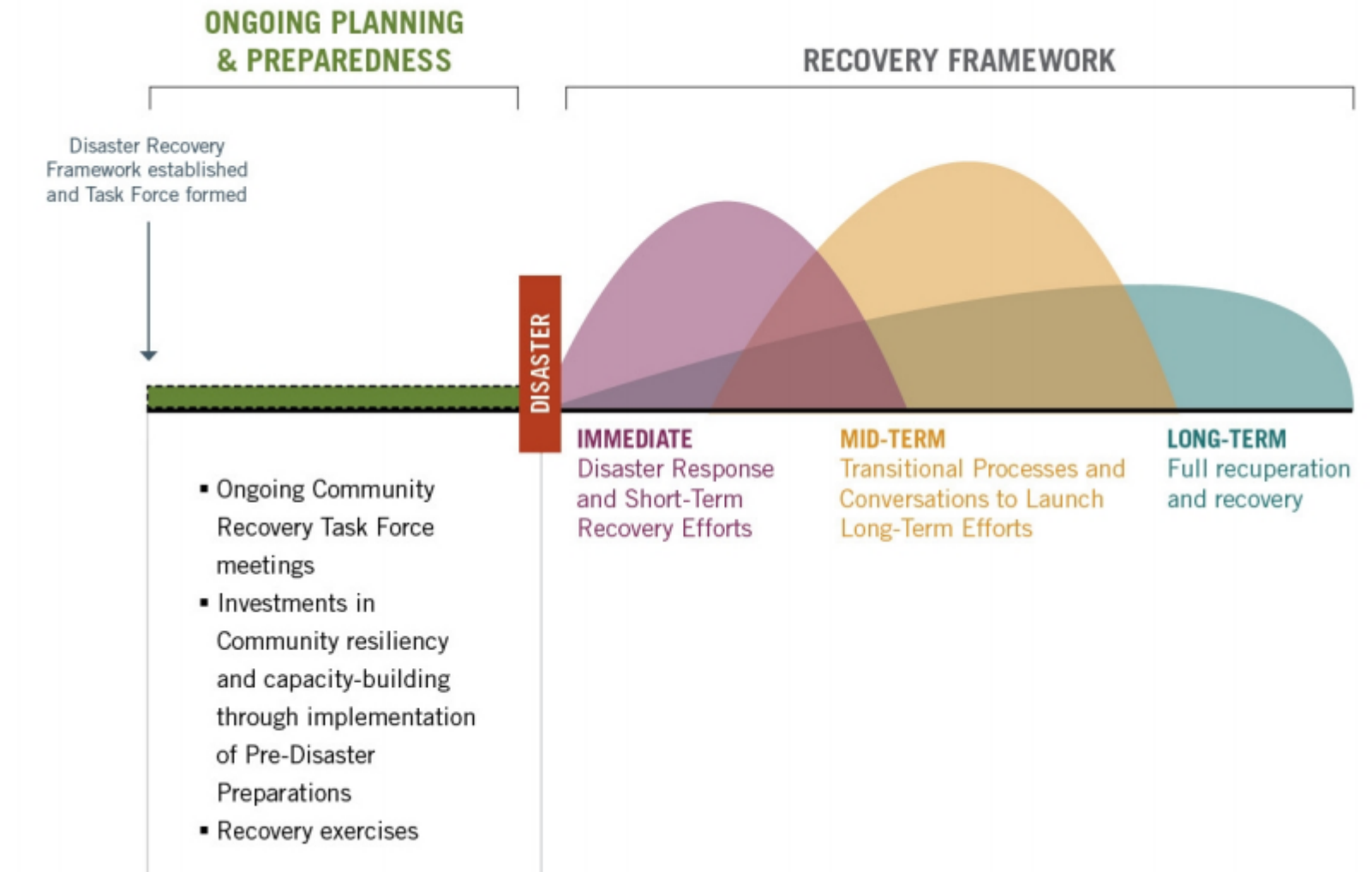


<http://onesanfrancisco.org/resilient-sf>

# Mayor's Executive Directive 19-01

- ▷ Conduct community outreach to inform City stakeholders about the Tall Buildings Safety Strategy.
- ▷ Develop additional regulations to address **geotechnical issues**.
- ▷ Explore adopting **higher seismic design standards**.
- ▷ Update the policies and procedures for implementing the **State's Safety Assessment Program** and clarify department roles and responsibilities for post-earthquake emergency response and safety inspection.
- ▷ Establish a **Disaster Recovery Taskforce** that will develop a recovery framework and a comprehensive **recovery plan** for the Financial District and adjacent neighborhoods.
- ▷ Provide information and knowledge sharing with other cities facing similar seismic challenges that are home to tall buildings

# Recovery Continuum



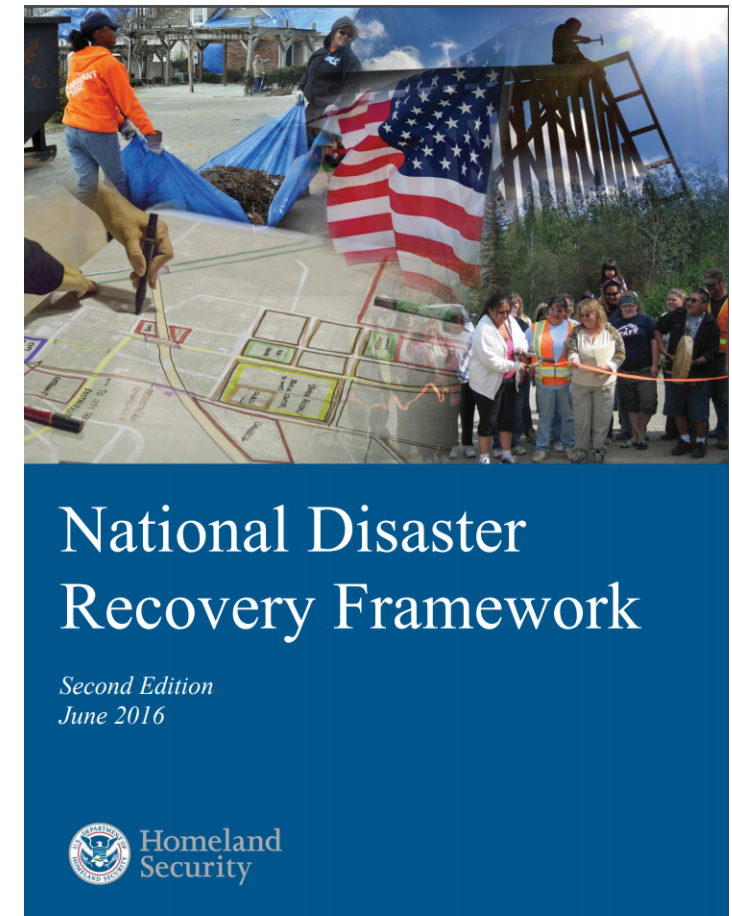
# Local Disaster Recovery Framework

## ▷ What it is

- Aligned with National Disaster Recovery Framework administered by FEMA
- Guides pre-and post-event recovery activities
- Describes roles, responsibilities, and coordination between City departments, state and federal agencies, community stakeholders
- Organized around Recovery Support Functions (RSFs)

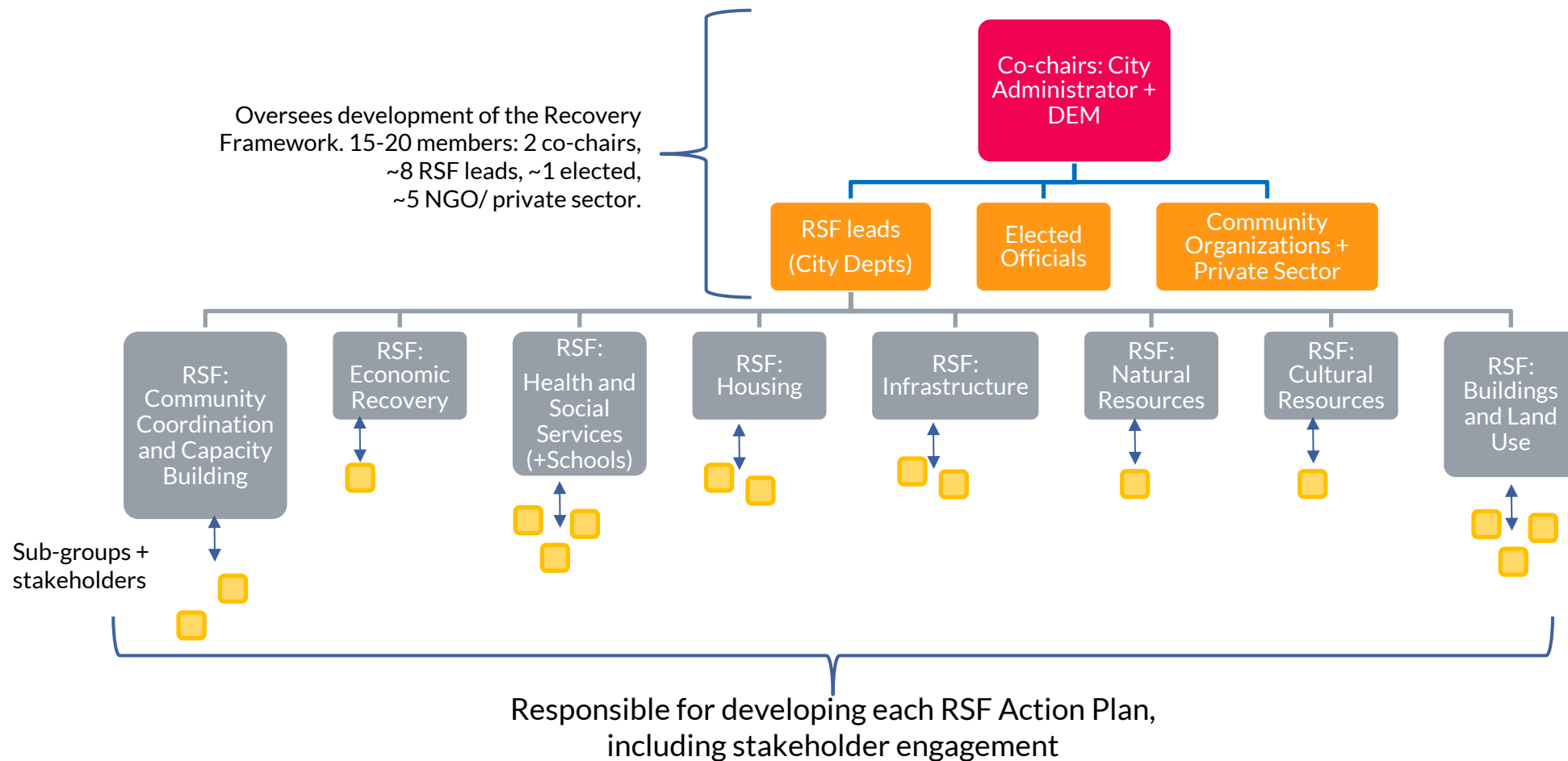
## ▷ Tasks

- Develop recovery goals, values and benchmarks for recovery
- Develop RSF action plans: scope, desired outcomes, capacity and constraints, pre and post-disaster actions, partners



# Disaster Recovery Taskforce

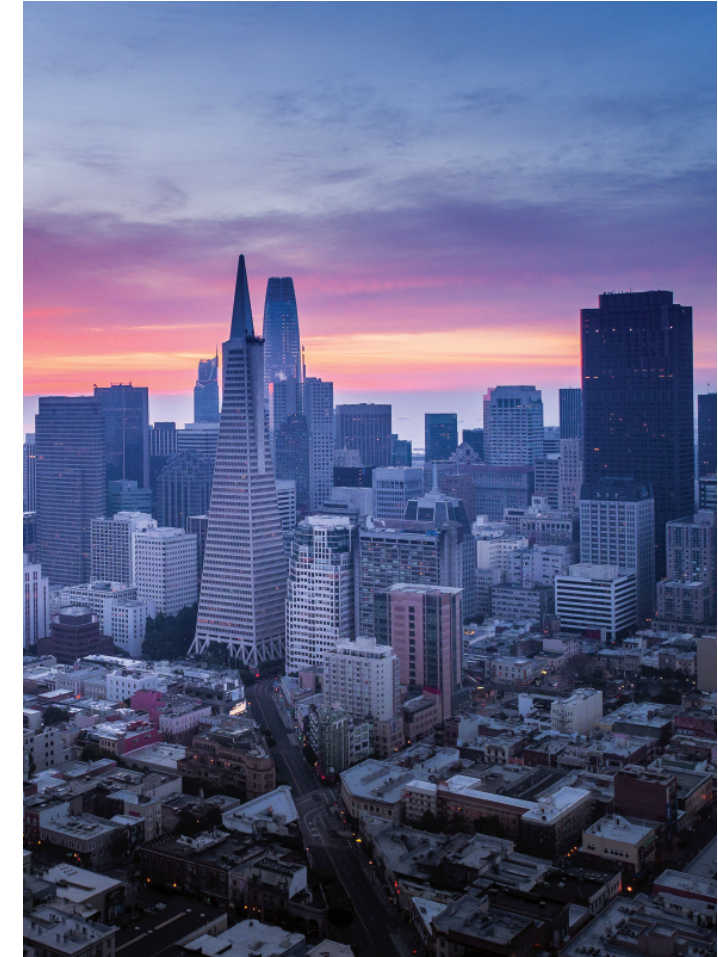
## Potential Structure





# Downtown Recovery Plan

- ▷ Assessment and action plan to speed recovery of downtown
  - Downtown-specific vulnerabilities and recovery challenges
- ▷ Leverage existing work on reducing damage and speeding recovery from an earthquake
  - Tall Buildings Study recommendations
  - Hazards and Climate Resilience Plan
  - Lifelines Restoration Performance Improvement Project
  - Earthquake Safety Implementation Plan
  - Capital Plan
  - Debris and Emergency Routes Plans
- ▷ Exercise with Recovery Taskforce

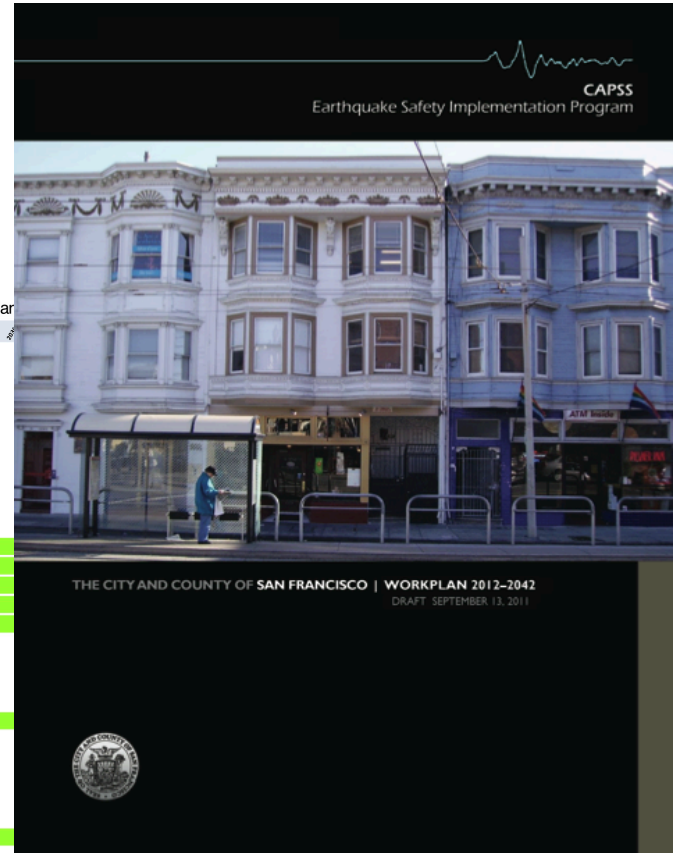


# Earthquake Safety Implementation Program

- ▷ Populations growth and changing conditions
- ▷ 2001 Community Action Plan for Seismic Safety
  - 10 year stakeholder driven consensus process
  - Earthquake Safety Implementation Program
  - Comprehensive plan for all buildings
  - Mandatory evaluation, retrofit
- ▷ Feasibility varies for some building subsets
  - Tall buildings
  - Similarly complex or recovery-critical buildings

CAPSS Earthquake Safety Implementation Program -- 30 Year Plan

Year	Task	Responsible Agency	Priority
2011	Task A.4.c. Develop repair/retrofit standards for wood-frame and concrete buildings	Building Inspection	Recommended Action
2011	Task A.4.d. Adapt disproportionate damage trigger	Building Inspection	Recommended Action
2011	Task A.4.e. Assess conformance of Community Safety Element with CAPSS and other recommendations	Department of Emergency Management	Recommended Action
2011	Task A.5.B. Support voluntary seismic upgrade of one- and two-family dwellings	Department of Building Inspection	Recommended Action
2011	Task A.5.C. Adopt facade maintenance regulations	Building Inspection	Recommended Action
2011	Task A.5.a. Develop and adopt shelter-in-place policies and procedures	Building Inspection	Recommended Action
2011	Task A.5.f. Update post-earthquake inspection (ATC 20) policies and procedures	Department of Building Inspection	Recommended Action
2011	Task A.6.C. Develop evaluation criteria and standards for older concrete and "most hazardous to life" buildings	Building Inspection	Recommended Action
2011	Task A.6 or Planning Code to limit nonconforming reconstruction unless minimum retrofit done	Planning Department	Recommended Action
2011	Task A.6.D. Develop evaluation standards and performance goals for all building types	Building Inspection	Recommended Action
2011	Task A.5.a. Develop funding sources to assist private property owners with seismic upgrade costs	Mayor's Office	Recommended Action
2011	Task A.5.b. Investigate Planning Code and other City agency incentives for seismic upgrade	Planning Department/Building Inspection	Recommended Action
2011	Task A.5.c. Seek Federal and State support for earthquake safety implementation	Mayor's Office	Recommended Action
2011	Task A.5.d. Offer "Ombudsman" services to provide technical and permitting, and other assistance	Department of Building Inspection	Recommended Action
2011	Task A.5.E. Explore alternative seismic retrofit solutions	Building Inspection	Recommended Action
2011	Task A.5.F. Further evaluate effects of retrofits on economically disadvantaged San Franciscans	Building Inspection	Recommended Action
2011	Task A.1.B. Provide information and assistance about renter's insurance and other insurance	Building Inspection	Recommended Action
2011	Task A.5.F. Review performance requirements for private schools K-12	Building Inspection	Recommended Action
2011	Task A.1.a. Mandatory evaluation and retrofit of 3+ story, 5+ unit multi-story wood frame residential buildings	Department of Building Inspection	Mandatory Evaluation
2011	Task A.1.a. Expand current public information programs	Building Inspection	Recommended Action
2011	Task A.4.g. Develop chimney repair/reconstruction guidelines	Building Inspection	Recommended Action
2011	Task A.8.B. Develop and implement Neighborhood Support Centers	Department of Emergency Management	Recommended Action
2011	Task A.5.G. Study scope and issues related to critical retail stores, suppliers, medical service providers, and others	Building Inspection	Recommended Action
2011	Task A.1.b. Mandatory evaluation and retrofit of concrete 10+ up and similar buildings	Department of Building Inspection	Mandatory Evaluation
2011	Task A.1.c. Encourage voluntary seismic upgrades of one- and two-family dwellings	Building Inspection	Recommended Action
2011	Task A.6.I. Study fire related earthquake resilience topics	Fire Department	Recommended Action
2011	Task A.8.A. Implement performance data collection of retrofitted buildings to evaluate effectiveness of retrofit measures	Department of Building Inspection	Recommended Action
2011	Task A.2.a. Mandatory evaluation of all wood frame residential buildings with 3+ dwelling units on sale or by deadline	Department of Building Inspection	Mandatory Evaluation
2011	Task B.2.D. Develop seismic upgrade and technician training programs for contractors	Department of Building Inspection	Recommended Action
2011	Task B.3.a. Mandatory evaluation and retrofit of Private K-12 schools to public-school equivalent standards	Department of Building Inspection	Mandatory Evaluation
2011	Task B.3.a. Outreach to critical retail stores, suppliers, medical, and others regarding nonstructural and simple structural upgrades	Building Inspection/Department of Building Inspection	Recommended Action
2011	Task B.2.a. Mandatory evaluation of older non-ductile concrete residential buildings	Department of Building Inspection	Mandatory Evaluation
2011	Task B.2.c. Develop earthquake inspection and posting special use buildings	Department of Building Inspection	Recommended Action
2011	Task B.6. Update codes for new buildings to reflect desired performance goals and acceptable confidence levels in meeting them	Building Inspection/Department of Building Inspection	Recommended Action
2011	Task B.6.H. Review performance of assisted living facilities and similar special purpose facilities	Building Inspection/Department of Building Inspection	Recommended Action
2011	Task B.1.b. Develop non-structural upgrade program for businesses	Building Inspection	Recommended Action
2011	Task B.2.B. Training of design professionals on seismic evaluation and retrofit programs	Department of Building Inspection	Recommended Action
2011	Task B.2.C. Develop links to distribute materials and provide retrofit incentives from building material suppliers and other companies	Department of Building Inspection	Recommended Action
2011	Task B.1.d. Mandatory evaluation and retrofit of Soft-Story Buildings with 3 or more stories and 3 or more dwelling units	Department of Building Inspection	Mandatory Evaluation
2011	Task B.2.f. Mandatory evaluation of all other wood-frame residential buildings on sale	Department of Building Inspection	Mandatory Evaluation
2011	Task B.6.C. Review ground failure mitigation measures for areas with high geological hazard	Building Inspection/Department of Building Inspection	Recommended Action
2011	Task B.2.d. Mandatory evaluation of residential with 5+ dwelling units and hotels/motels	Department of Building Inspection	Mandatory Evaluation
2011	Task B.1.B. Develop post-earthquake repair and retrofit standards for building types not covered in previous standards	Building Inspection	Recommended Action
2011	Task C.1.a. Mandatory evaluation on sale or by deadline of building types not otherwise covered	Department of Building Inspection	Mandatory Evaluation
2011	Task C.1.b. Evaluation of buildings retrofitted prior to 1991 or built to non-conforming performance standards	Building Inspection/Department of Building Inspection	Mandatory Evaluation
2011	Task C.2.a. Mandatory retrofit of older non-ductile concrete residential buildings	Department of Building Inspection	Mandatory Retrofit
2011	Task C.2.b. Mandatory evaluation and retrofit of nonstructural/structural elements to critical stores, suppliers and service providers	Building Inspection/Department of Building Inspection	Mandatory Evaluation
2011	Task C.2.c. Mandatory evaluation and retrofit of assembly (100+ occupancy) buildings	Building Inspection/Department of Building Inspection	Mandatory Evaluation
2011	Task C.2.d. Mandatory evaluation and retrofit of steel low-performance buildings	Building Inspection/Department of Building Inspection	Mandatory Evaluation
2011	Task C.2.e. Mandatory evaluation and retrofit of other low-performance buildings	Building Inspection/Department of Building Inspection	Mandatory Evaluation



THE CITY AND COUNTY OF SAN FRANCISCO | WORKPLAN 2012-2042  
DRAFT, SEPTEMBER 12, 2011



Implementation Phase B  
(2015 - 2020)

Implementation Phase C  
(2020 - 2042)

REV. 9/13/2011

# Mandatory Soft-Story Retrofit Program

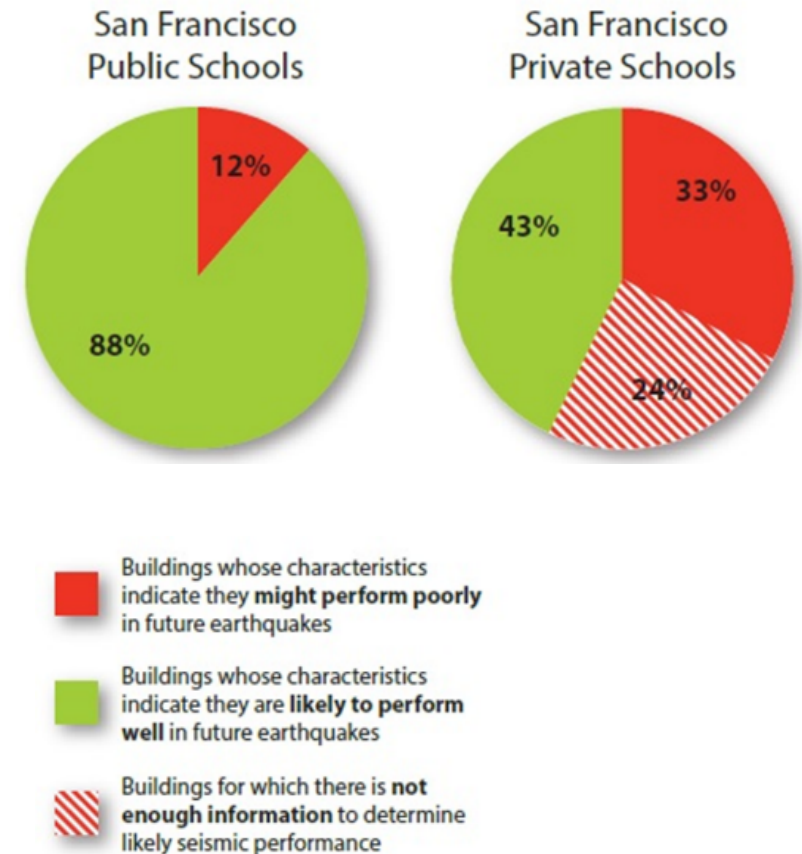
- ▷ Wood frame residential buildings with 3+ stories, 5+ units, built before 1978
- ▷ Affects ~112,096 residents
- ▷ Housing preservation and expansion through additional dwelling units (ADUs)
- ▷ PACE Financing

Program Timeline		
Tier	Permit Required by	CFC Required by
1	9/15/2015	9/15/2017
2	9/15/2016	9/15/2018
3	9/15/2017	9/15/2019
4	9/15/2018	9/15/2020

<b>Total Properties</b>	<b>6,962</b>
Properties Subject to the Ordinance	4,921
Number of Units	~48,317
Compliance Rate	96%
Permits Submitted	4,812
Permits Issued	1,059
Work Completed	3,023
Average Retrofit Cost	~\$71,000

# Private Schools Evaluations

- ▷ ~109 schools with 218 buildings subject to Private School Evaluation Ordinance (No. 202-14)
  - 94 concrete, 63 wood, 13 steel, 3 URM, 21 other or unknown.
- ▷ 24,000 children in SF private schools
- ▷ Private schools are not required to meet same level of seismic safety as public schools
- ▷ ESIP Task B.3.a recommends mandatory evaluation and retrofit of private schools



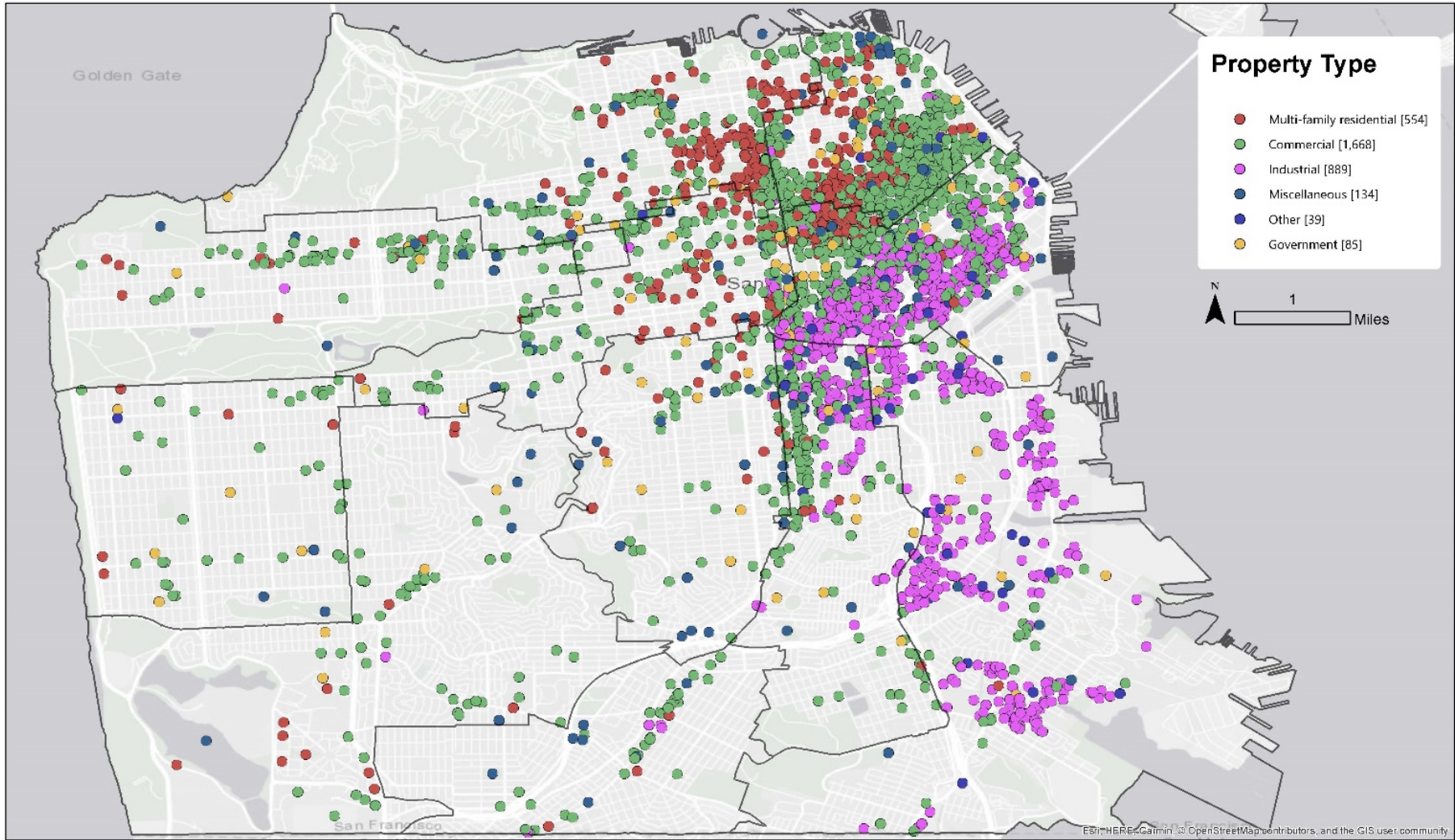
# Non-Ductile Concrete Buildings

## ▷ Issues

- ~3,400 pre-1980 concrete buildings; 116 city-owned
- Small percentage of older concrete buildings are very vulnerable to collapse in earthquakes
- Concrete Buildings contain much of San Francisco's affordable housing stock and 40% of private schools

## ▷ Recommendations

- ESIP Tasks B.2.a and C.2.a: mandatory evaluation and retrofit of older residential concrete and tilt-up buildings
- ATC Tall Buildings Study: evaluation and retrofit



## CONCRETE BUILDINGS

Illustrated here are all concrete buildings in the city except for the following: post 1980 construction, public schools, colleges and universities, hospitals, SF Port buildings, and 1-4 unit residential buildings.

3,400 buildings total

# Steel Frame Buildings

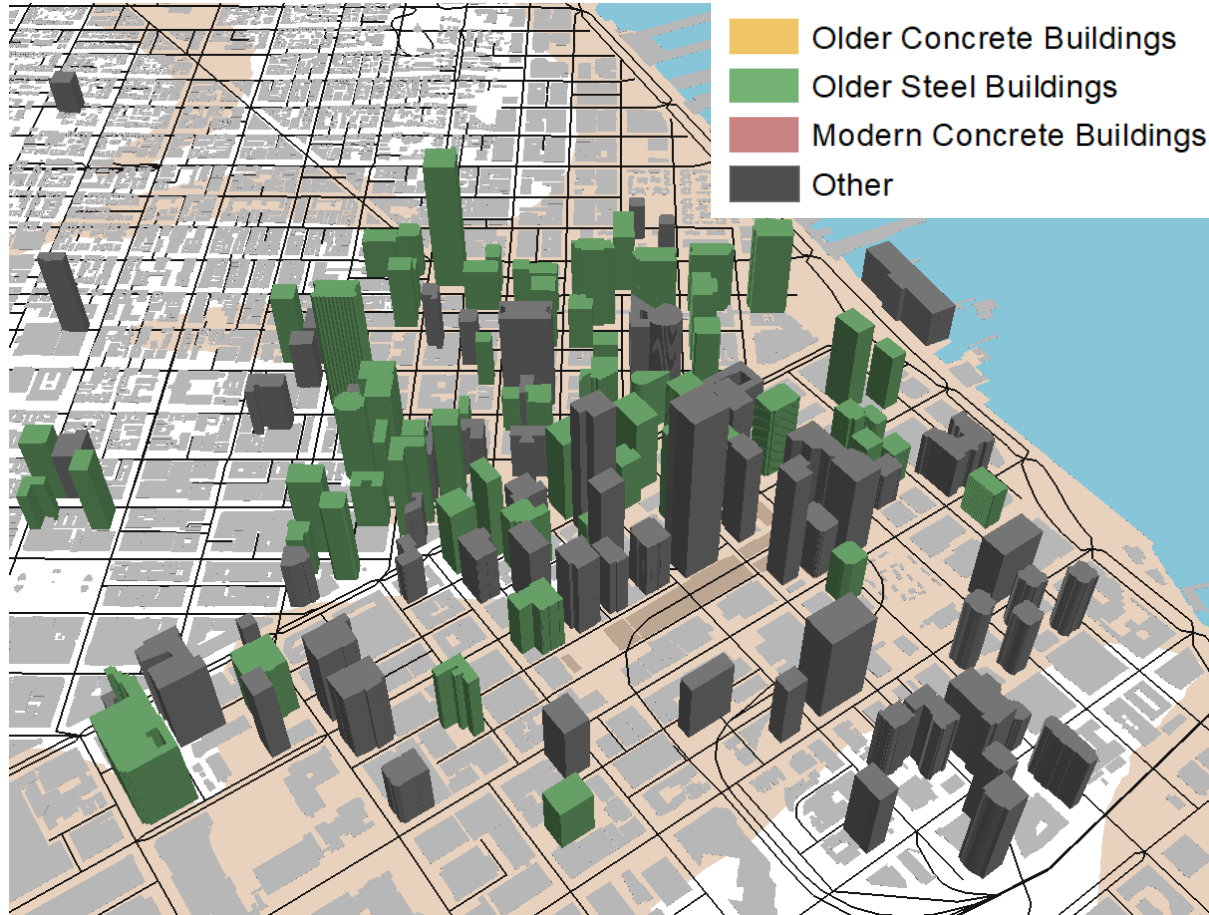
## ▷ Issues

- 86 buildings over 240ft built between 1964 and 1995
  - ~68 built before the Loma Prieta earthquake
- Potential collapse at high ground motions, especially where irregularities
- Primarily commercial uses and 10% of private schools

## ▷ Recommendations

- ESIP Task C.2.d: mandatory evaluation and retrofit of older steel buildings starting in 2030
- ESIP Task B.4.b/Tall Buildings Rec 3F: develop post-earthquake repair and retrofit standards for steel frame buildings.
- Tall Buildings Rec 2A: address issues related to possible weld vulnerabilities

# Steel Frame Buildings >240ft



- **Pre-Northridge Steel Framed Buildings**
  - 86 total
  - 50 to 65 welded SMF
  - 9 welded dual systems



Thanks!  
**Any questions?**

You can find me at:  
[Danielle.Mieler@sfgov.org](mailto:Danielle.Mieler@sfgov.org)

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# ***San Francisco Tall Buildings Study***

Ayse Hortacsu  
Applied Technology Council

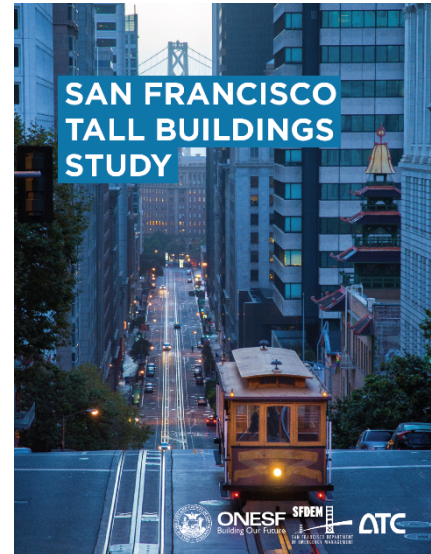
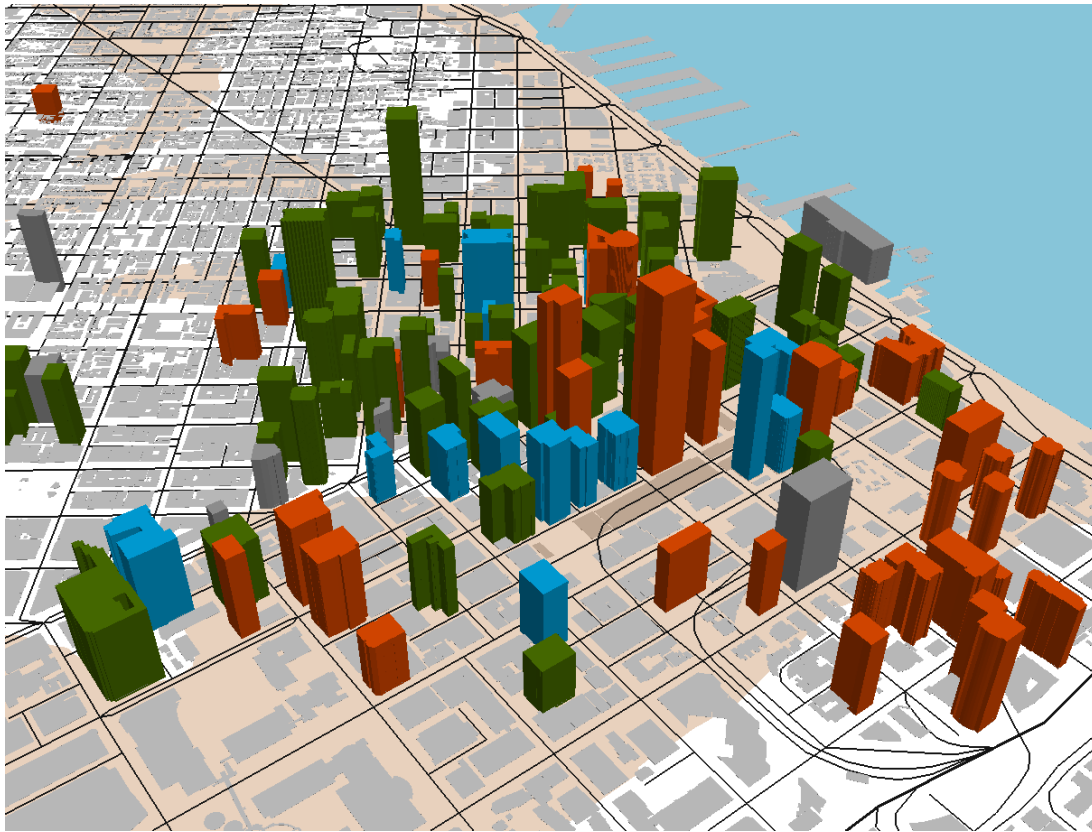
# Project Motivation and Objective

## 2011 Workplan

CAPSS Earthquake Safety Implementation Program – 30 Year Plan



Objective:  
Examine the earthquake performance of San Francisco's tall buildings and develop recommendations



# 16 Recommendations

Recommended Action	Short-Term	Mid-Term	Long-Term
<b>1. Actions for Reducing Seismic Risk Prior to Earthquakes – New Buildings</b>			
1A. Develop Regulations to Address Foundation and Geotechnical Issues			
Training and checklist	X		
Develop geotechnical regulations		X	
1B. Establish Recovery-Based Seismic Design Standards			X
<b>2. Actions for Reducing Seismic Risk Prior to Earthquakes – Existing Buildings</b>			
2A. Apply the Repair Provisions of the San Francisco Existing Building Code with Respect to Possible Loma Prieta damage		X	
2B. Amend the San Francisco Existing Building Code Triggers			
Alteration and change of occupancy triggers	X		
Acquisition triggers		X	
2C. Recommend Minimum Levels of Earthquake Insurance or Other Collateral to Ensure Post-Earthquake Recovery			X
2D. Review Requirements for Post-Earthquake Fire Suppression and Evacuation Systems		X	
<b>3. Actions for Reducing Seismic Risk Following Earthquakes</b>			
3A. Develop New Policies and Procedures for Implementing the State's Safety Assessment Program	X		
3B. Extend and Improve the Building Occupancy Resumption Program			
Conduct simulation-based training	X		
Update procedures	X		
Extend program		X	
3C. Clarify and Update Roles and Responsibilities Associated with Post-earthquake Emergency Response and Safety Inspection	X		
3D. Update and Amend the San Francisco Existing Building Code Triggers for Repair Projects		X	
3E. Update Administrative Bulletin 099 and Clarify its Application to Tall Concrete Structural Systems			X
3F. Develop a New Administrative Bulletin for Post-Earthquake Inspection and Evaluation of Welded Steel Moment Frames			X
3G. Create Protocols and Procedures for Establishing Cordons around Damaged Buildings	X		
3H. Require Existing Buildings to File Recovery Plans			X
<b>4. Actions to Improve the City's Understanding of its Tall Building Seismic Risk</b>			
4A. Maintain and Expand the Database of Tall Buildings	X		
4B. Develop a Comprehensive Recovery Plan for the Financial District and Adjacent Neighborhoods			X

<http://onesanfrancisco.org/resilient-sf>

# Project Team

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## **ATC Project Technical Committee:**

- John D. Hooper (Task Leader)
- David Bonowitz
- Gregory Deierlein
- Shah Vahdani

## **ATC Reviewers for Geotechnical Task:**

- Mark Haley (Boston)
- Bill Walton (Chicago)

## **ATC Project Working Groups:**

- Carlos Molina-Hutt (University of British Columbia)
- Anne Hulseley (Stanford)
- Preetish Kakoty (UBC)
- Alireza Eksir Monfared (UBC)
- Wen-Yi Yen (Stanford)

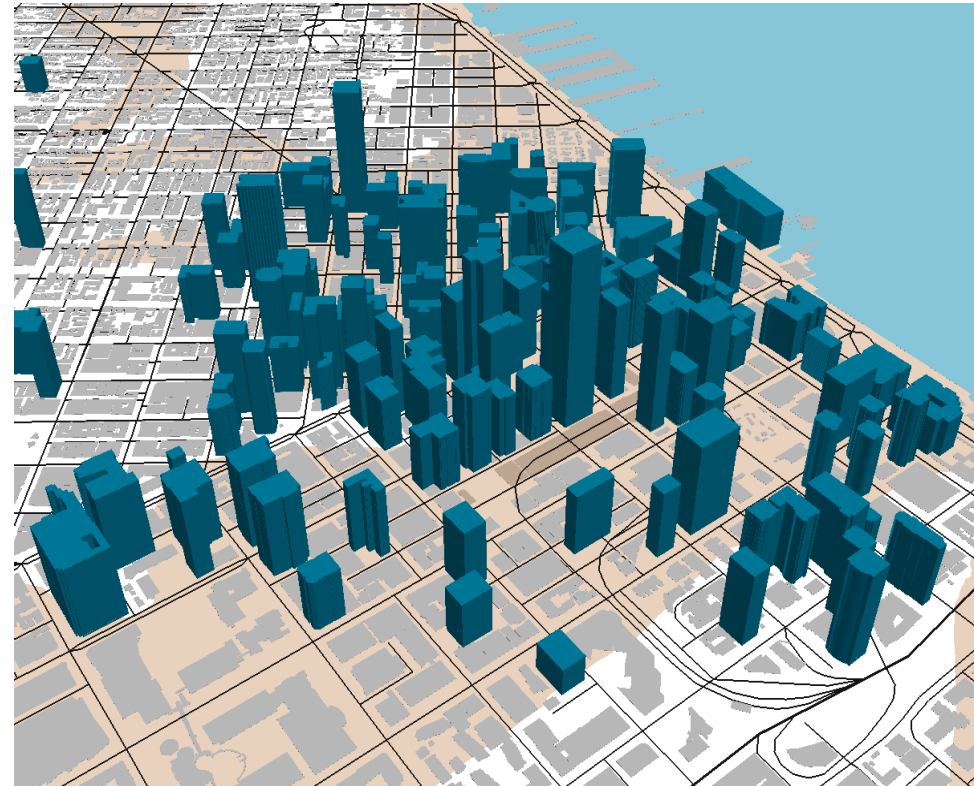
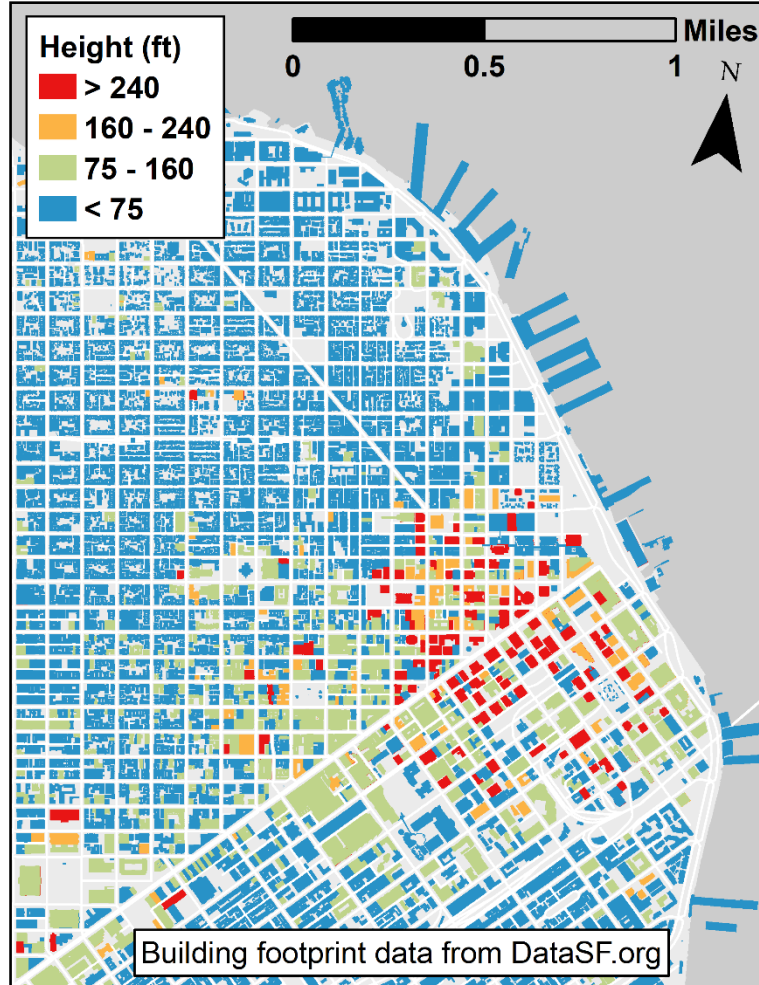
## **City of SF Tall Buildings Executive Panel:**

- Naomi Kelly, City Administrator (Chair)
- Mary Ellen Carroll, Dept. of Emergency Management
- Kathryn How, Public Utilities Commission
- Tom Hui, Dept, of Building Inspection
- Brian Strong, Office of Resilience and Capital Planning

## **Project Managers:**

- Danielle Mieler (ORCP)
- Ayse Hortacsu (ATC)
- Justin Moresco (ATC)

# Inventory of SF Tall Buildings



**156 Tall Buildings (Over 240 ft)**

# Building Data Sources

## General Building Stock

### *San Francisco Open Data Portal*

Relevant datasets:

- Property Tax Rolls
- Land Use
- Building Footprints (LIDAR)
- Seismic Hazard Zones (Liquefaction/Landslide)

## Buildings over 240 ft

### *Construction Permit Documents*

- Structural drawings

### *BORP Files*

- Reports

### *Interviews/surveys of Structural Engineering Designers*

*Emporis* (online database of buildings)

*SF Fire Department building inventory* (Buildings over 75 ft)

Information on material flammability and fire suppression systems

# Characterization of Tallness

Critical Height	Issue	Source and description
420 ft	Fire Safety Risk Category	Current code (CBC Section 403): Taller buildings must meet all fire-resistance requirements for Type IA construction, as well as additional egress requirements. Risk Category III based on occupant load of 5000
240 ft	<b>Risk Category; Seismic, structural</b>	Current code: <b>Height limit for shear wall and braced frame systems</b> in normal occupancy without torsion-prone configuration
160 – 180 ft	Fire Safety	Current code (Table 504.3): Maximum height for Type I.B construction, non-sprinklered or sprinklered, respectively
160 ft	<b>Risk Category; Seismic, structural</b>	Current code: Height limit for shear wall and braced frame systems in normal occupancy with torsion-prone configuration. Current code ( <b>AB-083</b> ): <b>definition of “tall building”</b> for Seismic Design of New Tall Buildings using <b>Non-Prescriptive Seismic-Design Procedures</b>
100 ft	Risk Category; Seismic, structural	Current code: Height limit for shear wall and braced frame systems in essential facilities (RC IV, SDC F) with torsion-prone configuration
65 – 85 ft	Fire Safety	Current code (Table 504.3): Maximum height for Type II, III, or IV construction, non-sprinklered or sprinklered, respectively
75 ft	<b>Fire Safety</b>	Current code (HSC 13210): <b>definition of “high-rise structure”</b> for specific <b>fire protection regulations</b> in the Health and Safety Code
5 stories	Seismic, nonstructural	Current code (SFNBC Chapter 4E): Façade inspection required for buildings with 5 or more stories.



# Building Structural Systems

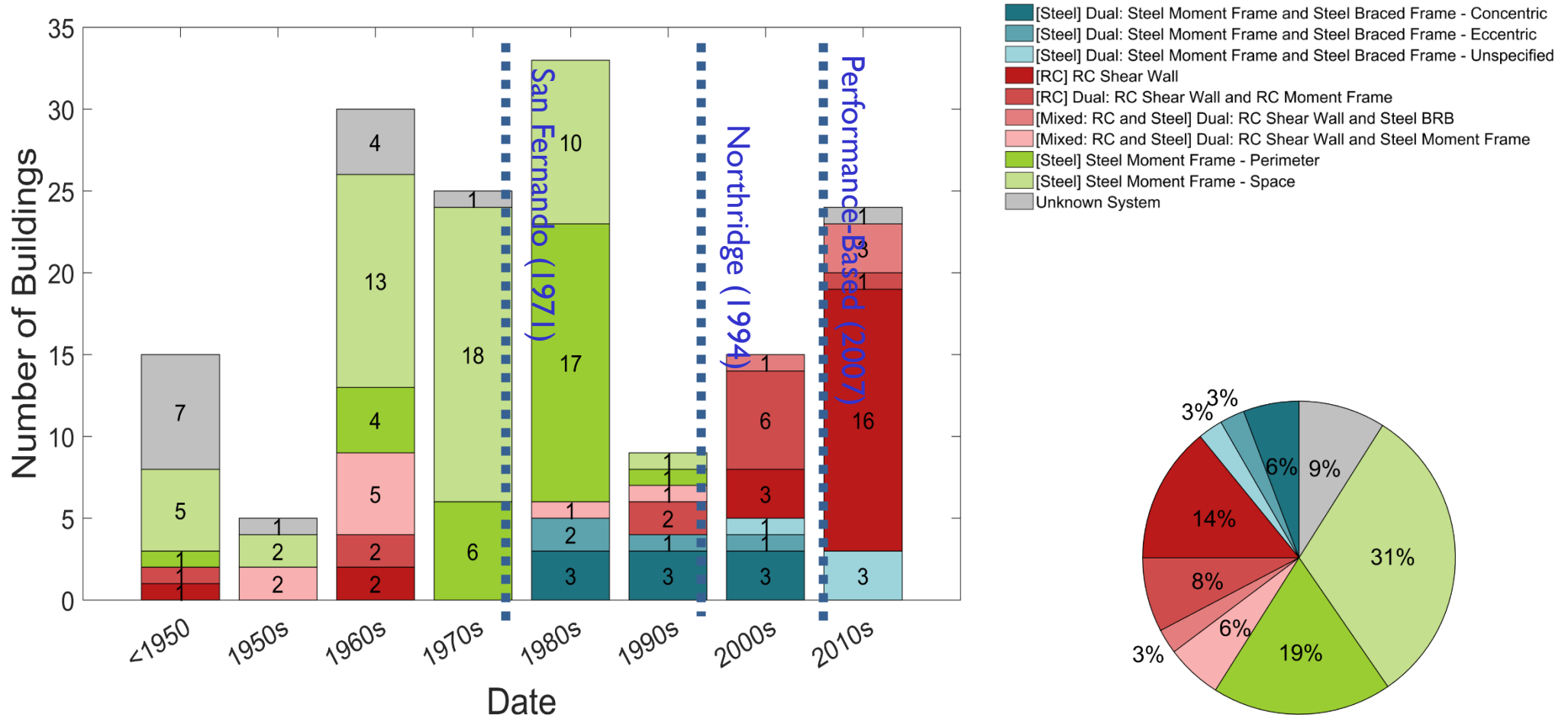


## Structural System

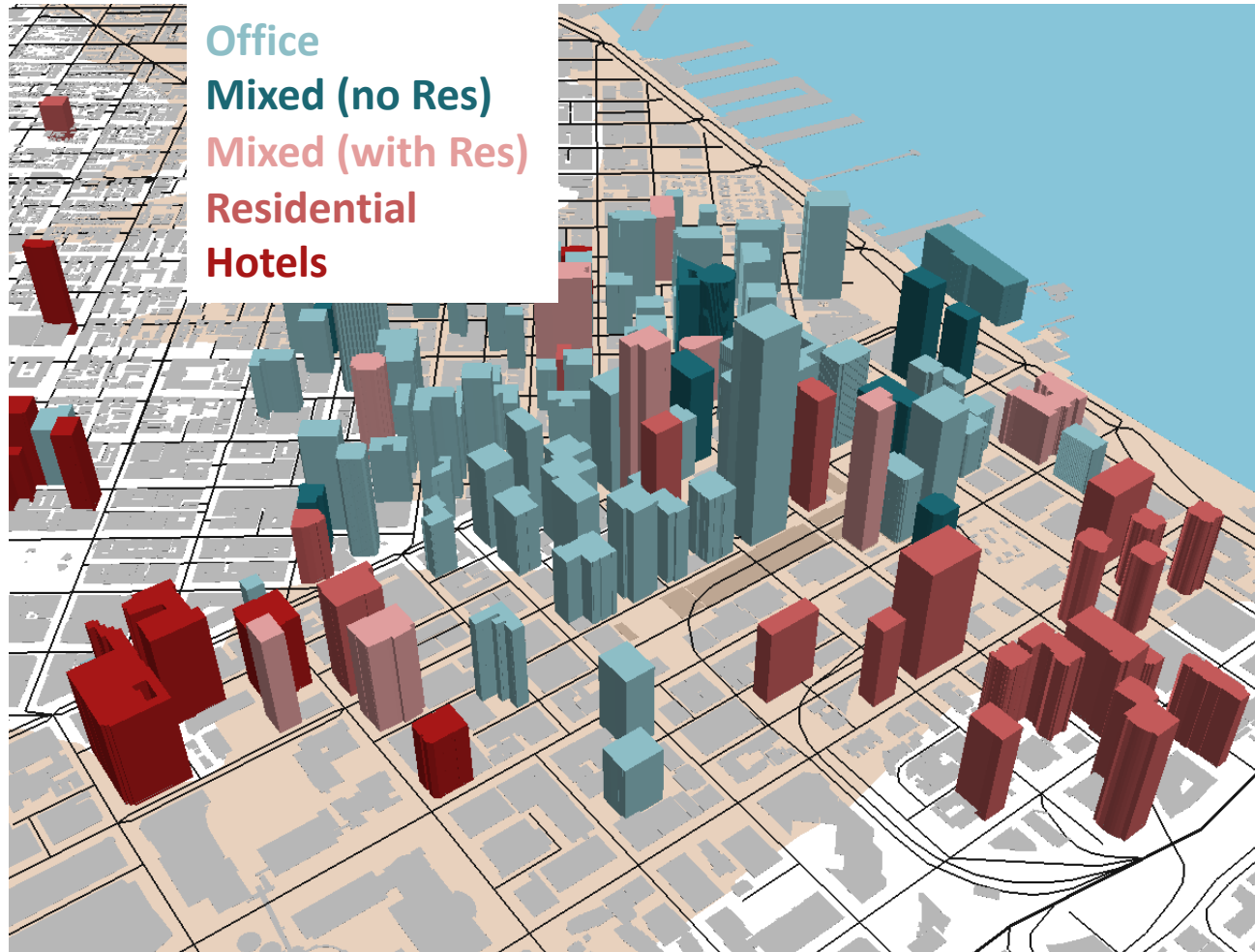
- [Steel] Moment Frame - Perimeter
- [Steel] Moment Frame - Space
- [RC] Shear Wall
- [Dual] Shear Wall + RC Moment Frame
- [Dual] Shear Wall + Steel Moment Frame
- [Dual] Shear Wall + BRB
- [Dual] Braced Frame - Eccentric
- [Dual] Braced Frame - Concentric and Eccentric
- [Dual] Braced Frame - Concentric
- Unknown

- The newer buildings (south of Market) tend to be concrete shear wall systems
- Older buildings are predominantly steel moment frame systems

# Structural Systems & Age



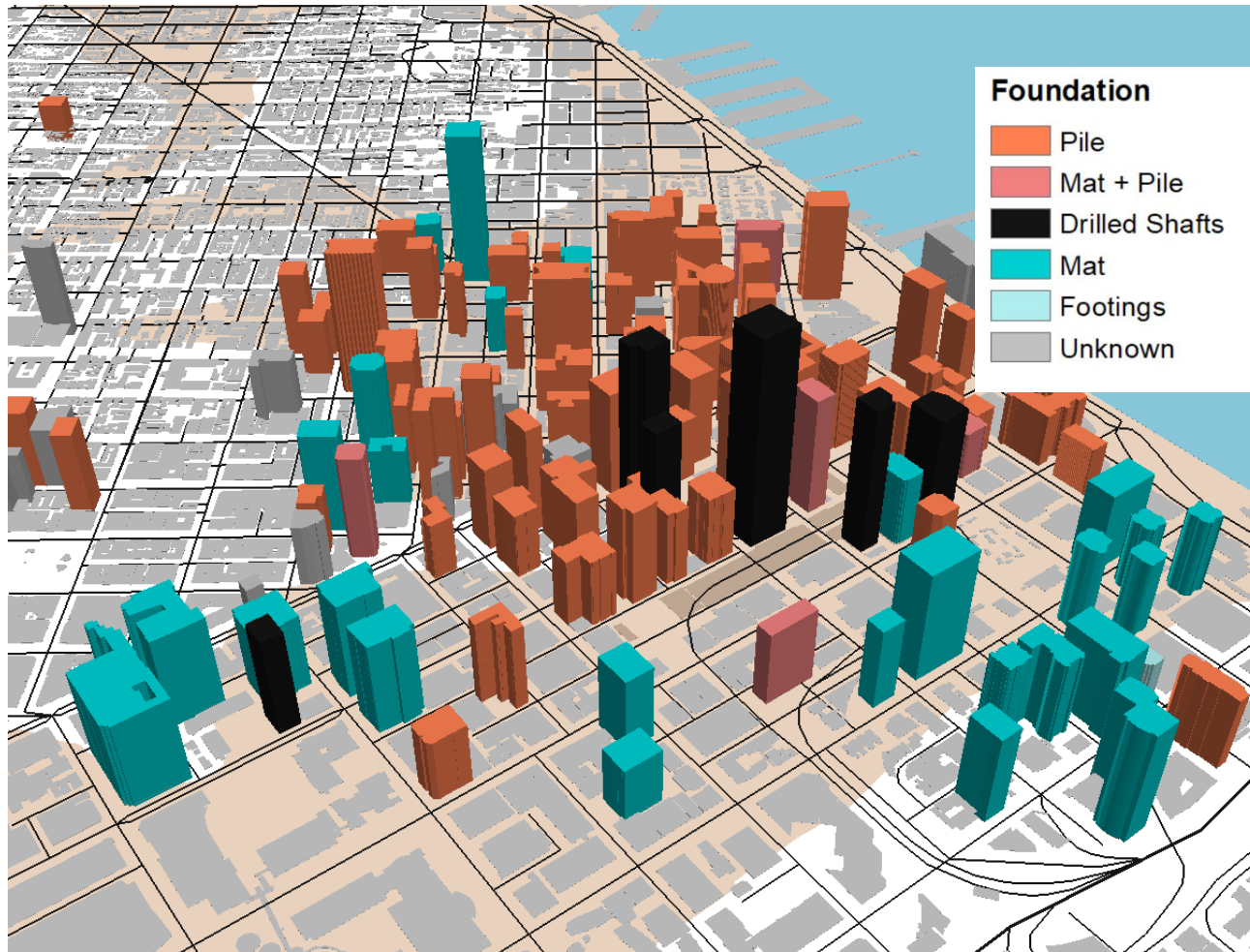
# Occupancies



<1960	1	3	0	0	15	1
1960s	0	3	2	0	16	9
1970s	0	4	0	3	17	1
1980s	0	5	4	4	20	0
1990s	0	2	1	1	4	1
2000s	0	1	1	0	5	8
>2010	0	0	3	0	7	14
	CIE	Hotel	MixRes	Mixed	Office	Res

- 55% office; 22% residential; 24% mixed/hotel
- Older buildings are mostly offices (Steel moment frames)
- Newer buildings (south of Market) tend to be residential (Concrete shear wall systems)

# Building Foundations



## Factors of Influence

1. Depth to rock
2. Soil Type/Stiffness
  - *Marine Deposits*
  - *Colma Sands*
  - *Old Bay Clay*
3. Building Height/Weight
4. Number of Basement Levels
5. Slope/Proximity to Shoreline
6. Adjacent/Underlying Structures
7. Ground Water Level

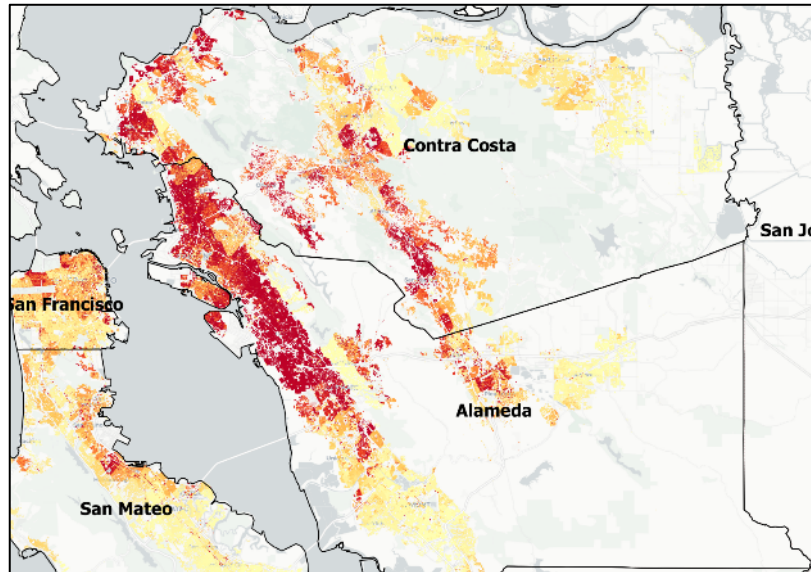
Plus, construction technologies, logistics and economics

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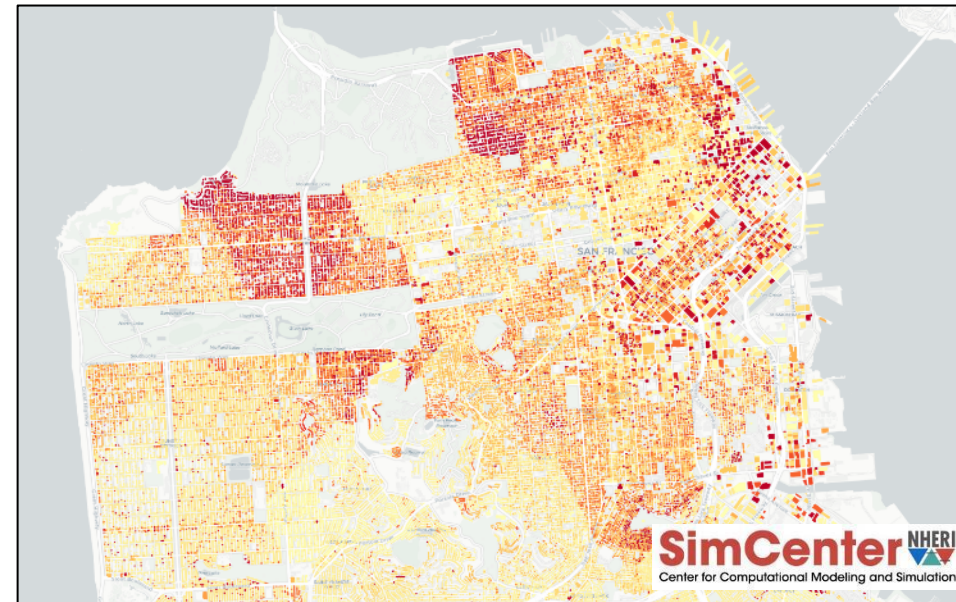
*Recommendation 4A:*  
***Make Accessible, Maintain, and  
Expand the Database of Tall Buildings***

# High Resolution Simulations

Parcel-level resolution enables unprecedented quantification of engineered interventions for policy level decisions



Regional Simulation



San Francisco Parcels

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*Recommendation 3G:*  
***Create Protocols and Procedures  
for Establishing Cordons Around  
Damaged Buildings***

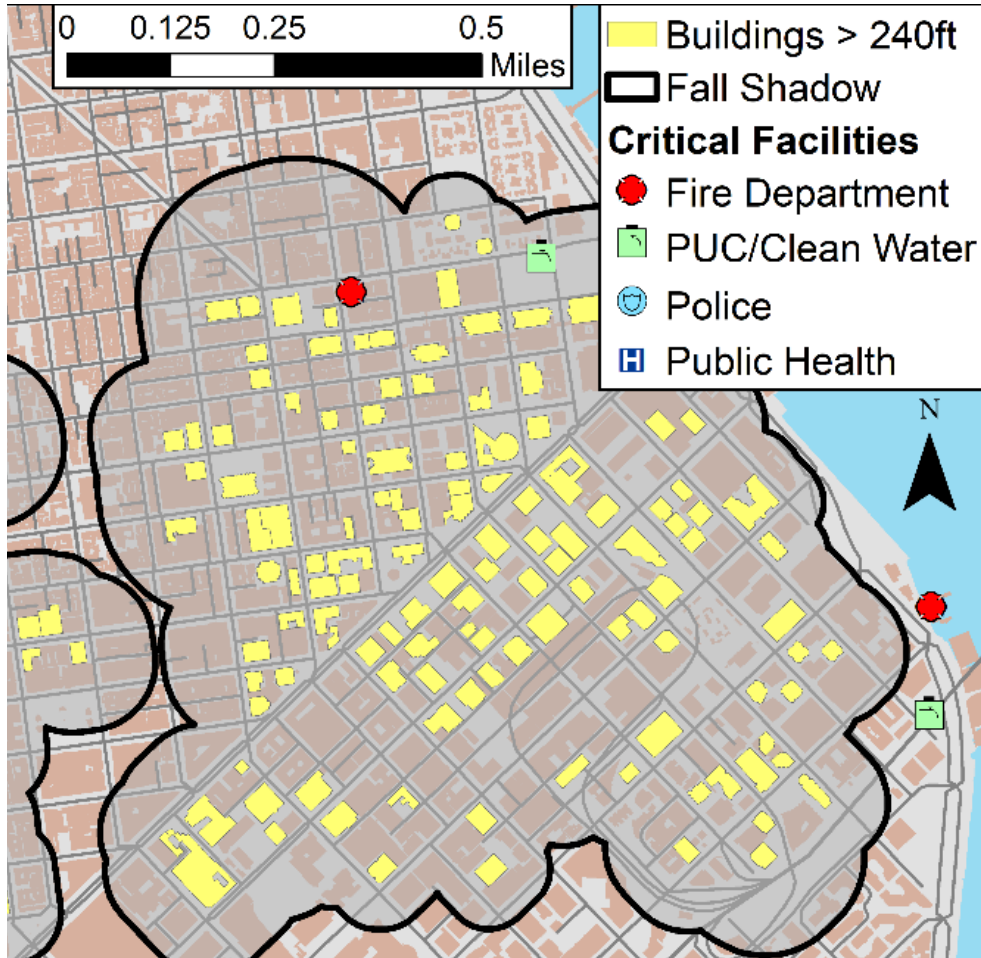
# 3G. Cordons

- Issue: Standard procedure applied to tall buildings is problematic for:
  - Emergency response
  - Transit
  - Neighborhood buildings
    - Housing, commerce
  - Neighborhood recovery
  - City resilience





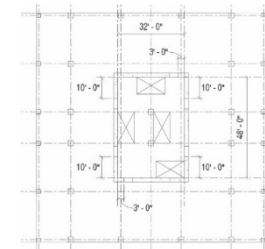
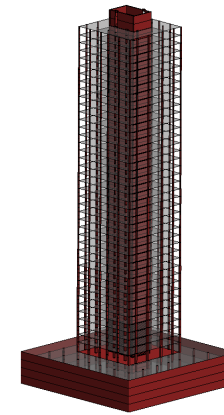
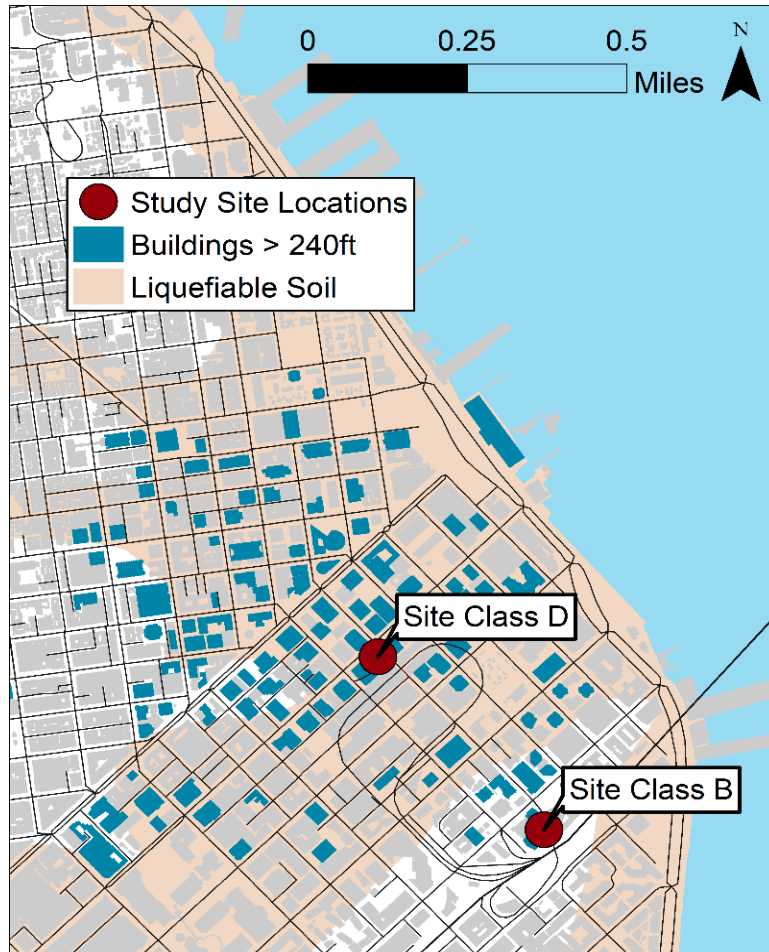
# 3G. Cordons



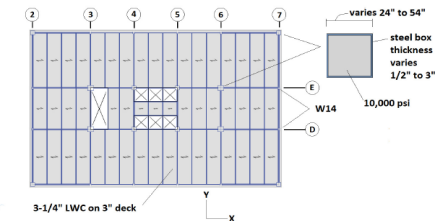
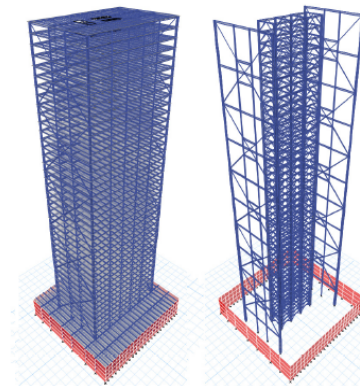
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*Recommendation 1B*  
***Establish Recovery-Based  
Seismic Design Standards***

# New Building Archetype Studies



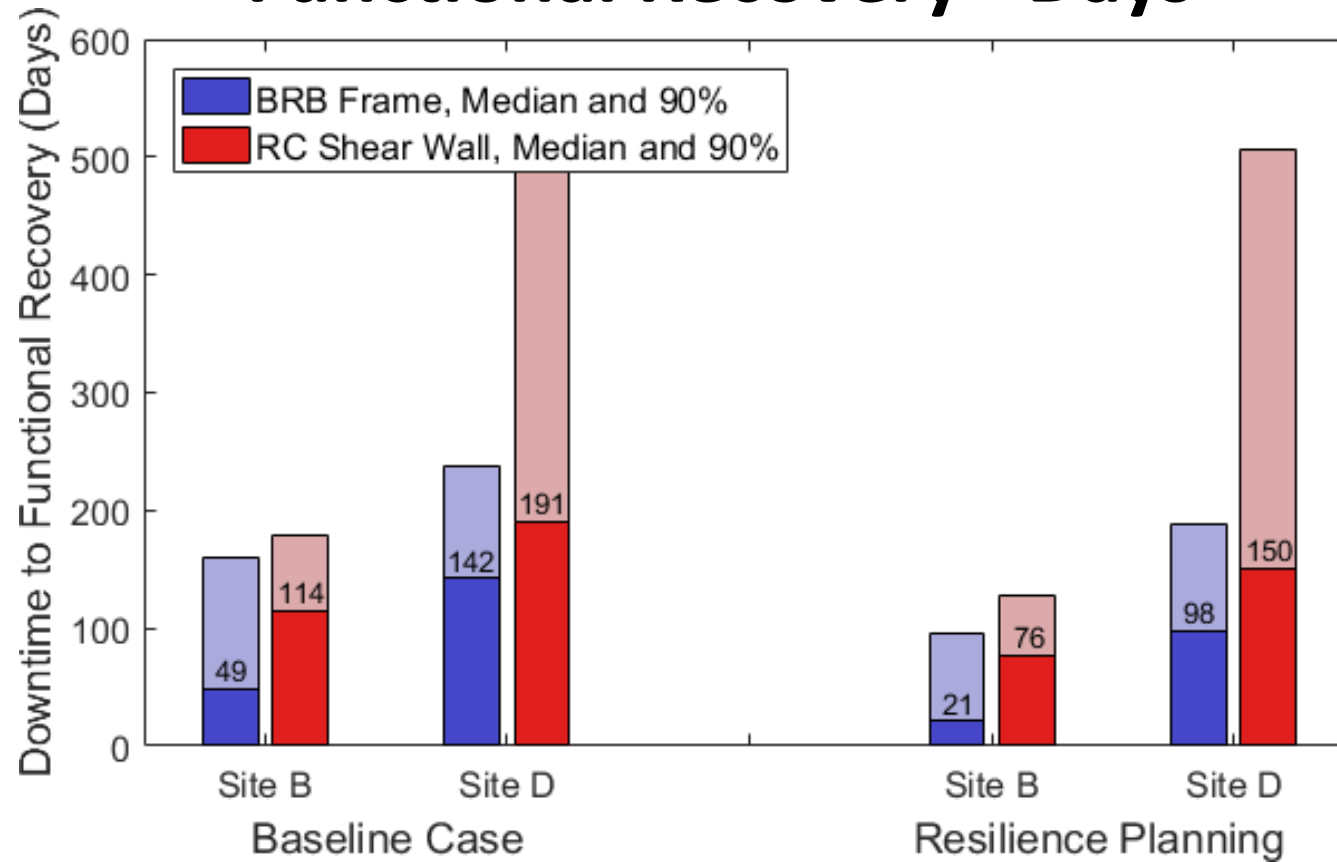
40-story RC Residential Building



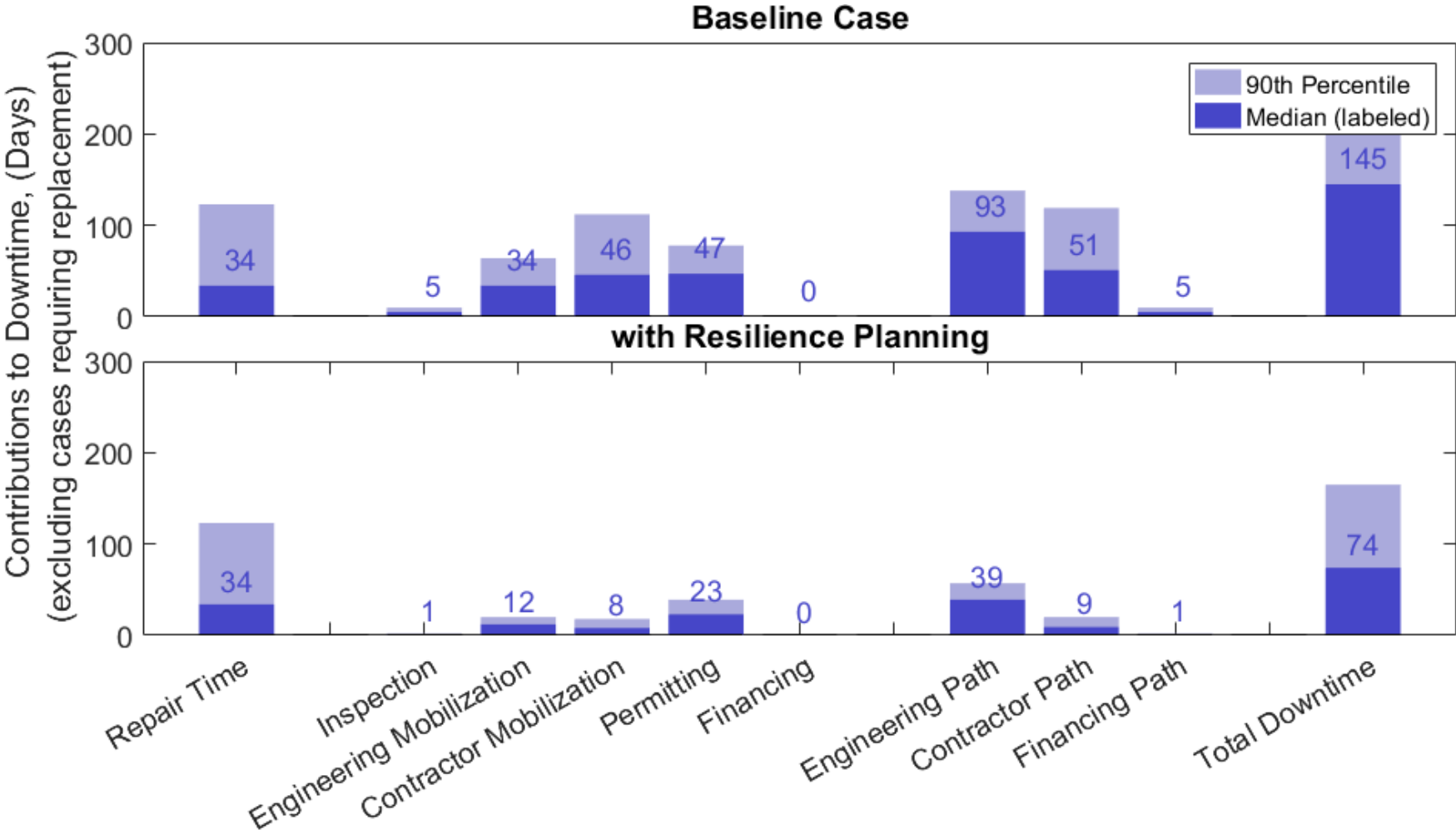
40-story Steel BRBF Office Building

# Performance: New Buildings

## Functional Recovery - Days



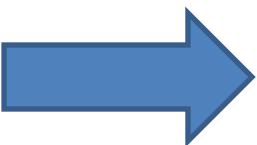
# Reduction of Impeding Factors



# ESIP

**Table 3-2 Tentative Recommended Recovery Goals for San Francisco Buildings (continued)**

Building Use	Recommended Recovery Goal <sup>1</sup> for a Major Earthquake <sup>2</sup>				
	0-24 Hours	Days	Weeks	Months	Years
<i>Housing / Neighborhoods</i>					
Single-family homes (1 to 2 units)				■	
Multi-family housing			■		
Subsidized / Below Market Rate housing		■			
Hotels and Motels			■		
<i>Commerce / Livelihood</i>					
Recovery-critical retailers			■		
Major employers			■		
City services, non-emergency			■		
Other business and mercantile uses				■	



<sup>1</sup> ■ indicates the desired time in which the vast majority (80 to 90 percent) of buildings citywide that contain the listed use, new and existing, should have their basic pre-earthquake functions restored.

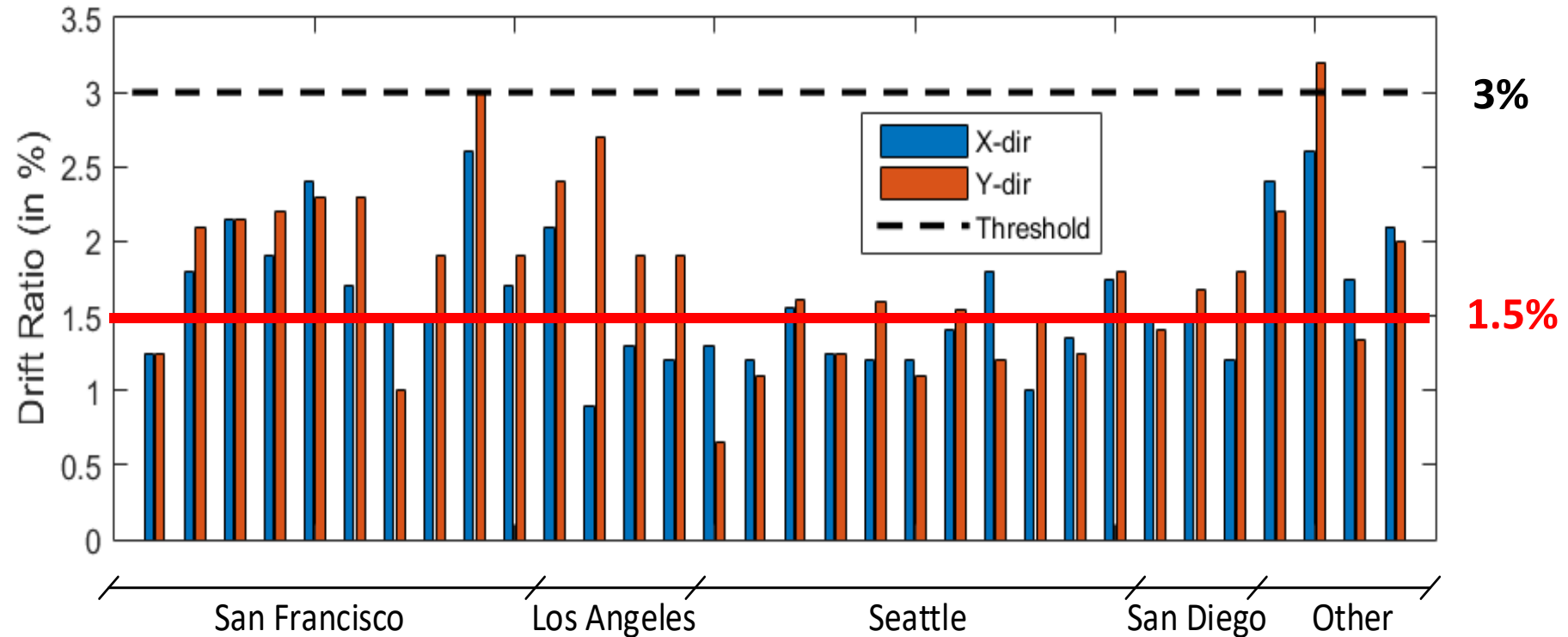
# 1B. Recovery-Based Seismic Design Standards

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To shorten downtime in new tall buildings, DBI should develop an Administrative Bulletin (with building code amendments as needed) that specifies:

- **Recovery-based seismic design and construction requirements**
- **Measures to mitigate externalities that impede recovery**

# Seismic Drift Requirements



**Comparison of Calculated Story Drifts under MCE Ground Motions**



---

*Recommendation 4B:*  
***Develop a Comprehensive  
Recovery Plan for the Financial  
District and Adjacent  
Neighborhoods***

# 4B. Downtown Recovery Plan

---

- Issue: What about aggregate effects?
  - Effects on the tall building neighborhood
  - Effects *of* the tall building neighborhood
- Study the bigger picture
  - Broaden the focus from individual buildings
  - What will the recovery timeline look like?
    - Extent of immediate functional loss
    - Pace of reoccupancy and recovery over time
  - Are additional programs, policies needed?

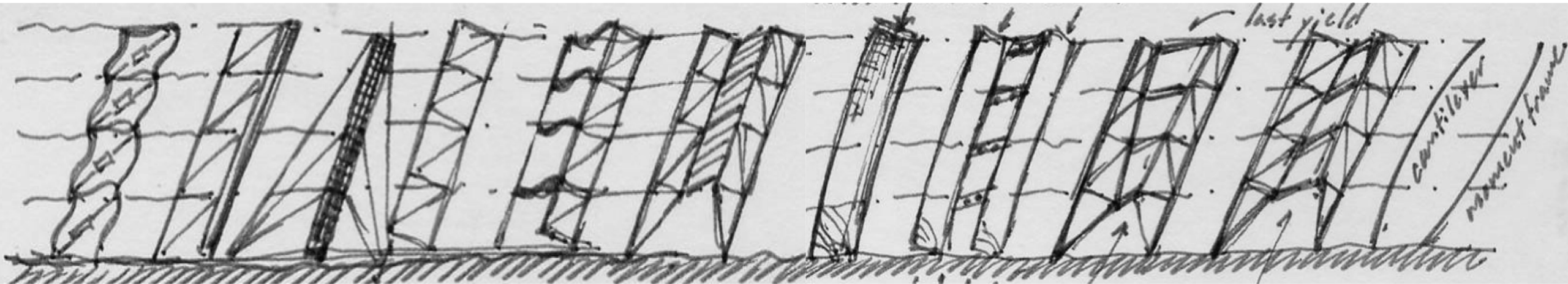
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***Thank you***

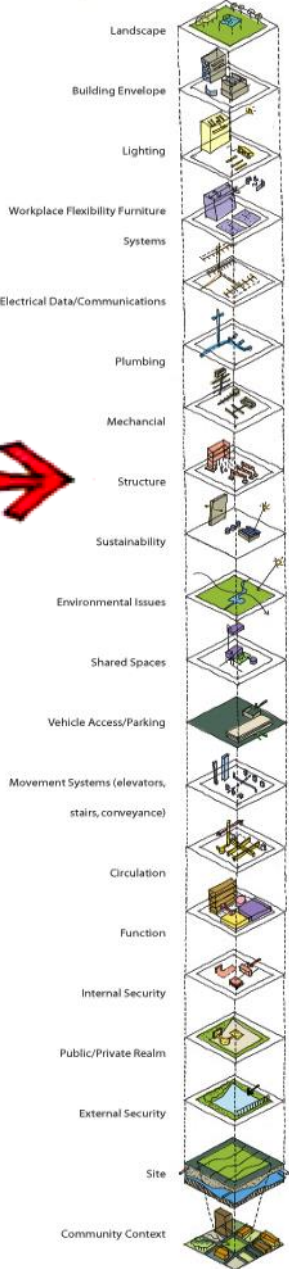
ayse@atcouncil.org

[www.ATCouncil.org](http://www.ATCouncil.org)

# Choose Resilience



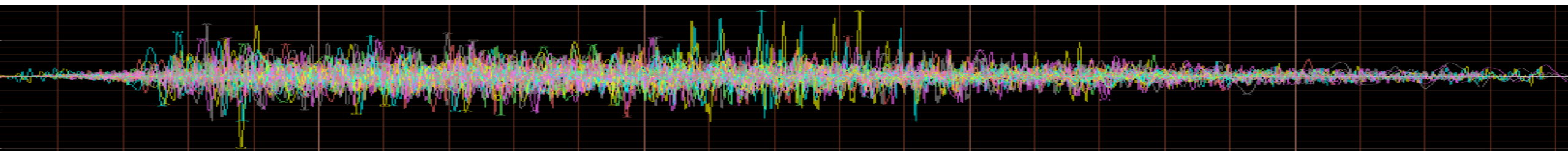
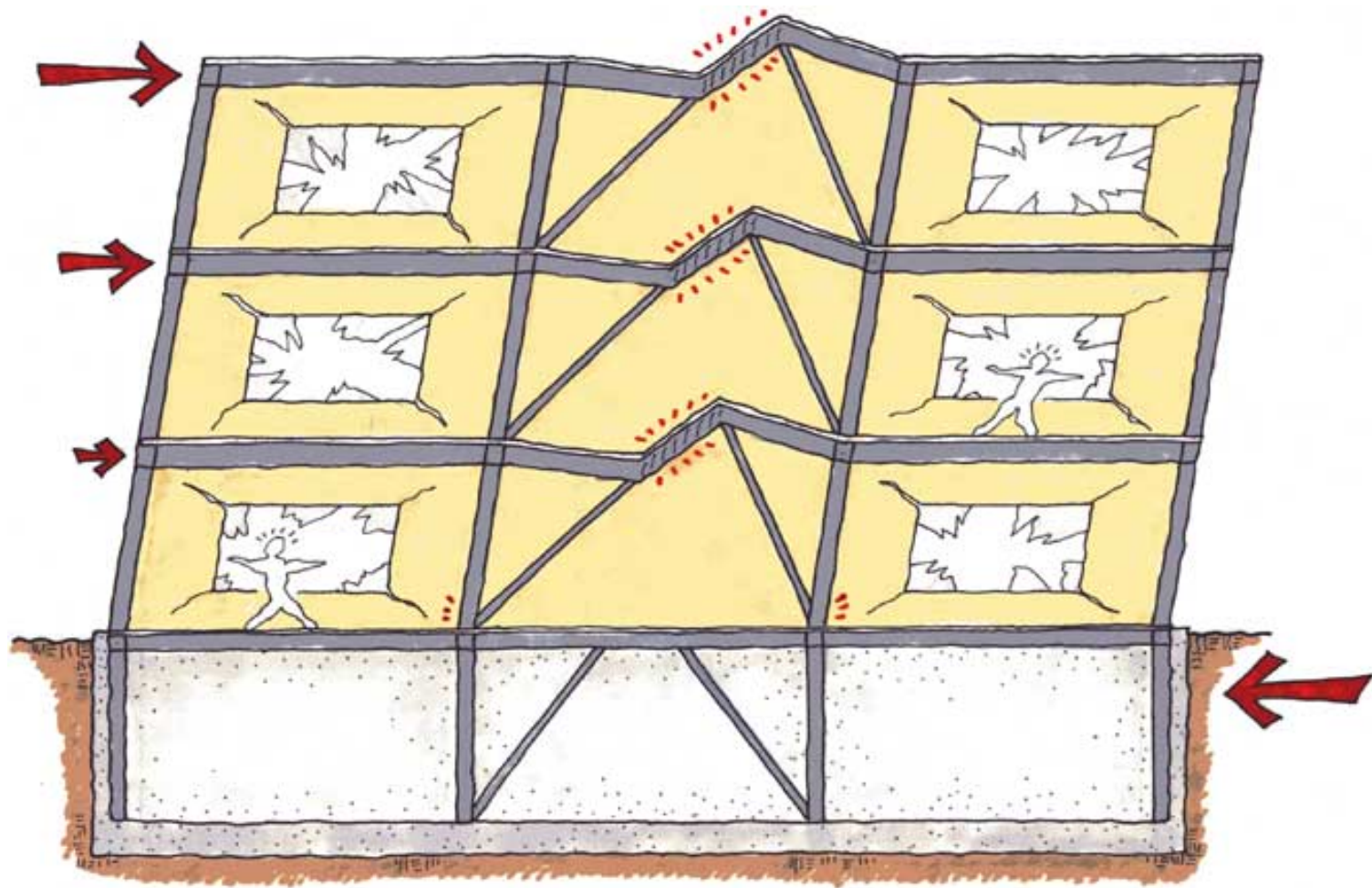
Structure



**Structure** →  
25% of building value

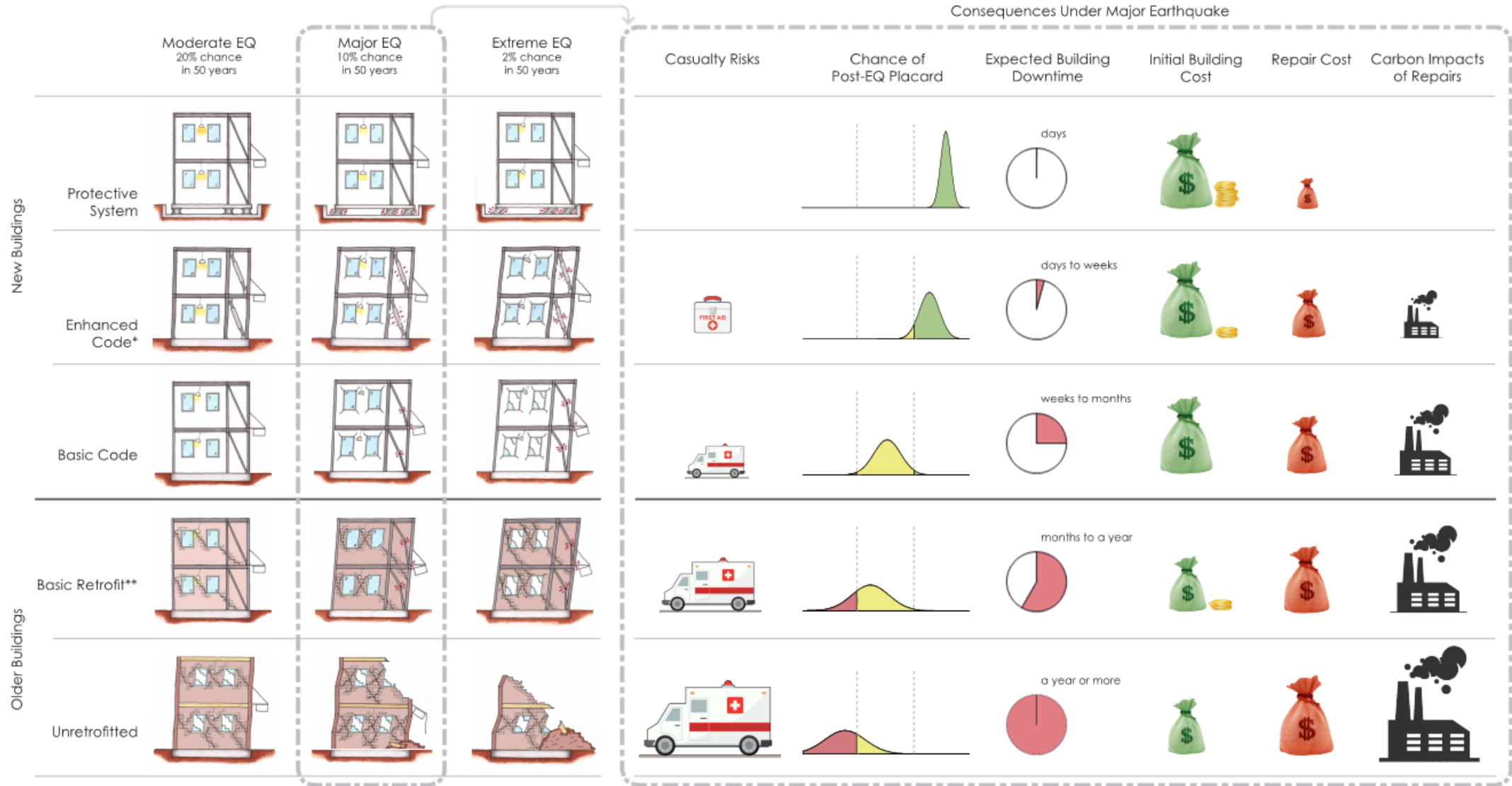


75% of building value



# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

Design Decisions Have Measurable Consequences

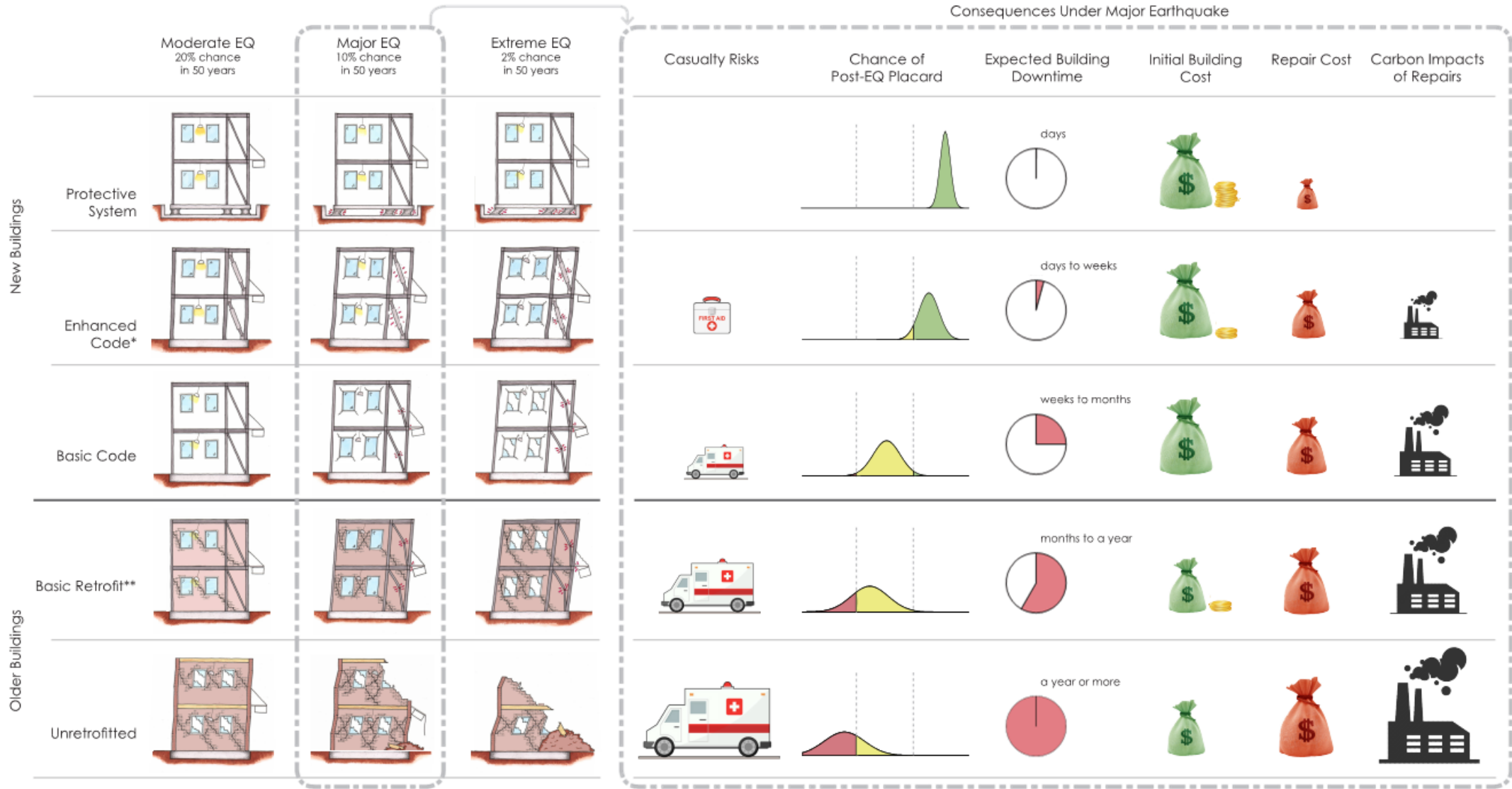




# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

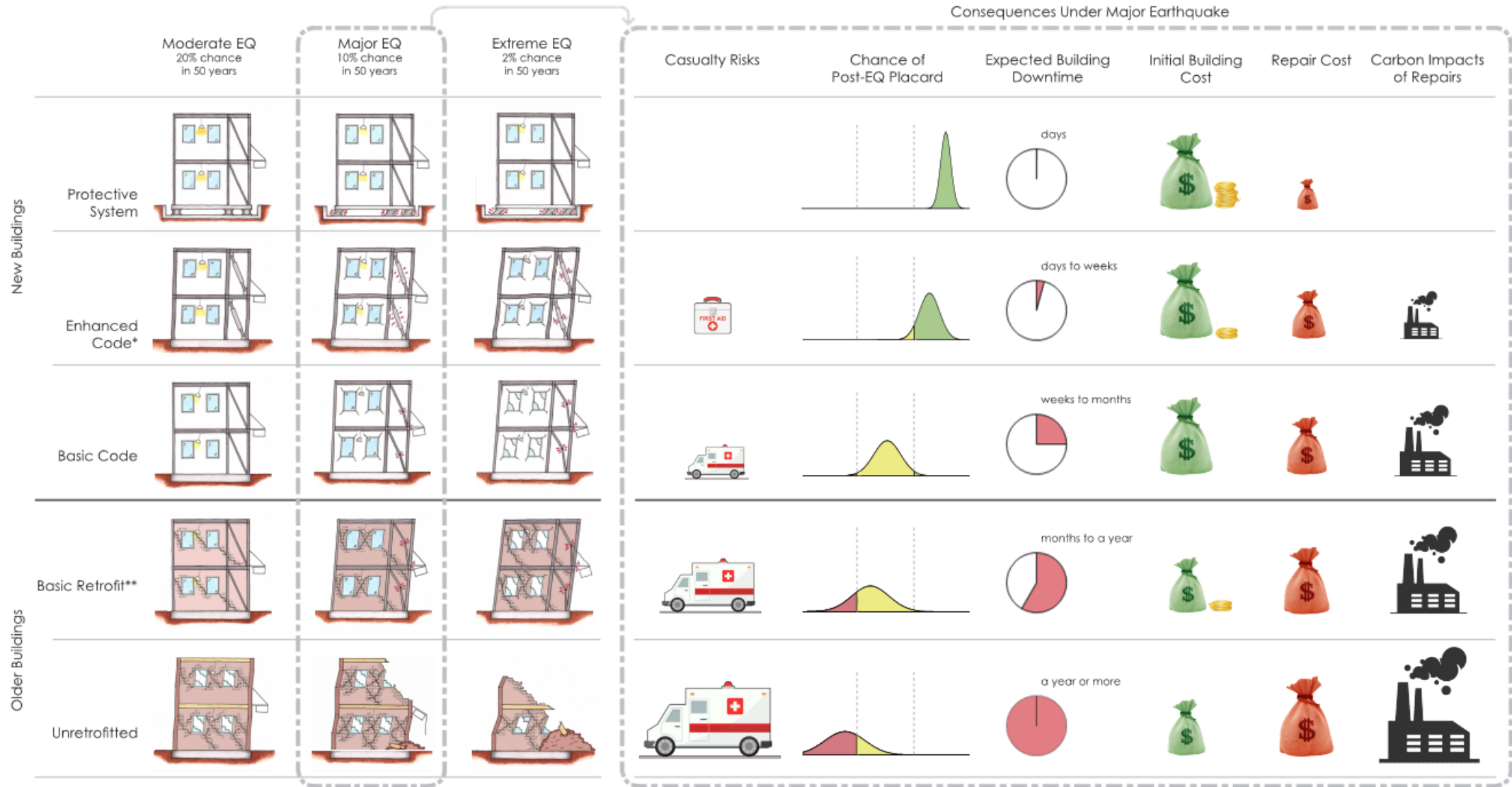
Design Decisions Have Measurable Consequences

Better Performance



# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

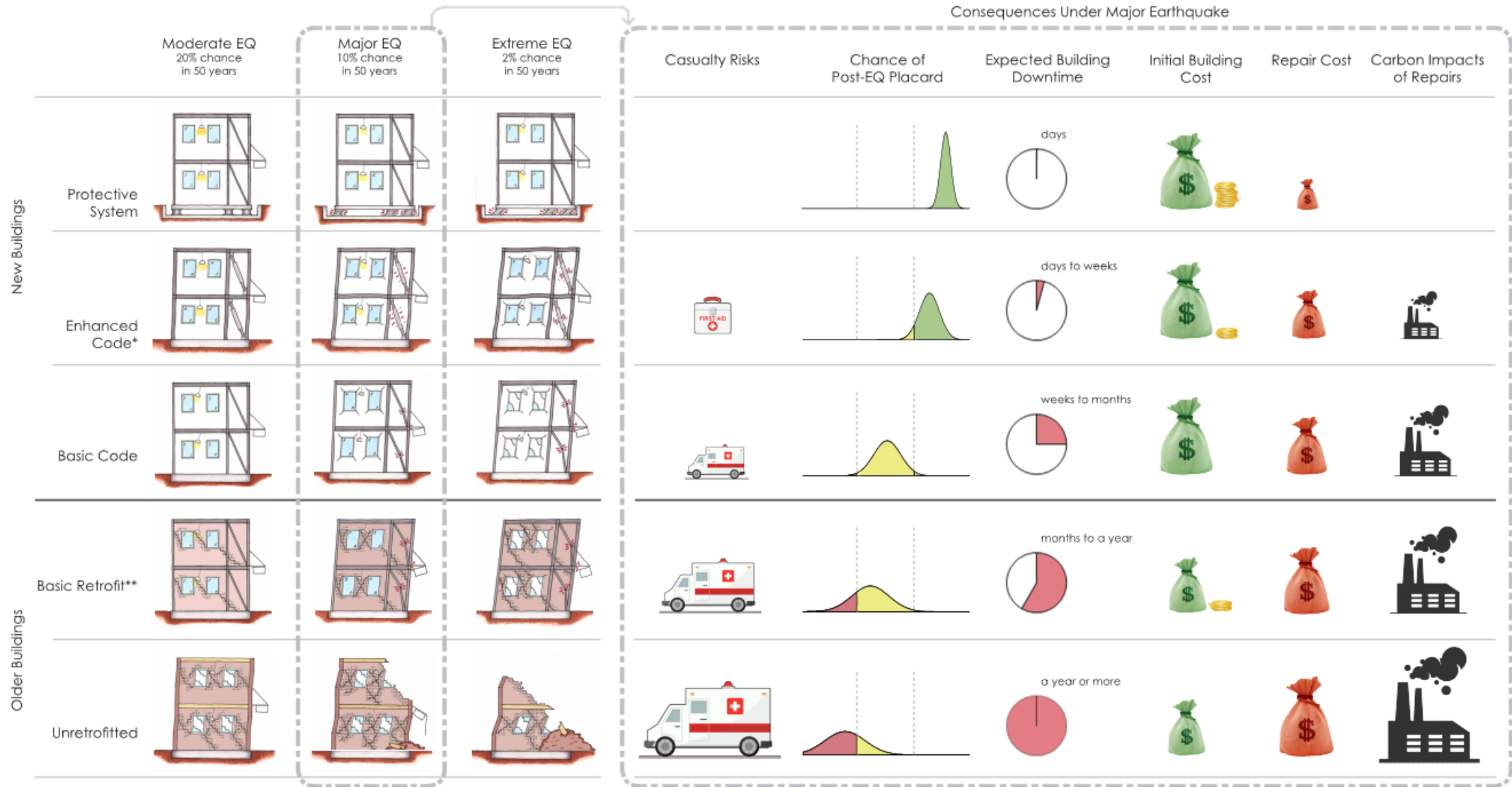
Design Decisions Have Measurable Consequences



Bigger EQs

# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

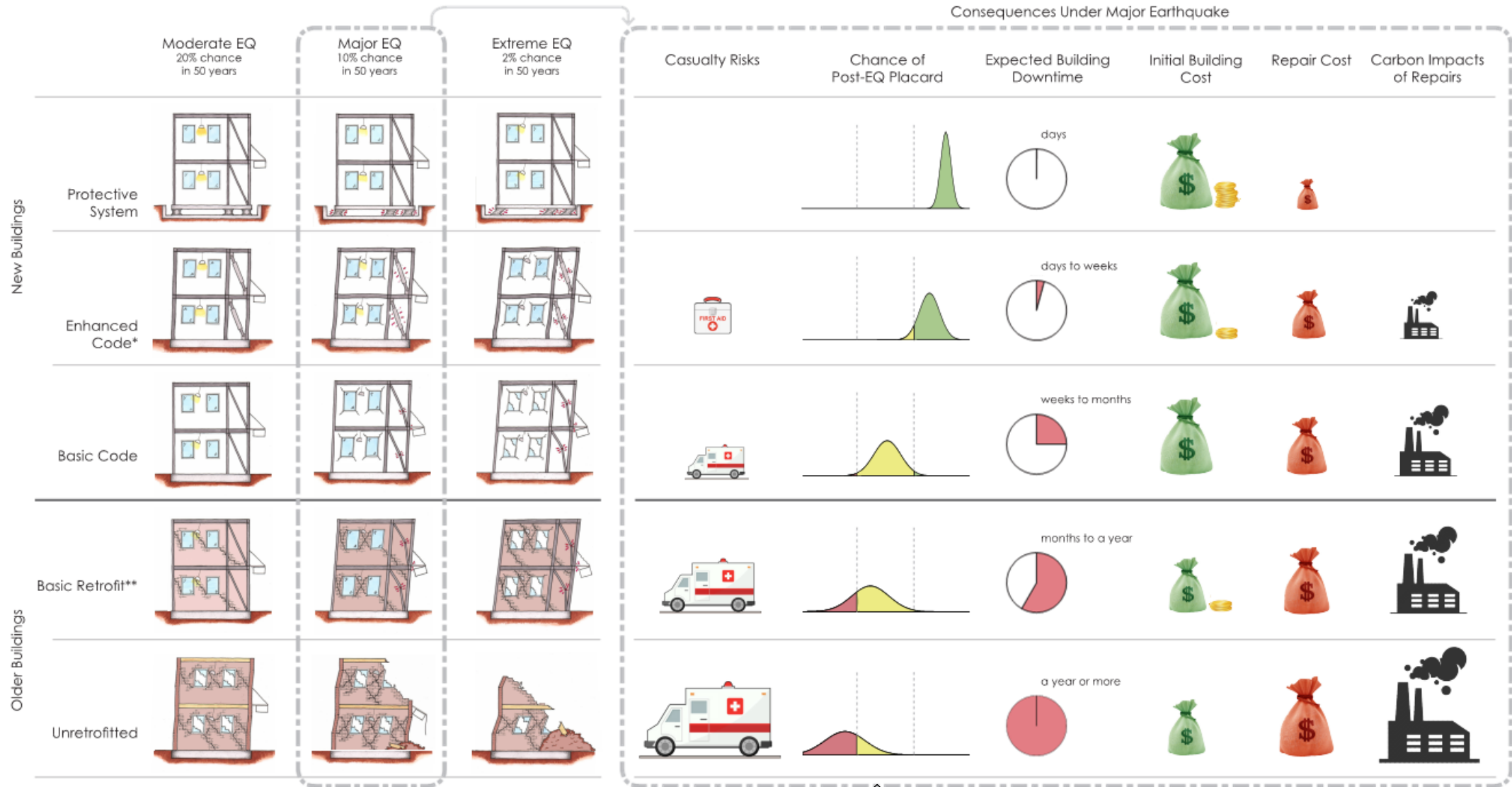
Design Decisions Have Measurable Consequences



safety

# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

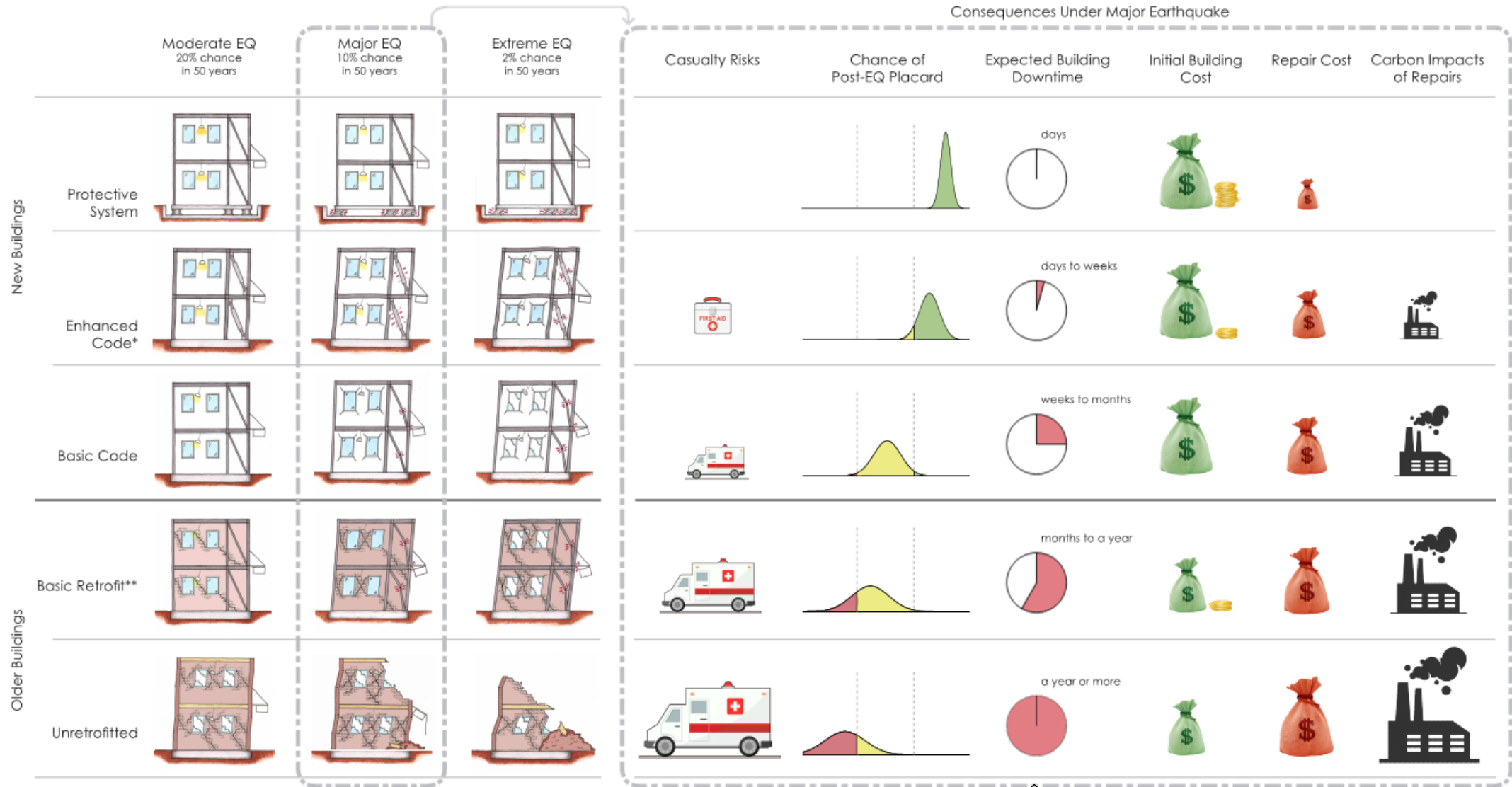
Design Decisions Have Measurable Consequences



↑  
access

# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

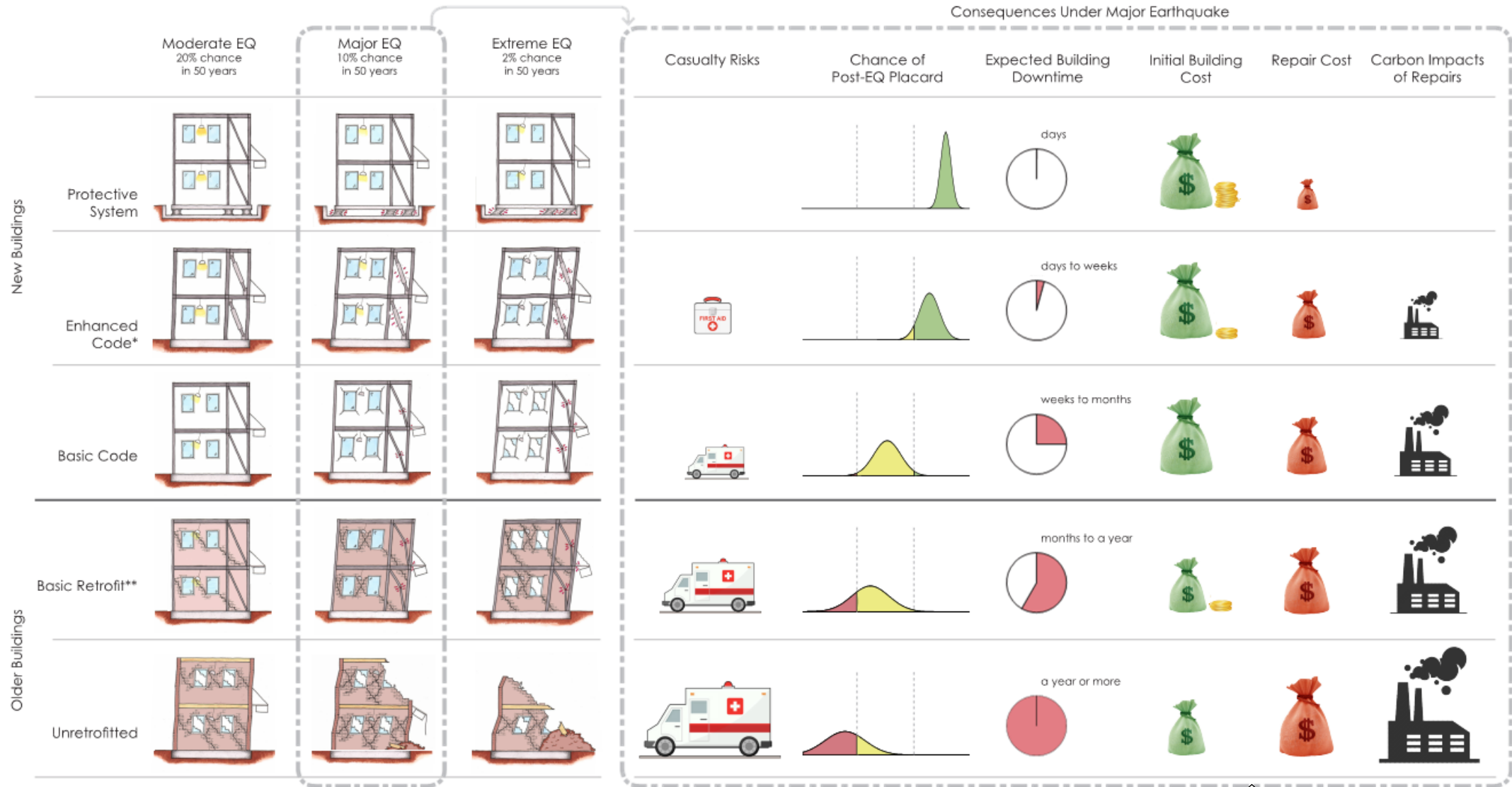
Design Decisions Have Measurable Consequences



downtime

# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

Design Decisions Have Measurable Consequences

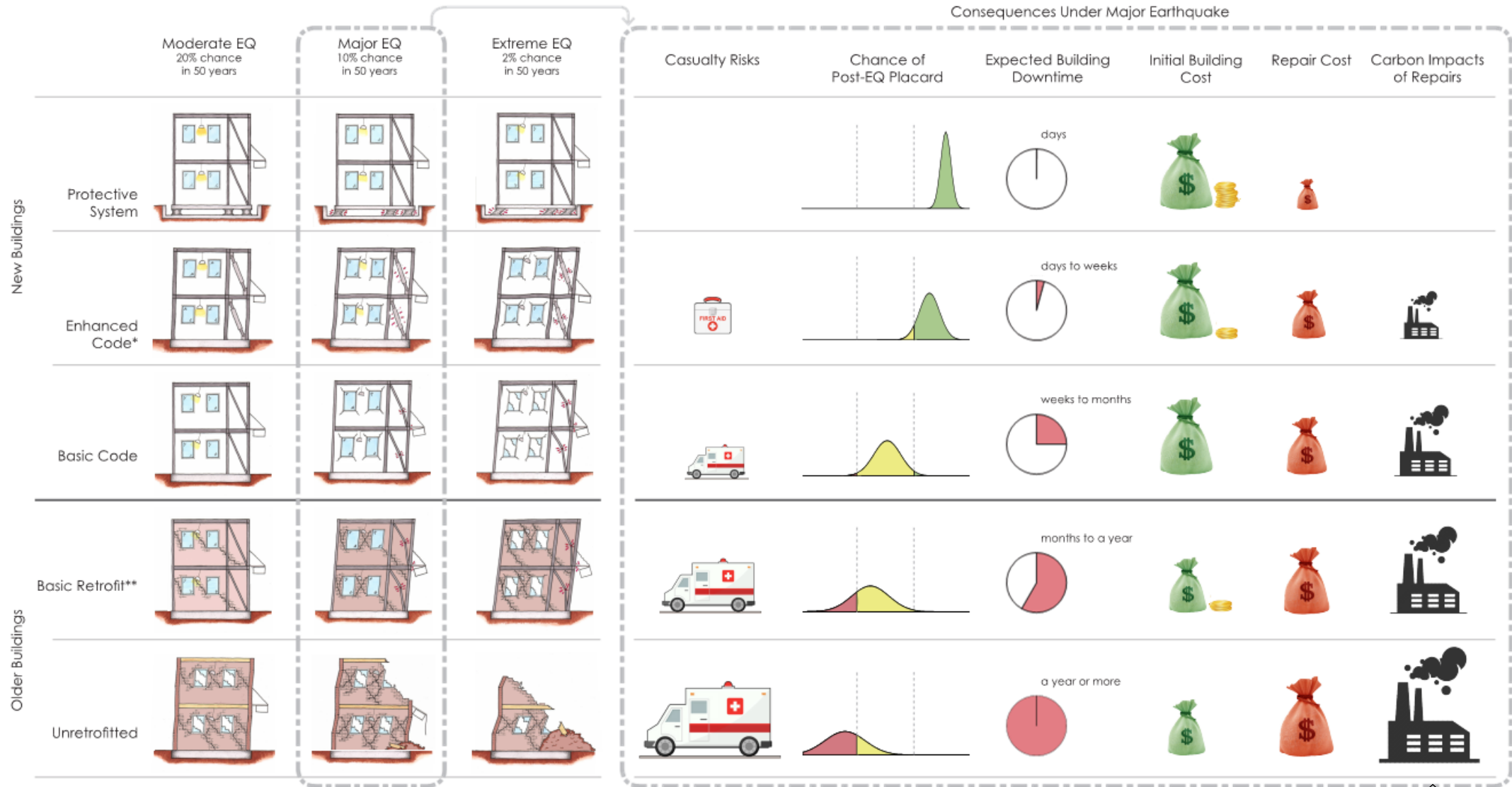


costs



# OPTIONS FOR EARTHQUAKE RESISTANT DESIGN

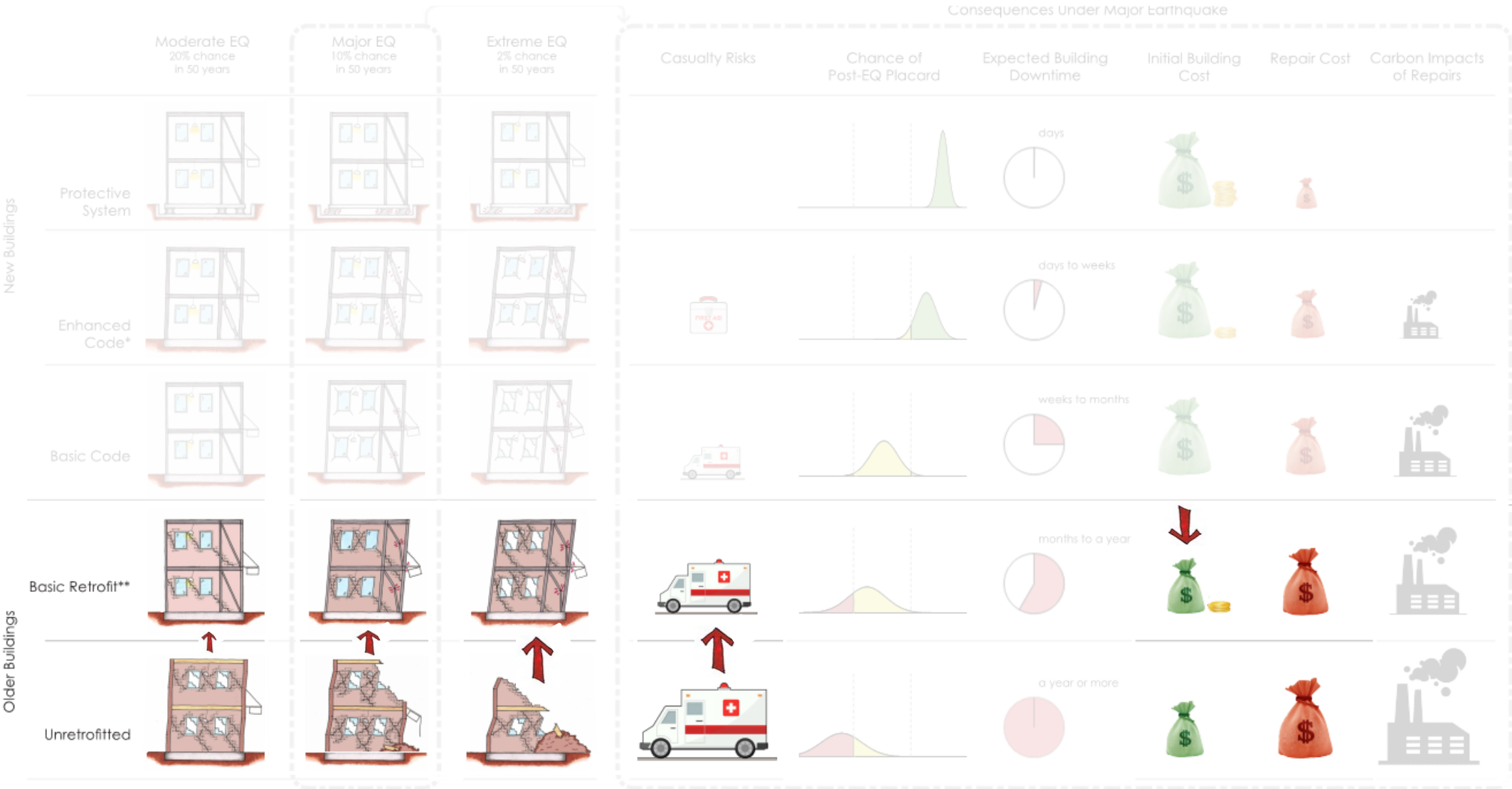
Design Decisions Have Measurable Consequences



CO<sub>2</sub>impact



# Retrofits Focus on Safety and Cost





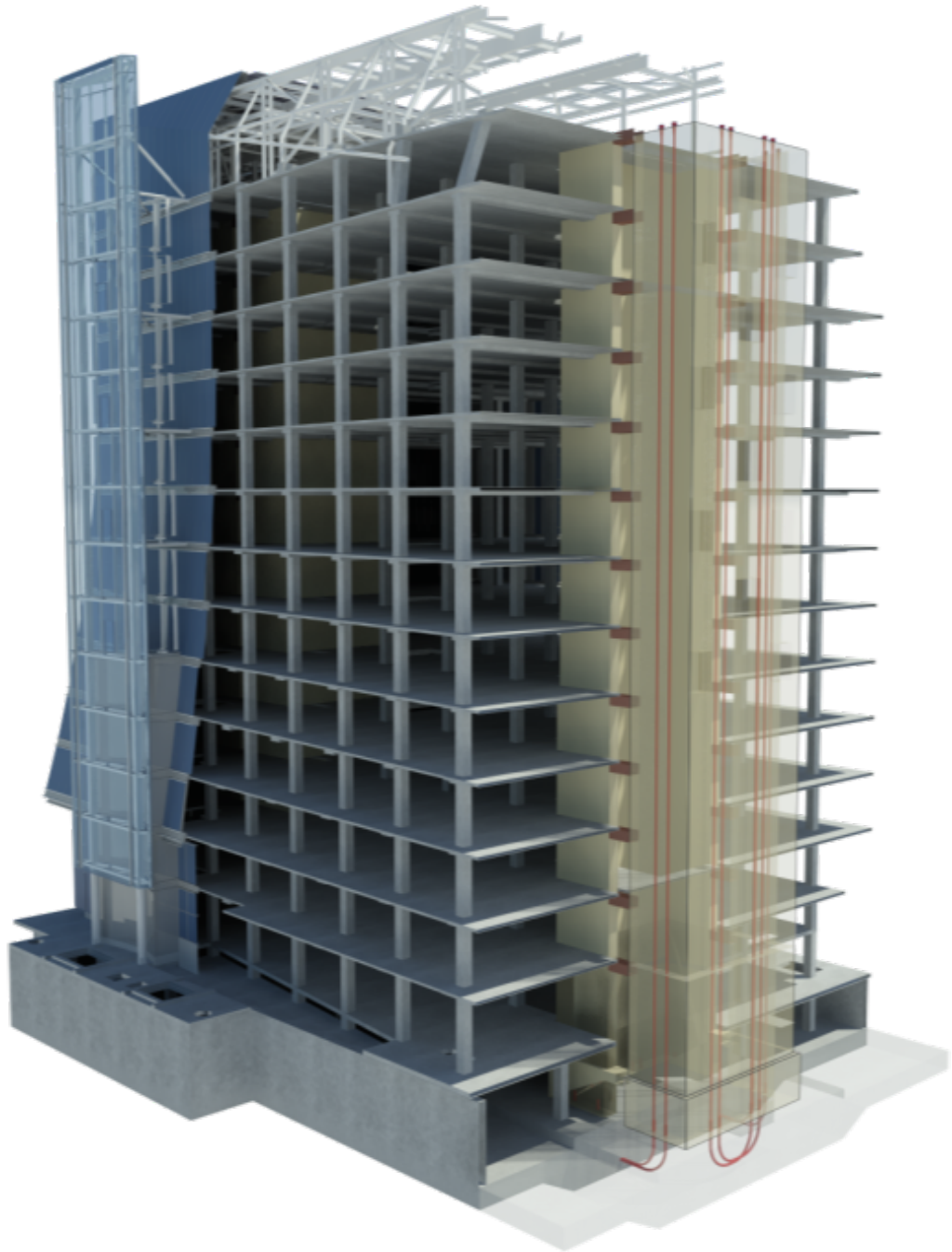
# Examples

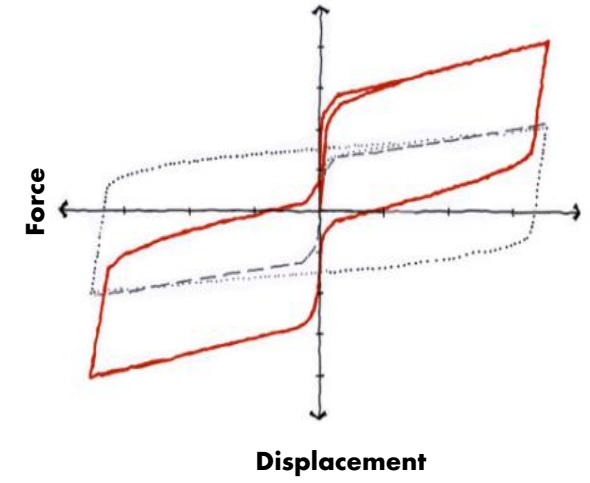
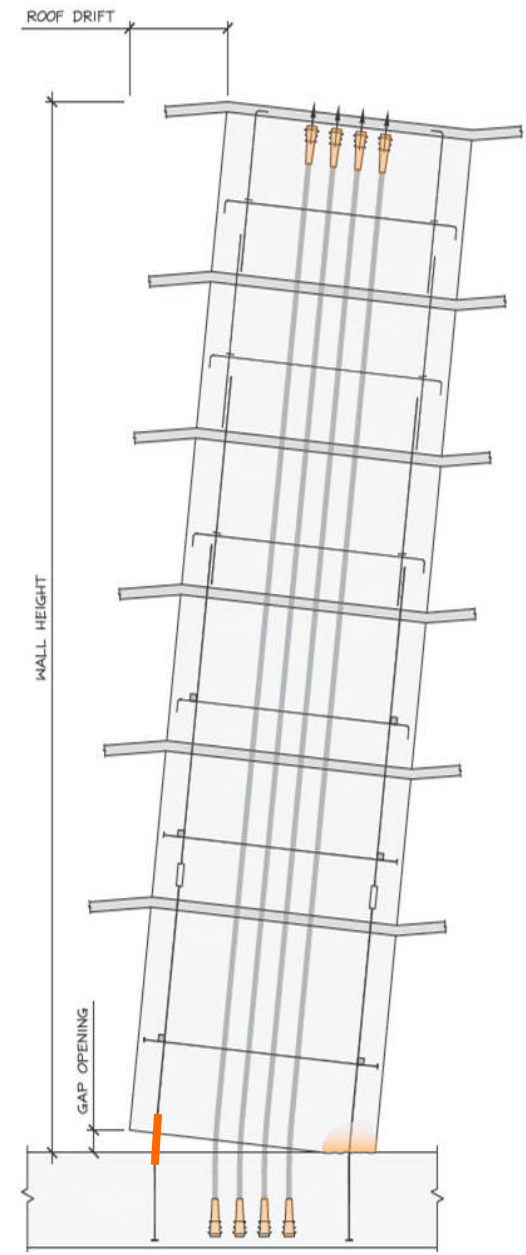
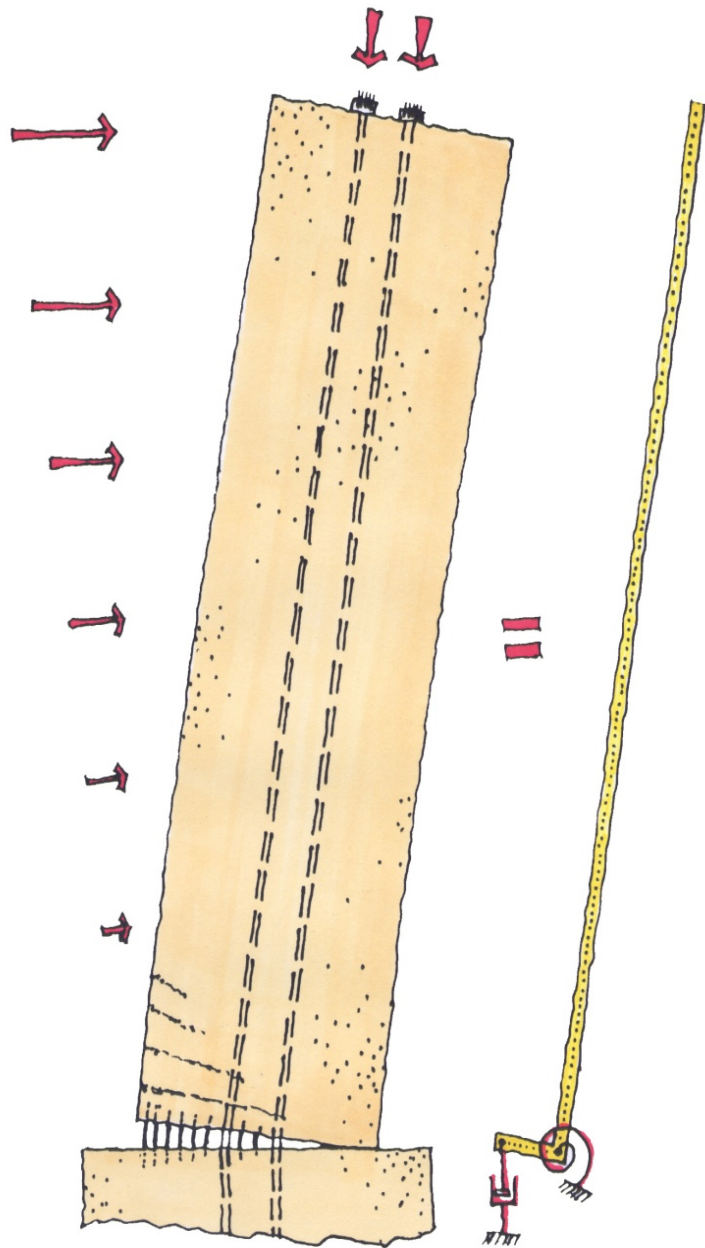
## SF Public Utilities Headquarters

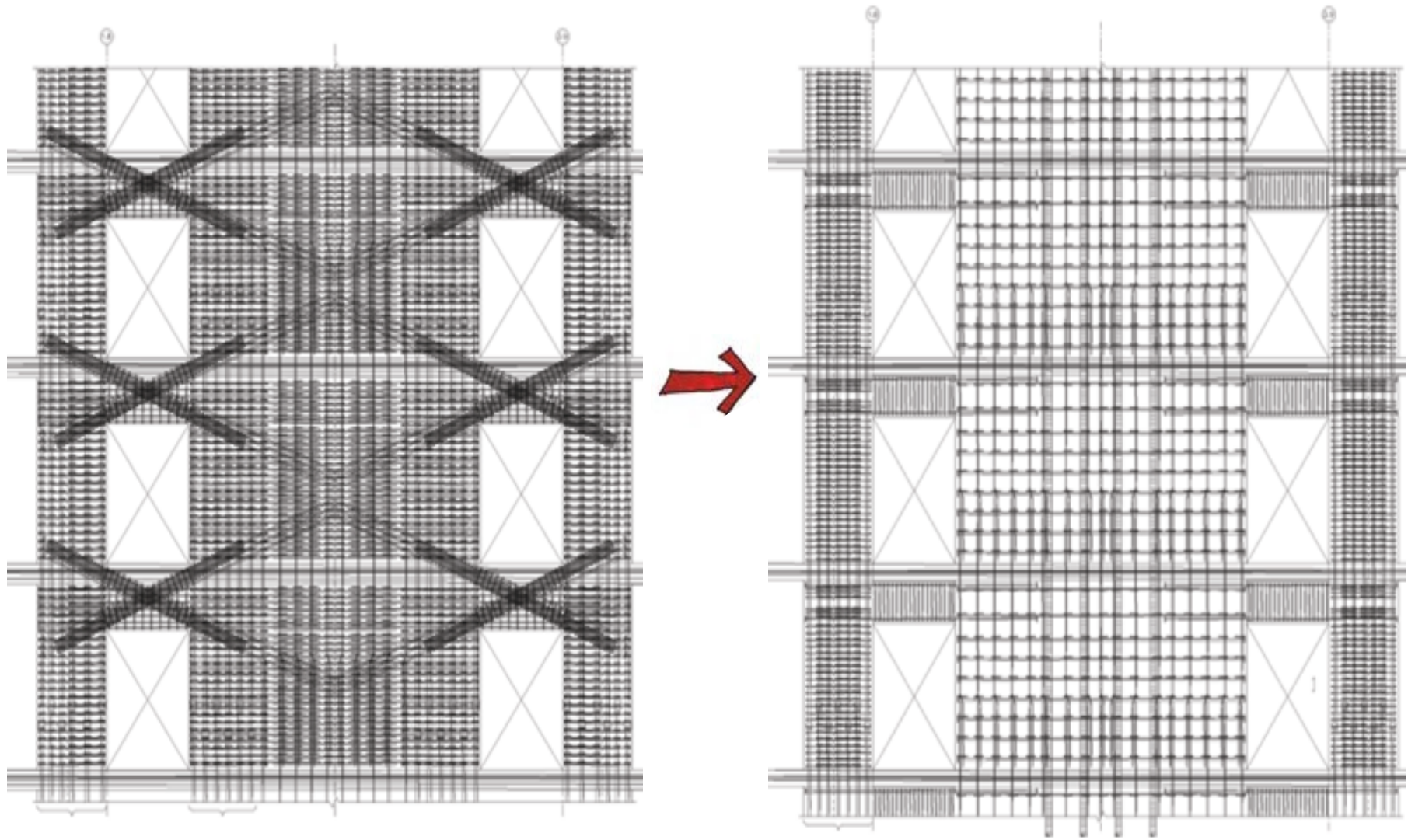


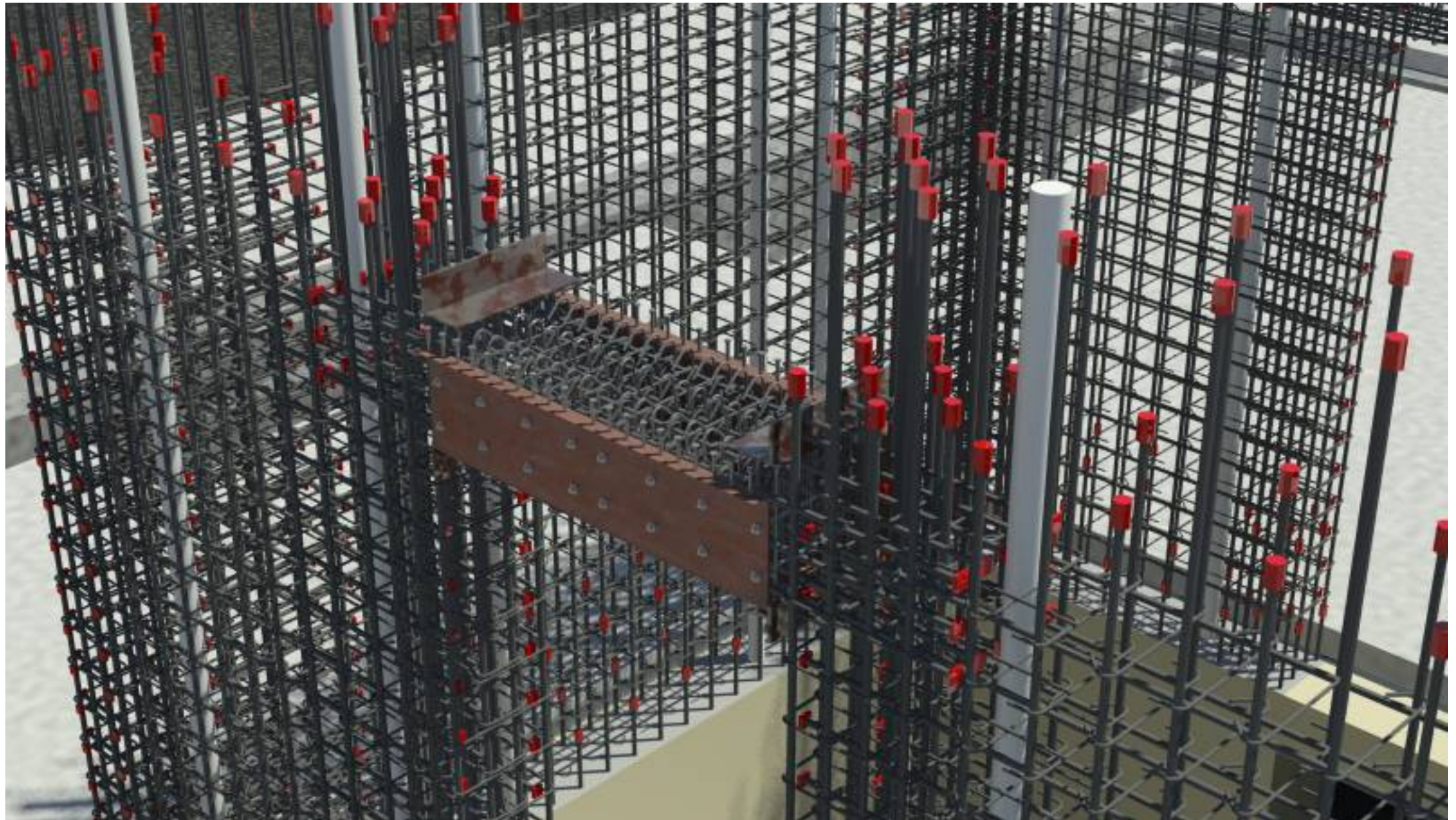
*Architect: KMD/Stevens*











# Casa Adelante



Architect: HCL

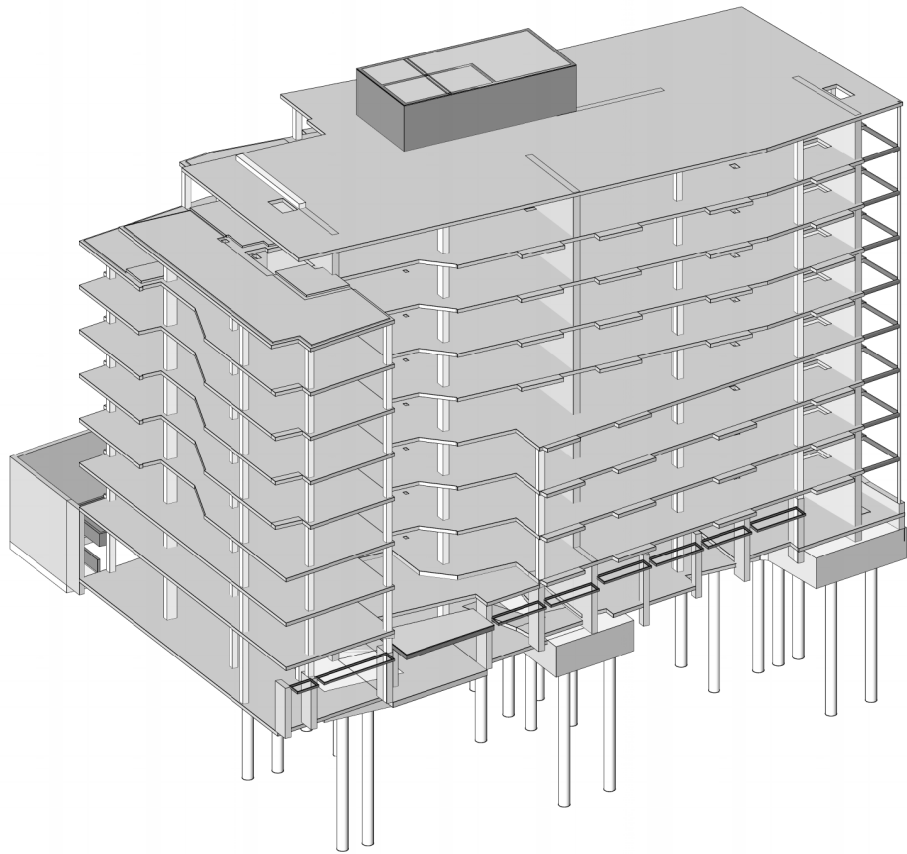


**100% Affordable Senior Housing**

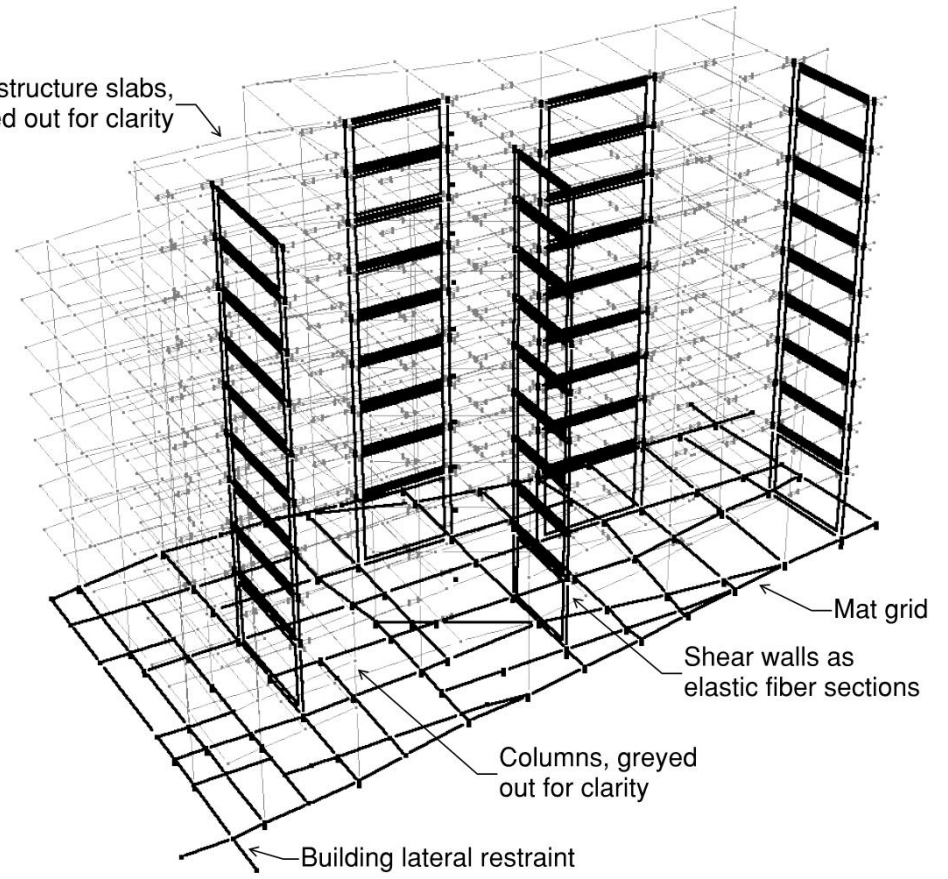
**20% of Units for Formerly Homeless**

**No Money for Improved Performance**

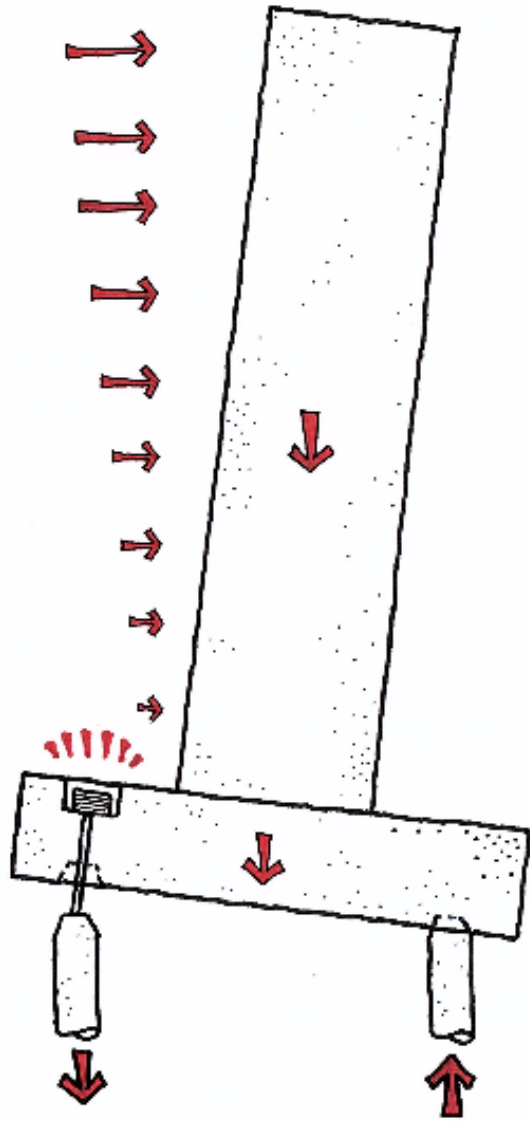




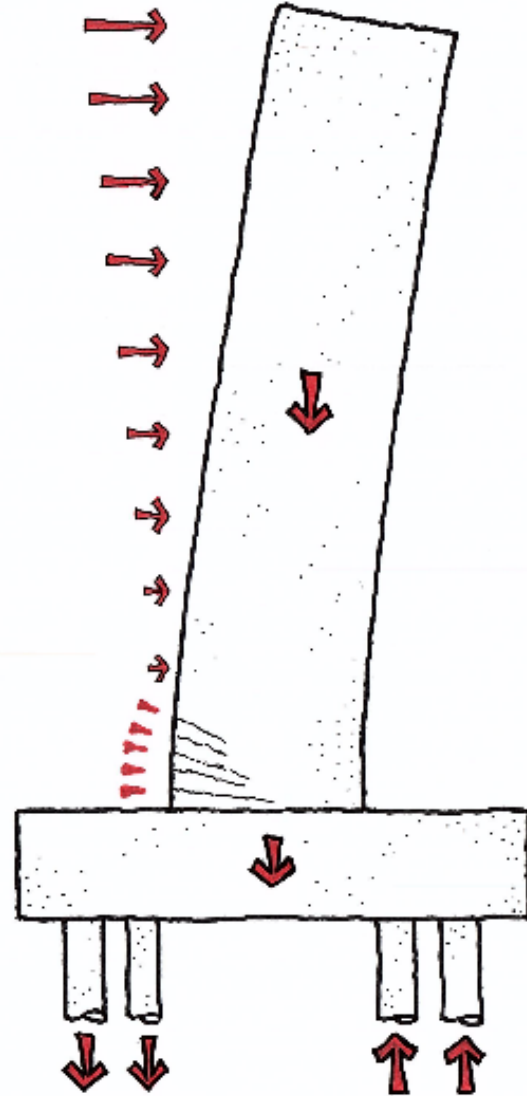
Superstructure slabs,  
greyed out for clarity

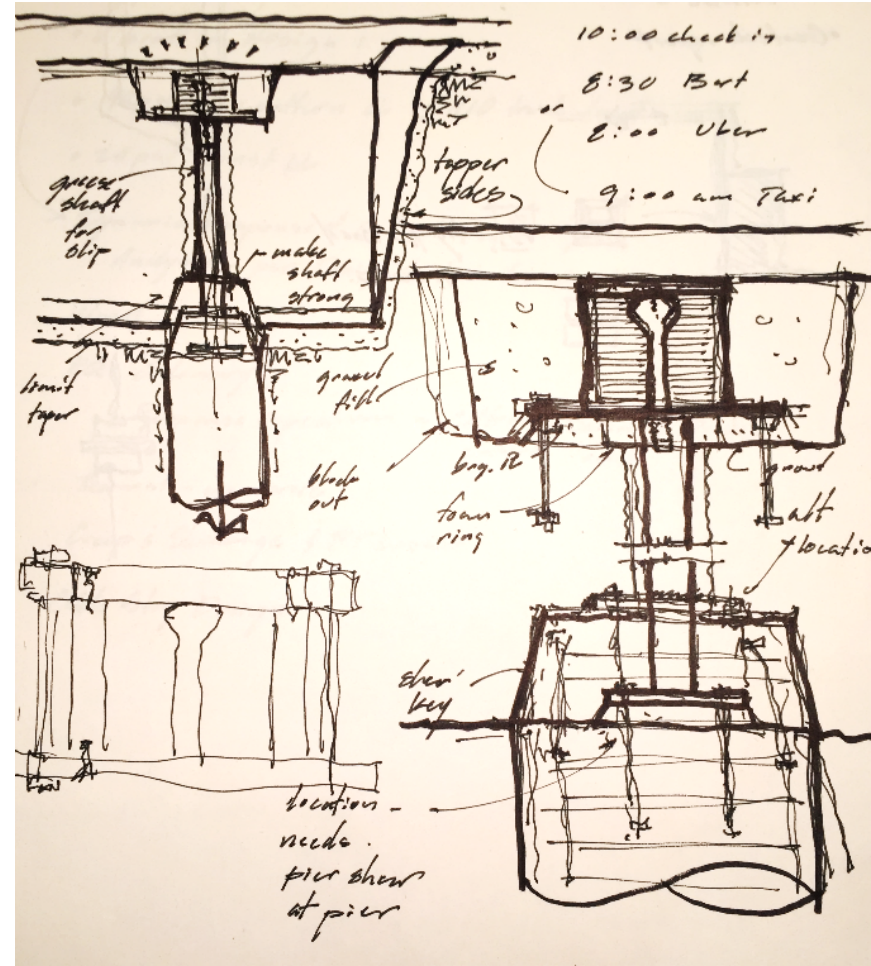
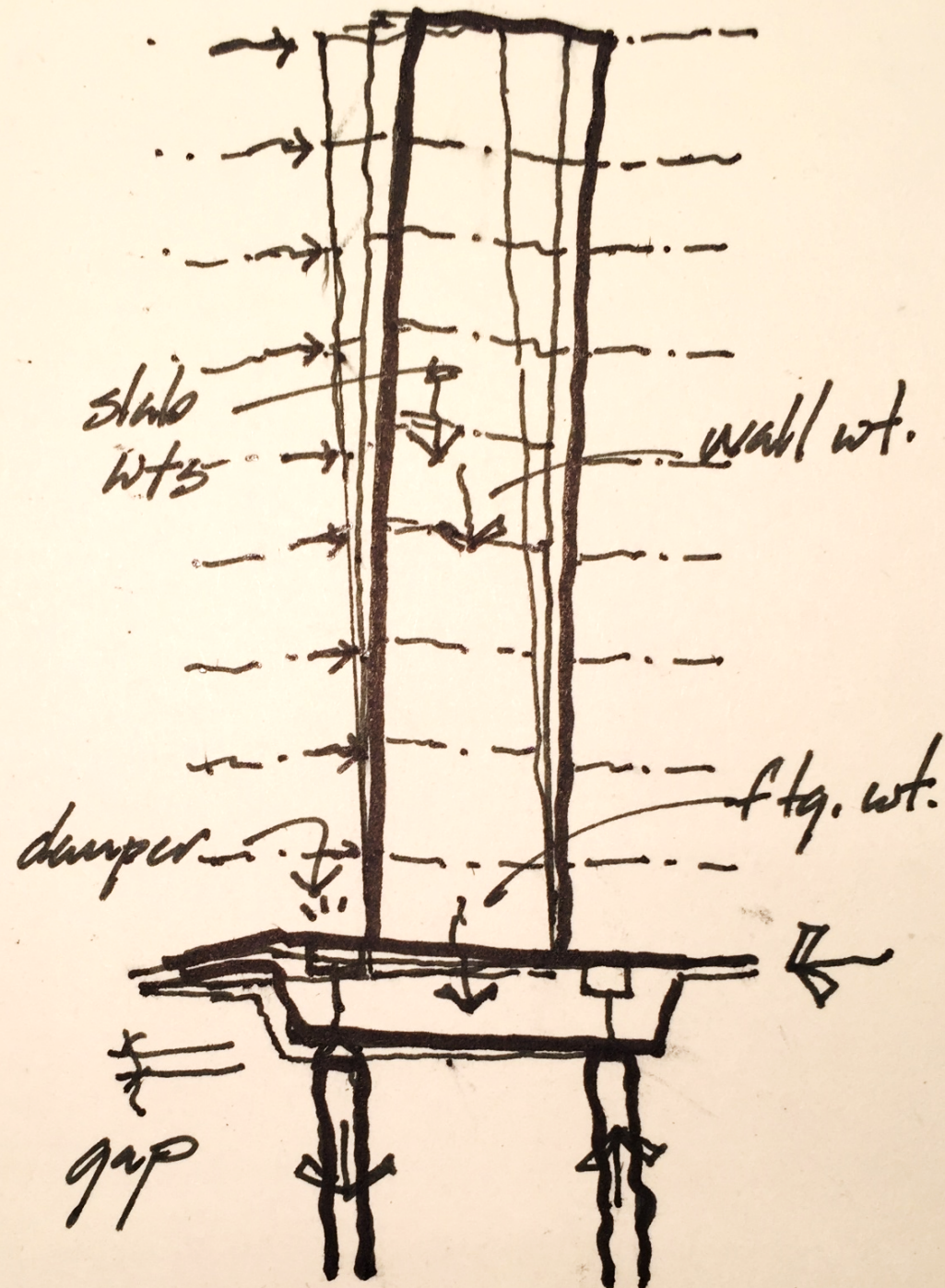


Performance Based Design



Conventional Design

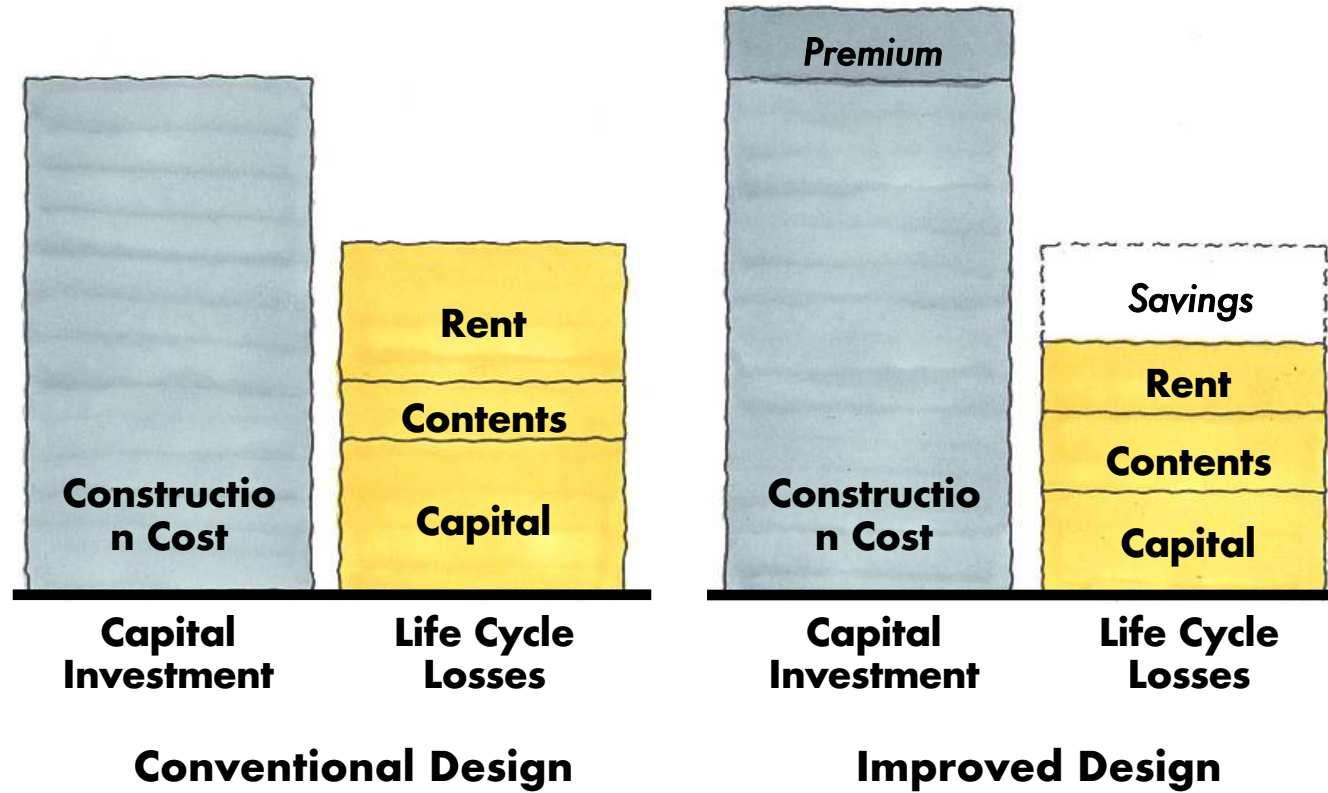








# Life Cycle Analysis

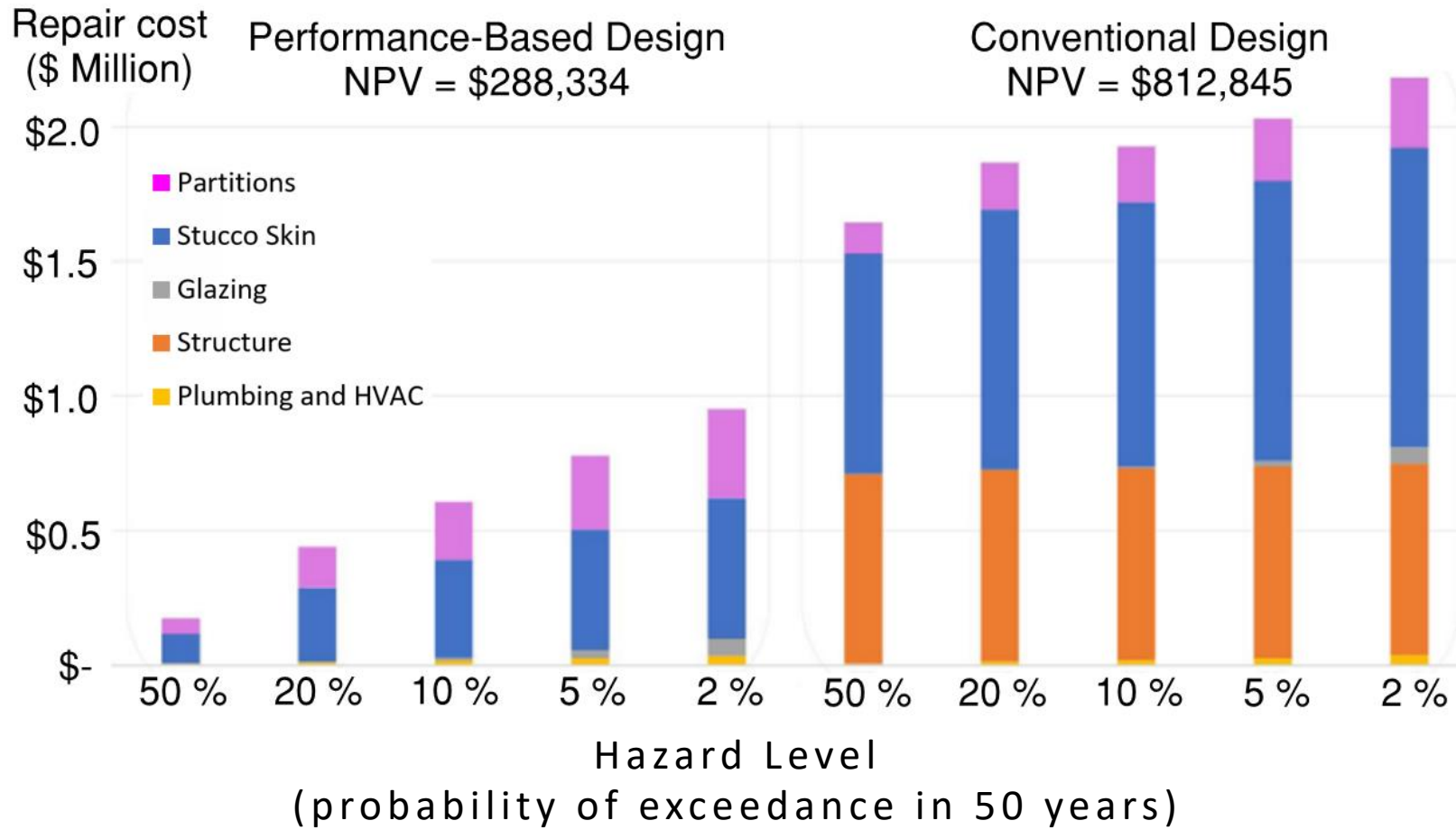


**\$42M Project Cost**

**Cost Delta**

**\$100K for Resilience – 0.24%**







# Choose Resilience

