Resilient Design for Functional Recovery

Expected Functional Recovery Performance of Current ASCE 7 Code-Minimum Buildings, and Specific Needs for Resilience-Based Design

Work by: Ed Almeter, Laxman Dahal,
D. Jared DeBock, Curt Haselton, Abbie Liel
(and Dustin Cook via NIST collaboration)
(benchmark/workshop results reviewed by ATC-138 team)

Presented by: D. Jared DeBock, PhD, PE,
and Curt B. Haselton, PhD, PE

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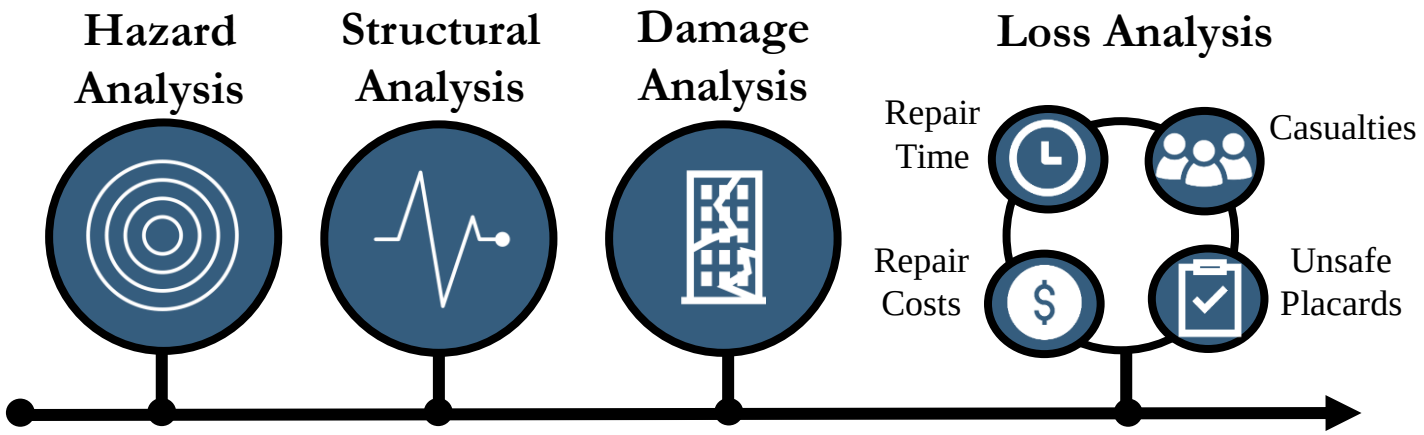
FEMA P-58 and New Functional Recovery Module



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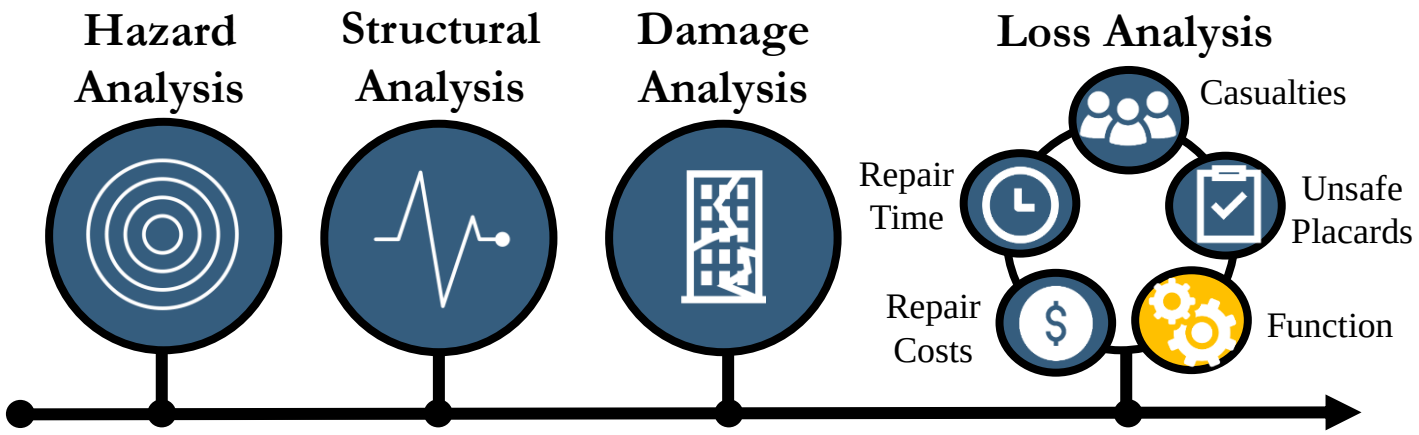

The FEMA P-58 Functional Recovery Module extensions now assesses:

(a) Reoccupancy time, and

(b) Functional Recovery time.

We now want to use this new Functional Recovery Module to (a) assess performance of ASCE 7 code-minimum designs, and (b) determine what is needed for resilient design (for buildings to quickly regain function).

Overview and Outline

Part 1: Expected FR Performance for New ASCE 7 Code-Minimum Buildings [DeBock]

- Building/site text matrix (592 buildings shown here)
- Functional recovery time results for modern buildings
  - ✓ Individual building examples
  - ✓ Results for all buildings (average and variability)
  - ✓ “Common offenders” (which building systems/components are damaged)
- Sensitivity assessments:
  - ✓ Methodology components (e.g. if we include impeding times)
  - ✓ Design aspects (e.g. RC II vs. RC IV)
- Summary/discussion

Part 2: Needs for Resilience-Based Design and Example [Haselton]

- Overall design needs/requirements for resilient design
- Example resilient design with RC II, RC IV, and resilience

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Building Test Matrix: Building Types

Structural System	Age	Occupancy	Risk Category	Stories
Wood Light Frame	New	Residential	II	1, 2
Wood Light Frame	New	Residential	II, IV	5
Wood Light Frame	New	Office	II, IV	5
Precast Concrete Tilt-Up	New	Warehouse	II, IV	1
Precast Concrete Tilt-Up	Pre-NR	Warehouse	II, IV	1
Steel Perimeter Moment Frame	New	Office, Healthcare	II, IV	3, 5, 12, 20
Steel Perimeter Moment Frame	Pre-NR	Office	II, IV	5, 12
Steel BRBF, no back-up frame	New	Office	II, IV	5, 12
Steel BRBF, with back-up frame	New	Office	II, IV	5, 12
Steel Concentric Braced Frame	New	Office	II, IV	5, 12
Reinforced Concrete Moment Frame	New	Office, Residential	II, IV	5, 12
Reinforced Concrete Moment Frame	Pre-1971	Office	II	5, 12
RC Shear Wall (coupled in one direction)	New	Office, Healthcare	II, IV	3, 5, 12, 20
RC Shear Wall (coupled in one direction)	New	Residential	II, IV	5
RC Cantilever Shear Wall	Pre-1971	Office	--	5, 12

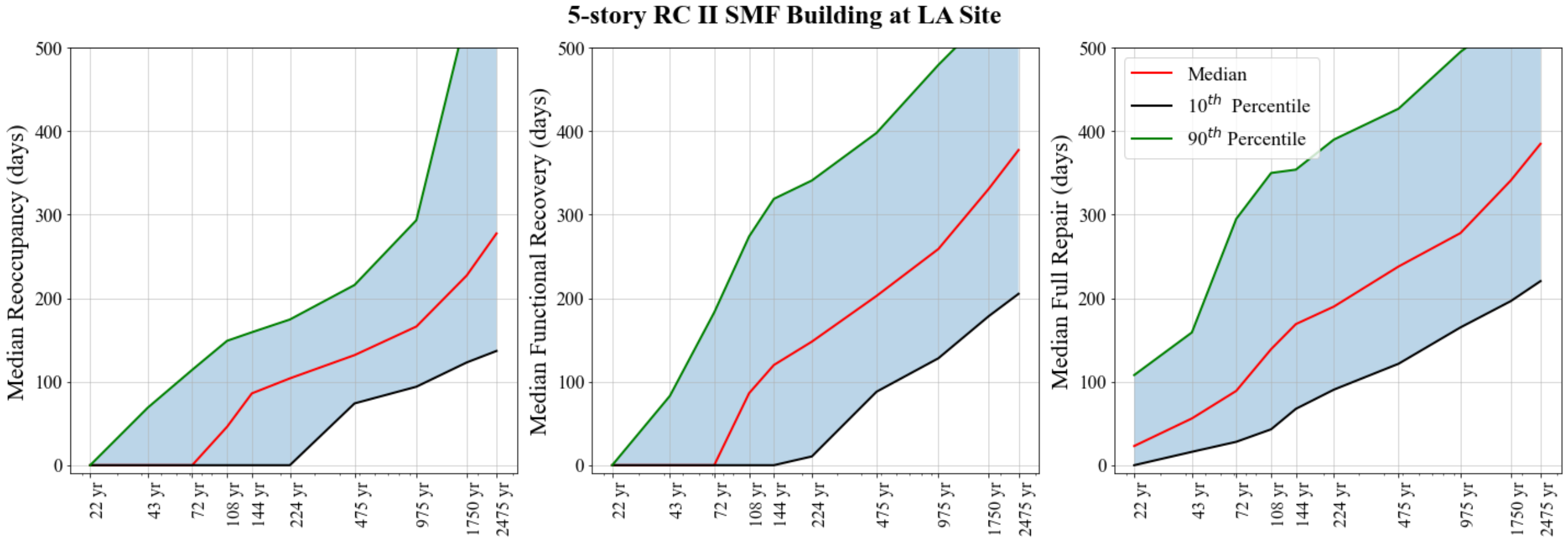
Building Test Matrix: Site Locations

City	State	Site Class	S_S [g]	S_1 [g]	SDC	Lat	Long	FEMA 570 Site ID	Return Period @ DE (years)	Return Period @MCE (years)
Los Angeles	California	D	2.40	0.84	E	34.05	-118.25	1	581	1356
Riverside	California	D	1.50	0.60	D	33.95	-117.40	6	330	839
San Francisco	California	C	1.50	0.64	D	37.75	-122.40	16	415	986
San Diego	California	D	1.25	0.48	D	32.70	-117.15	9	--	
Oakland	California	D	1.86	0.75	D	37.80	-122.25	12	--	
Sacramento	California	D	0.67	0.29	D	38.60	-121.50	15	--	
San Jose	California	D	1.50	0.60	D	37.35	-121.90	18	--	
Seattle	Washington	C	1.37	0.53	D	47.60	-122.30	22	--	
Portland	Oregon	D	0.98	0.42	D	45.50	-122.65	25	--	
Salt Lake City	Utah	D	1.54	0.56	D	40.75	-111.90	26	--	
St. Louis	Missouri	C	0.44	0.17	C	38.60	-90.20	30	--	
Memphis	Tennessee	D	1.01	0.35	D	35.15	-90.05	31	--	
New York	New York	C	0.28	0.07	B	40.75	-74.00	34	--	
Anchorage	Alaska	D	1.50	0.68	D	61.22	-149.90	--	--	
Hilo	Hawaii	C	1.50	0.60	D	19.71	-155.09	--	--	
Average									**442**	**1060**

592 building cases run. Baseline plots are for new RC II buildings at three high seismic sites (LA, Riverside, SF), and variations are noted.

Results for Individual Buildings: New Steel Moment Frame

Take Away: Low times at SLE (just for median), several months at DE, a year at MCE.



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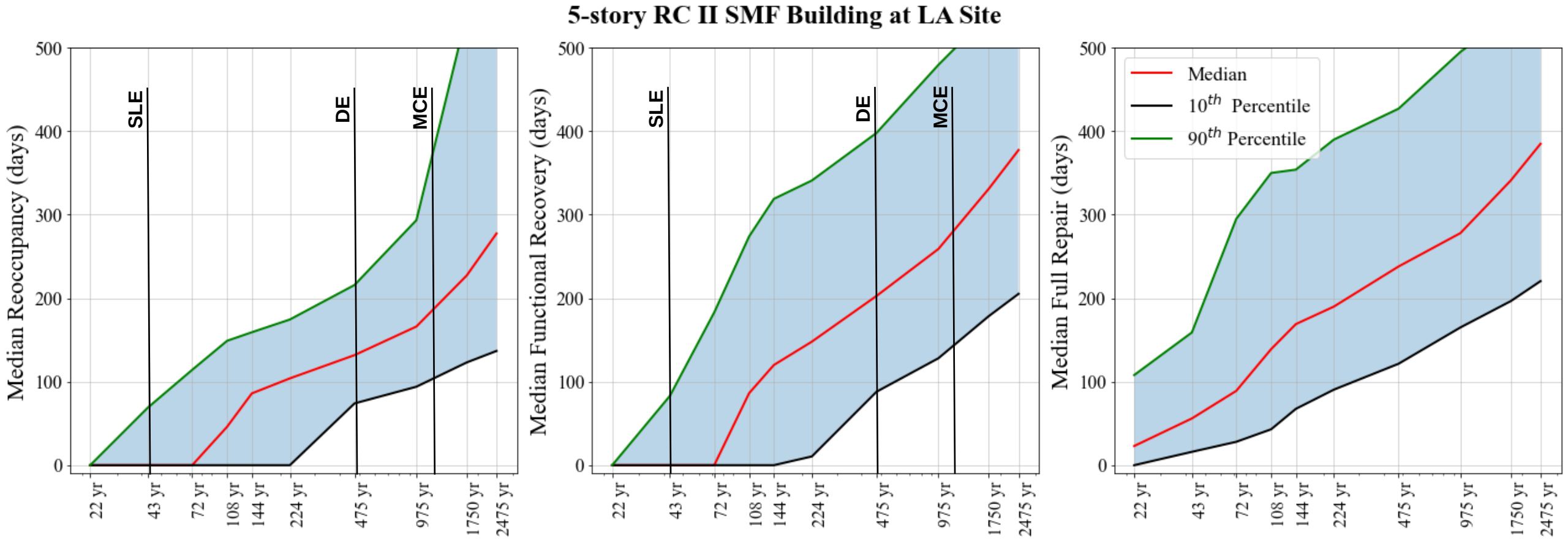

Results for Individual Buildings: New RC Shear Wall

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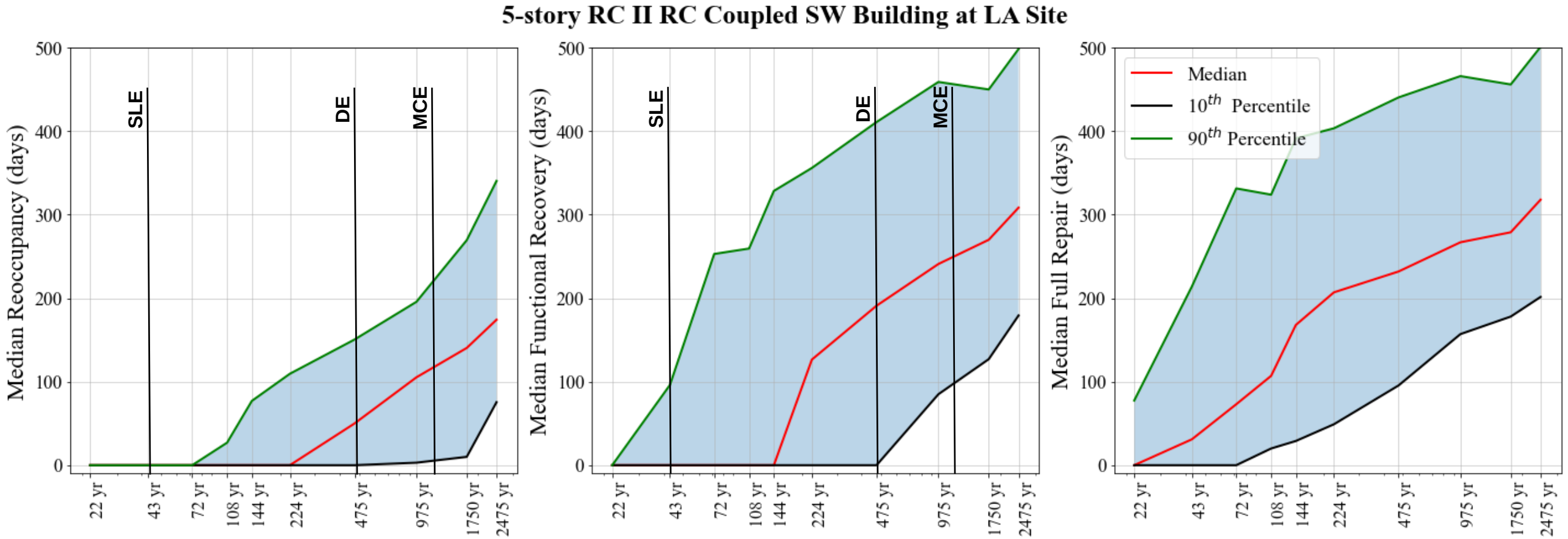
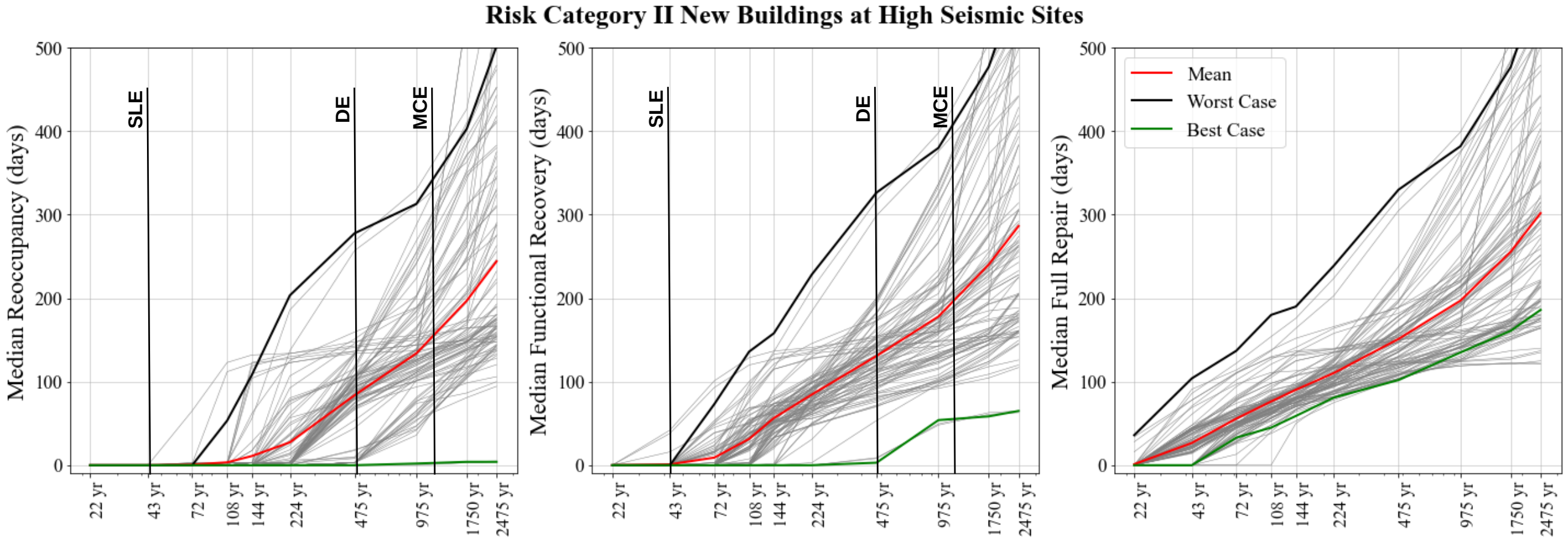


Results for Full Set of Buildings: RC II

Take Away: Lots of spread between buildings (since code doesn't design for function).



Sanity Checks:

- Typical Best Case: 1-Story Residential WLF in LA
- Typical Worst Case: 12-story Office SCBF in Riverside

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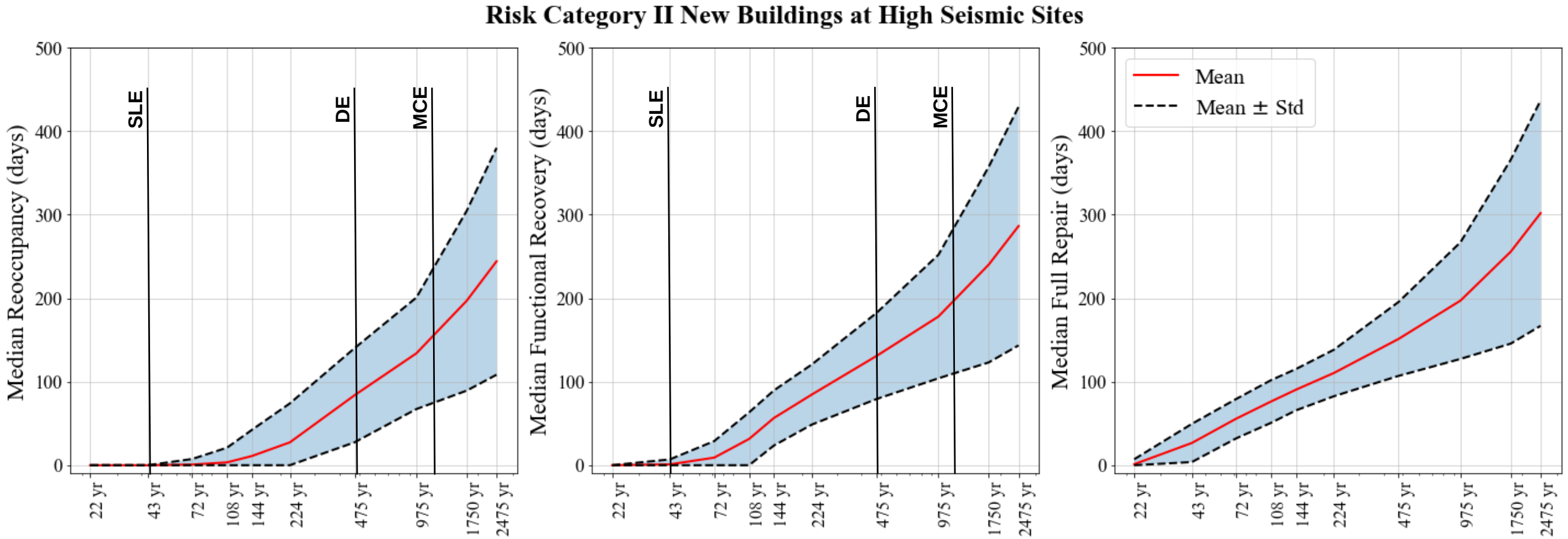
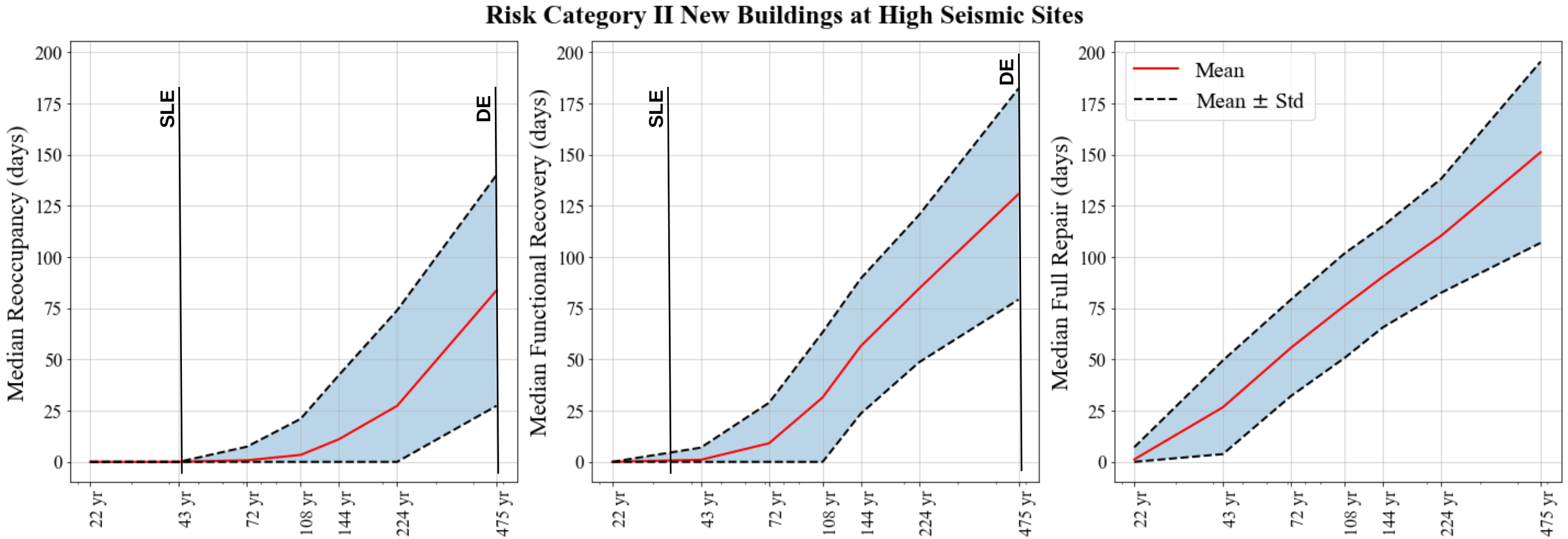


Results for Full Set of Buildings: RC II vs. RC IV



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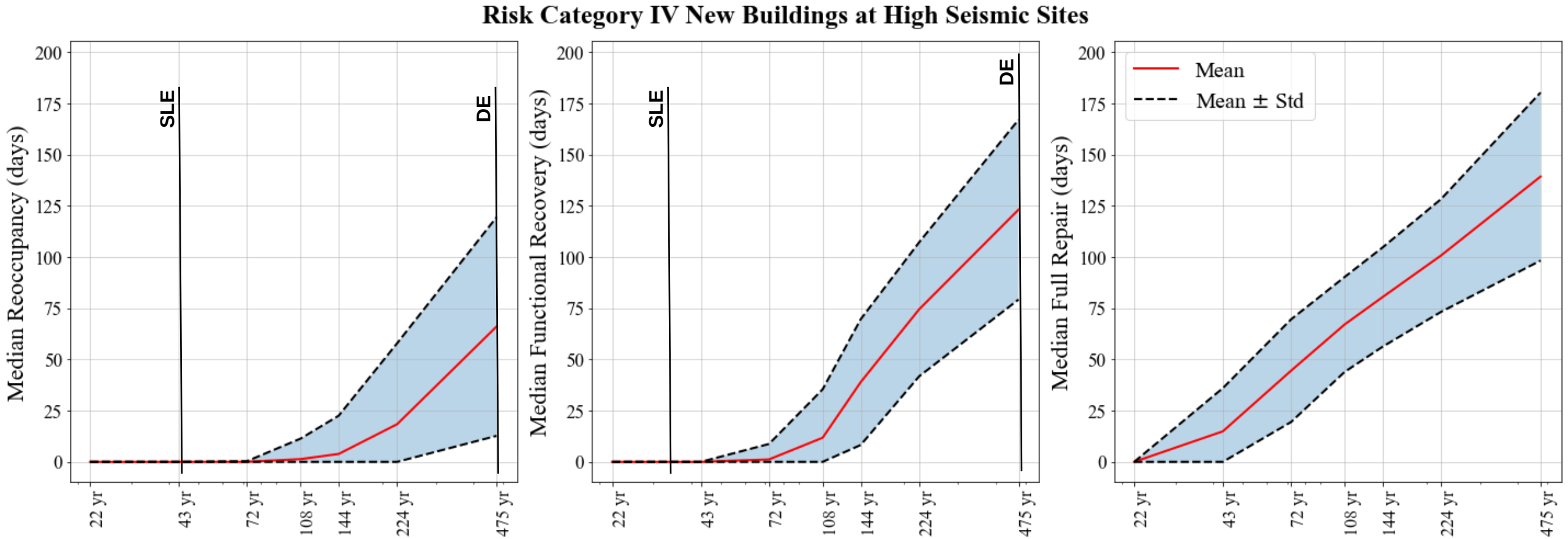
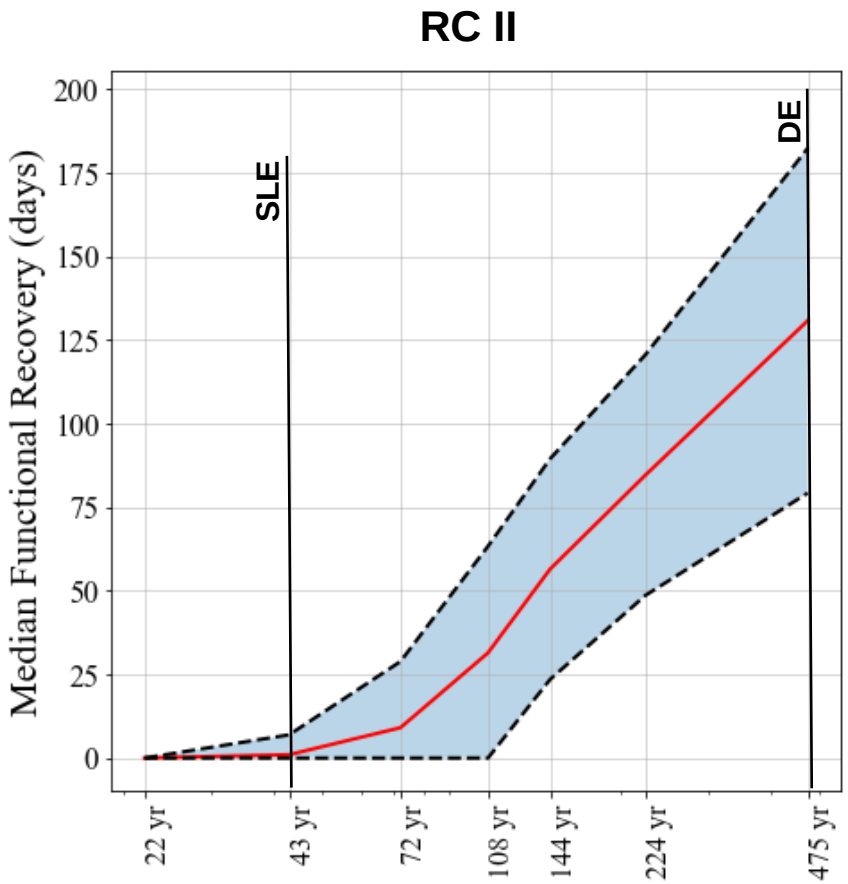
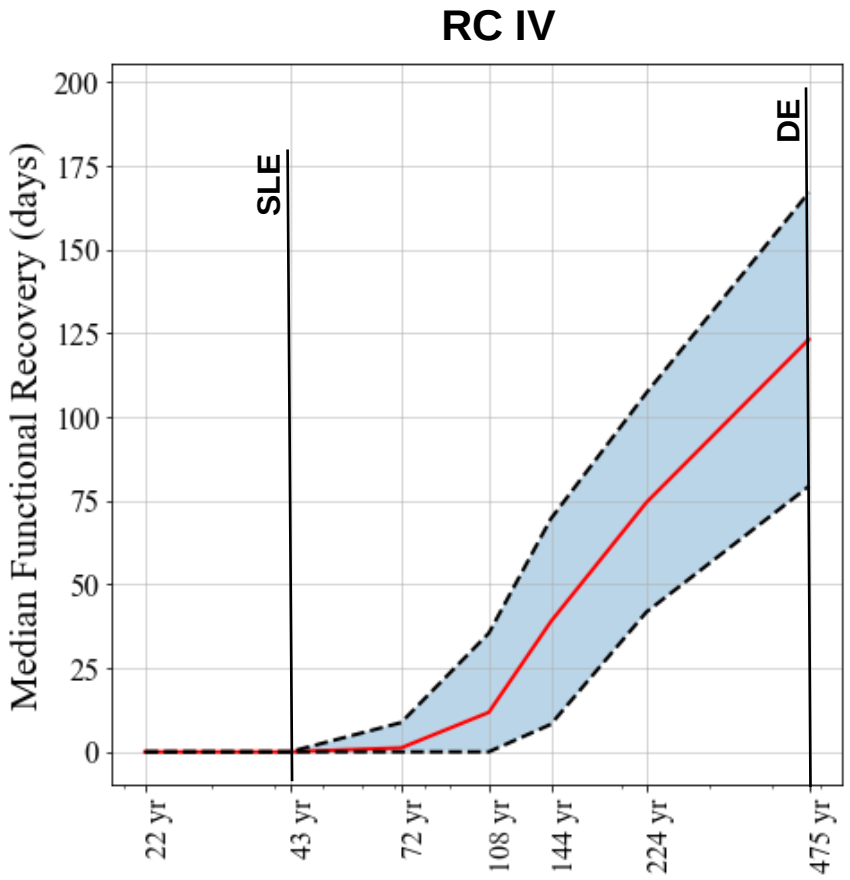


Results for Full Set of Buildings: RC II vs. RC IV

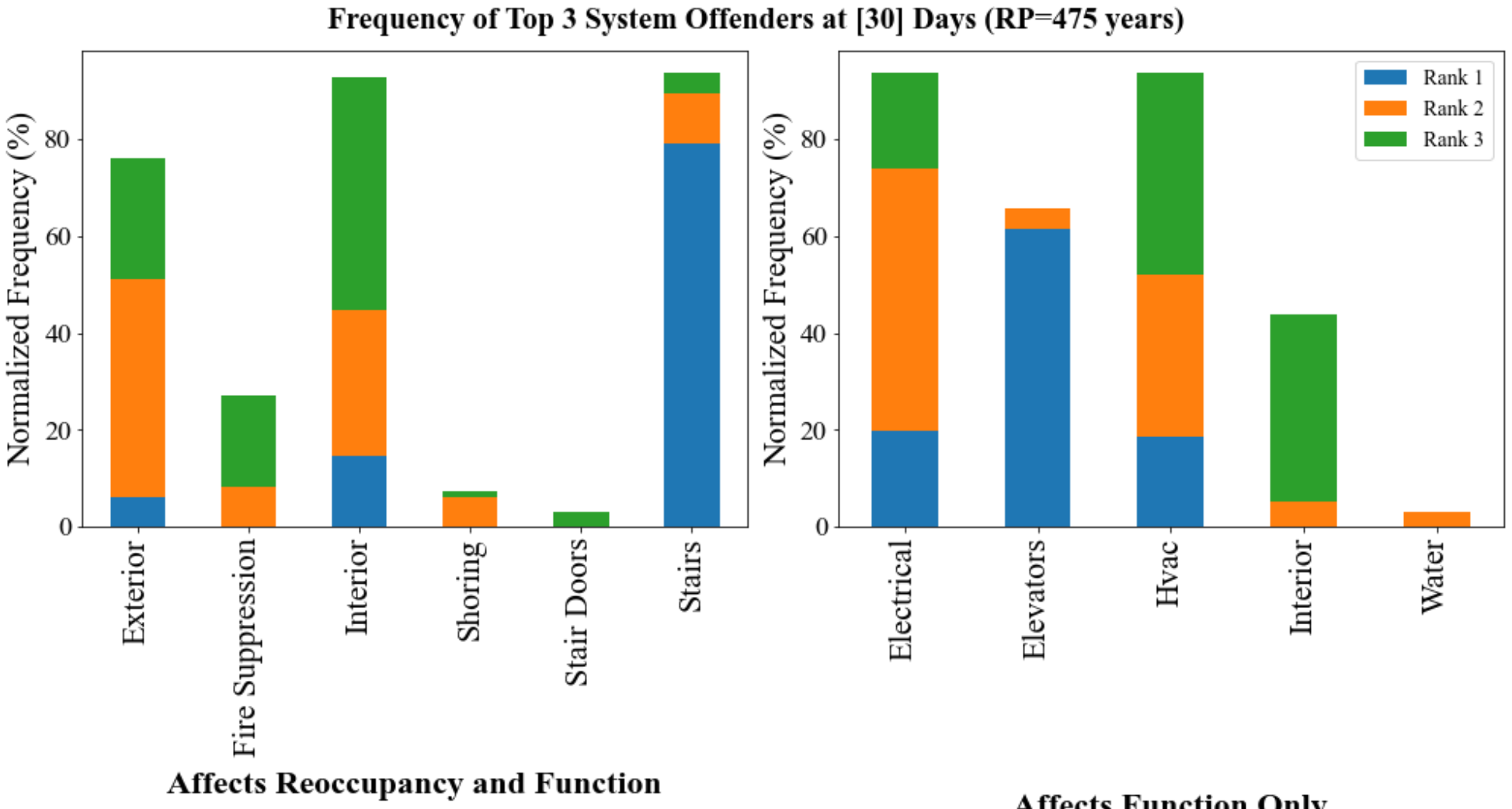
Take Away: Risk Category IV delays the onset of damage around SLE, but results similar at DE (and MCE) levels.





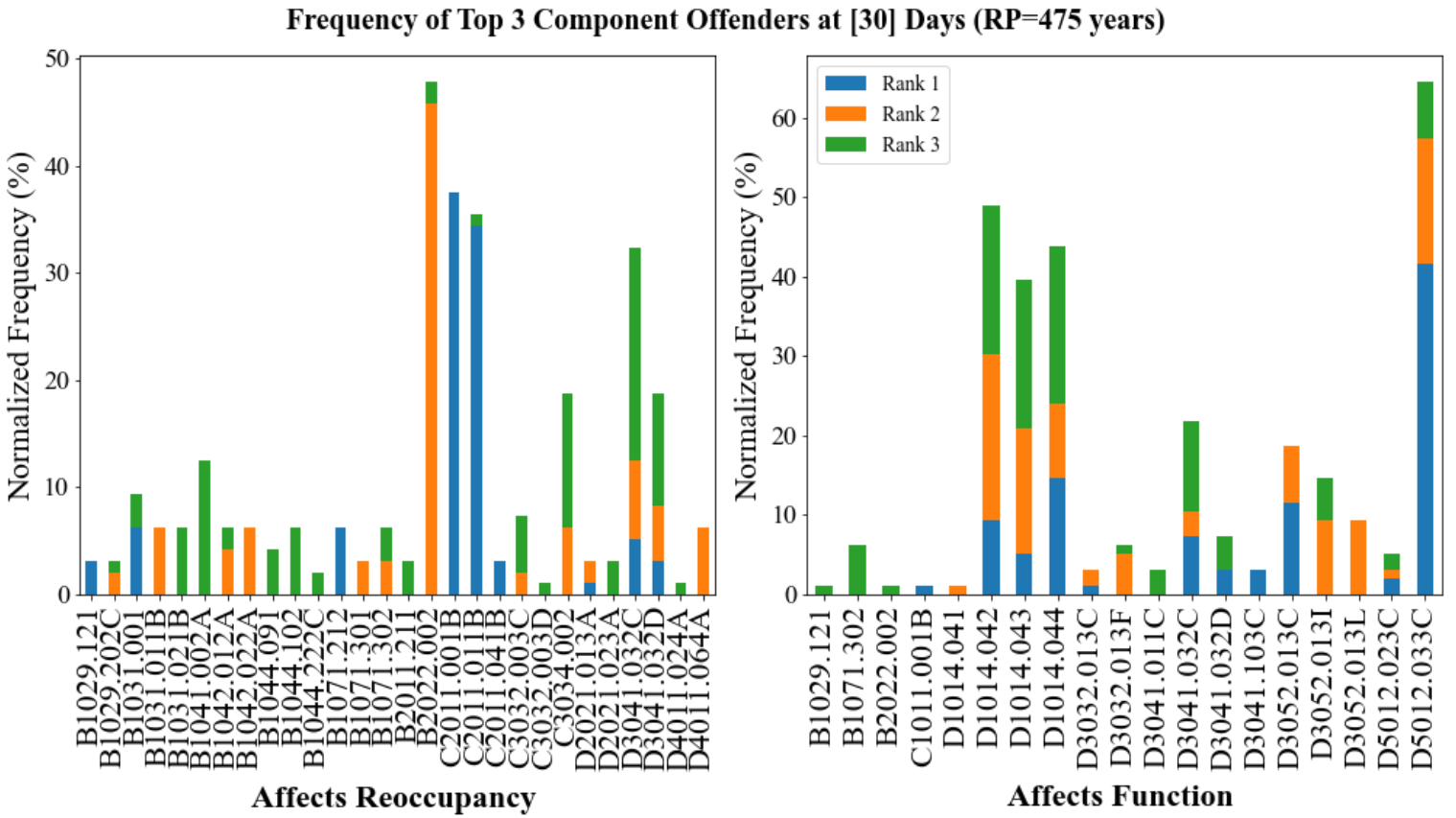
Most Frequent System/Component “Offenders”

Take Away: FEMA P-58/ATC-138 identifies system causing issues, so they can be designed resiliently.



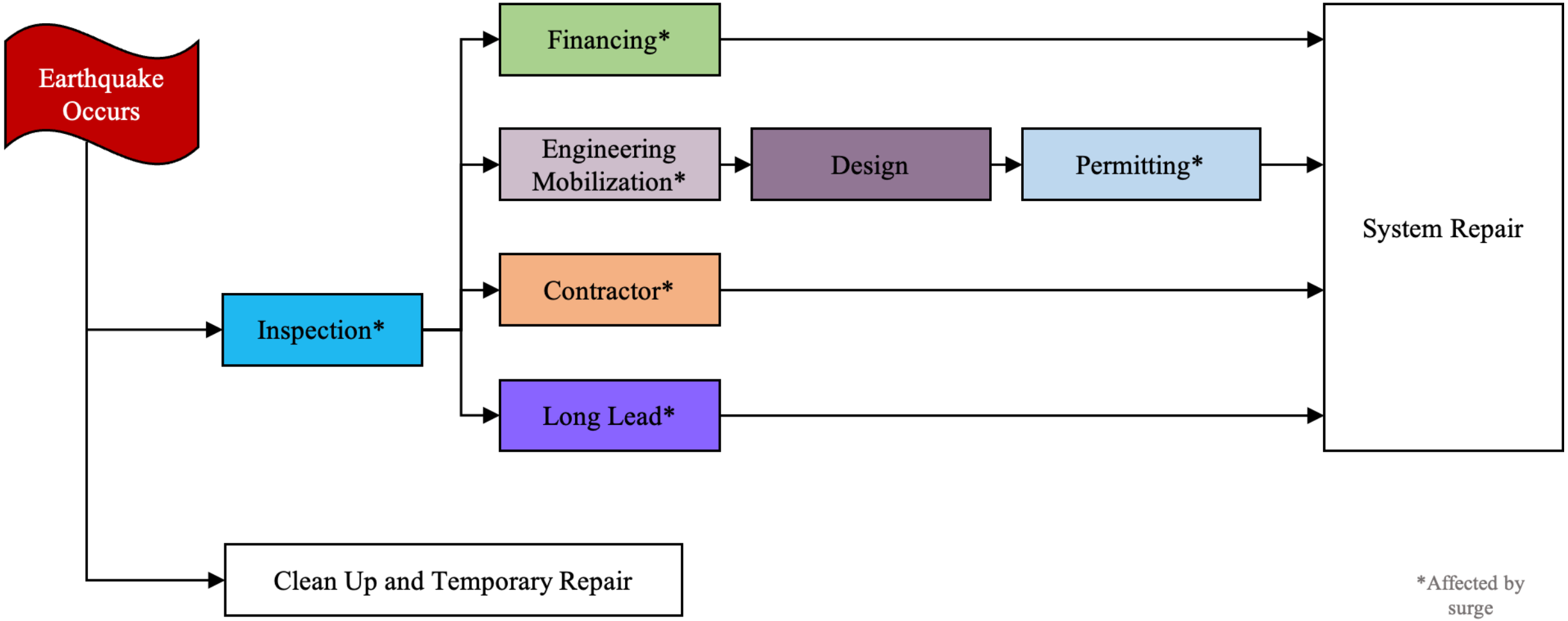
Most Frequent System/Component "Offenders"

Take Away: FEMA P-58/ATC-138 also identifies the specific components causing issues, so they can be designed resiliently.



- Reoccupancy offenders (ordered, mostly falling hazards):
  - Stairs when no seismic joint (C2011.xx)
  - Curtain/exterior walls (B2022/B1071)
  - HVAC components (C3041)
  - Pendant lighting (C3034.002)
  - Suspended ceilings (C3032.003c)
- Functional Recovery (ordered):
  - Electrical distribution panel (D5012)
  - Elevators (D1014)
  - HVAC components – ducting, drops, VAV boxes (D3041)
  - Air handling units (D3052)
  - Cooling tower (D3031)
  - Exterior walls (B1071)

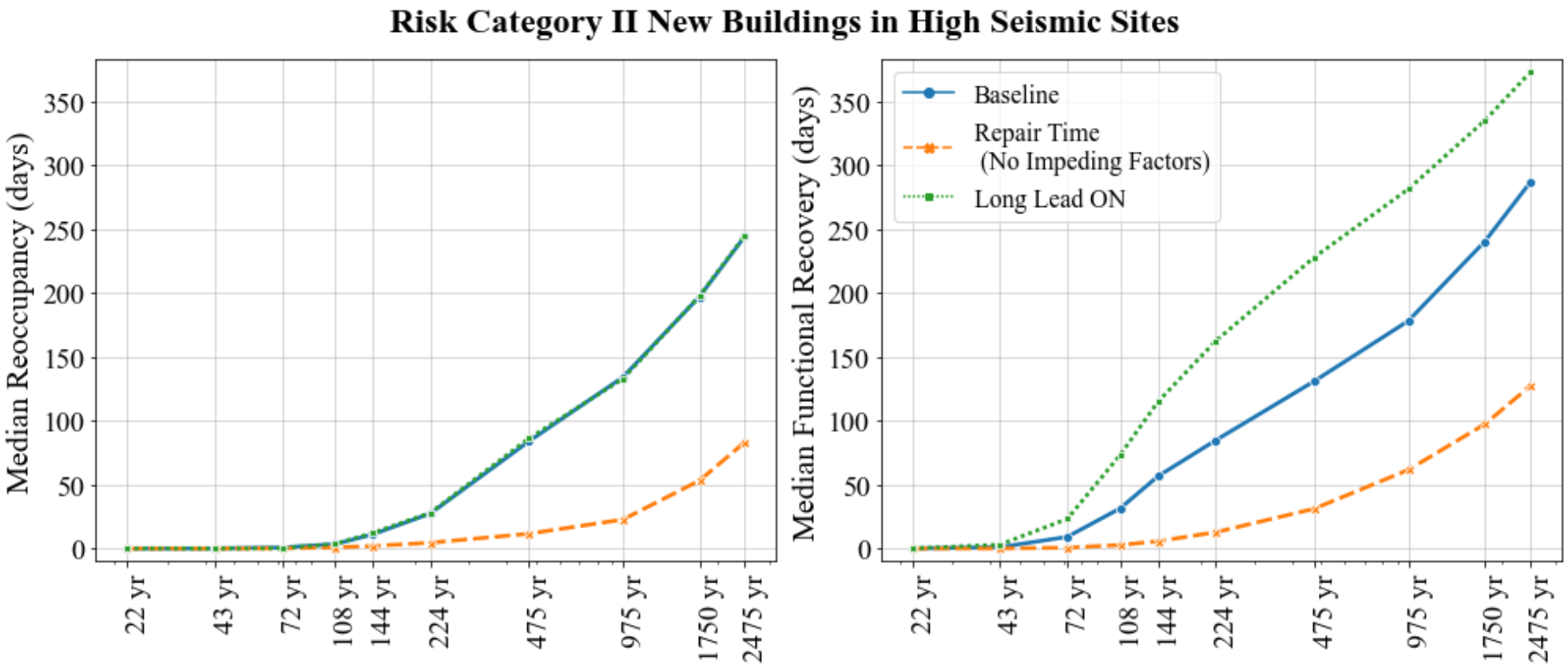
Sensitivity to Methodology Components



*Affected by surge

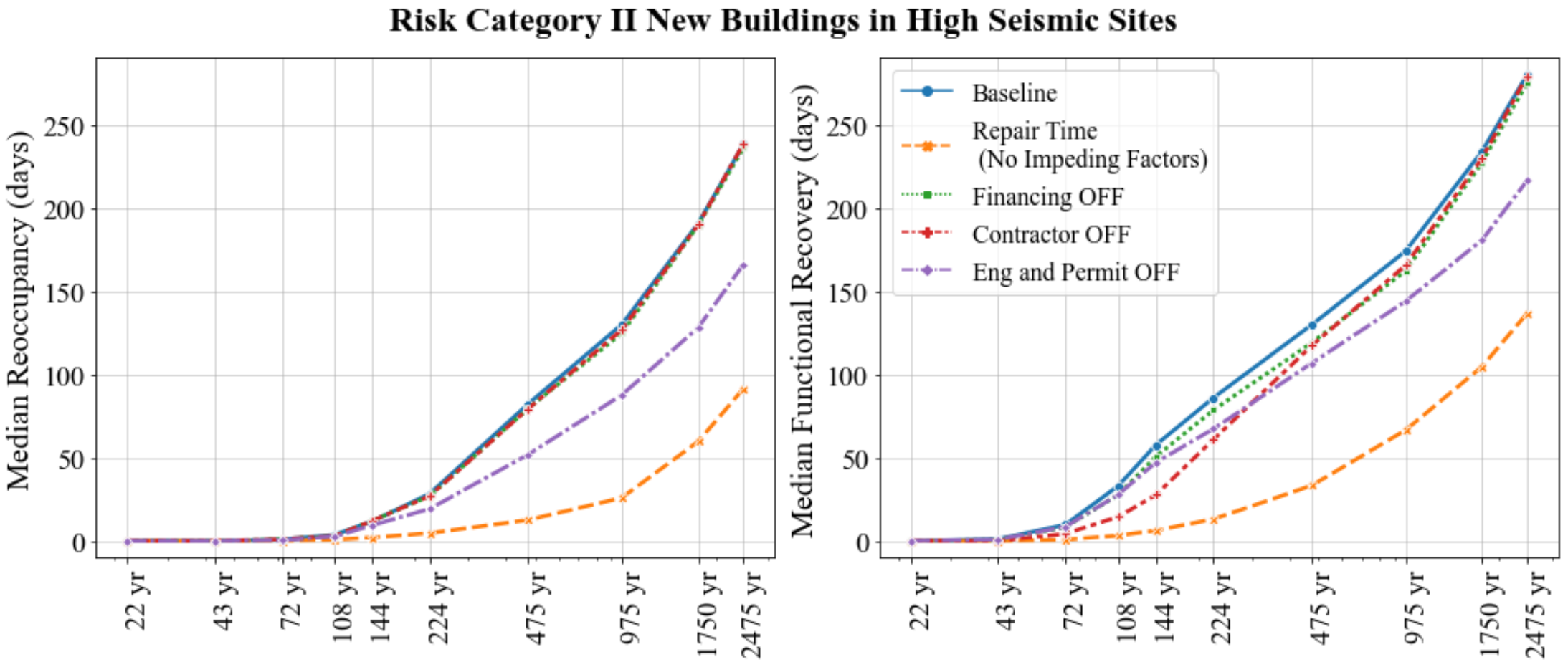
Sensitivity to Method Components: Impeding and Long-Lead

Take Away: Impeding factors and long-lead items increase recovery times substantially.



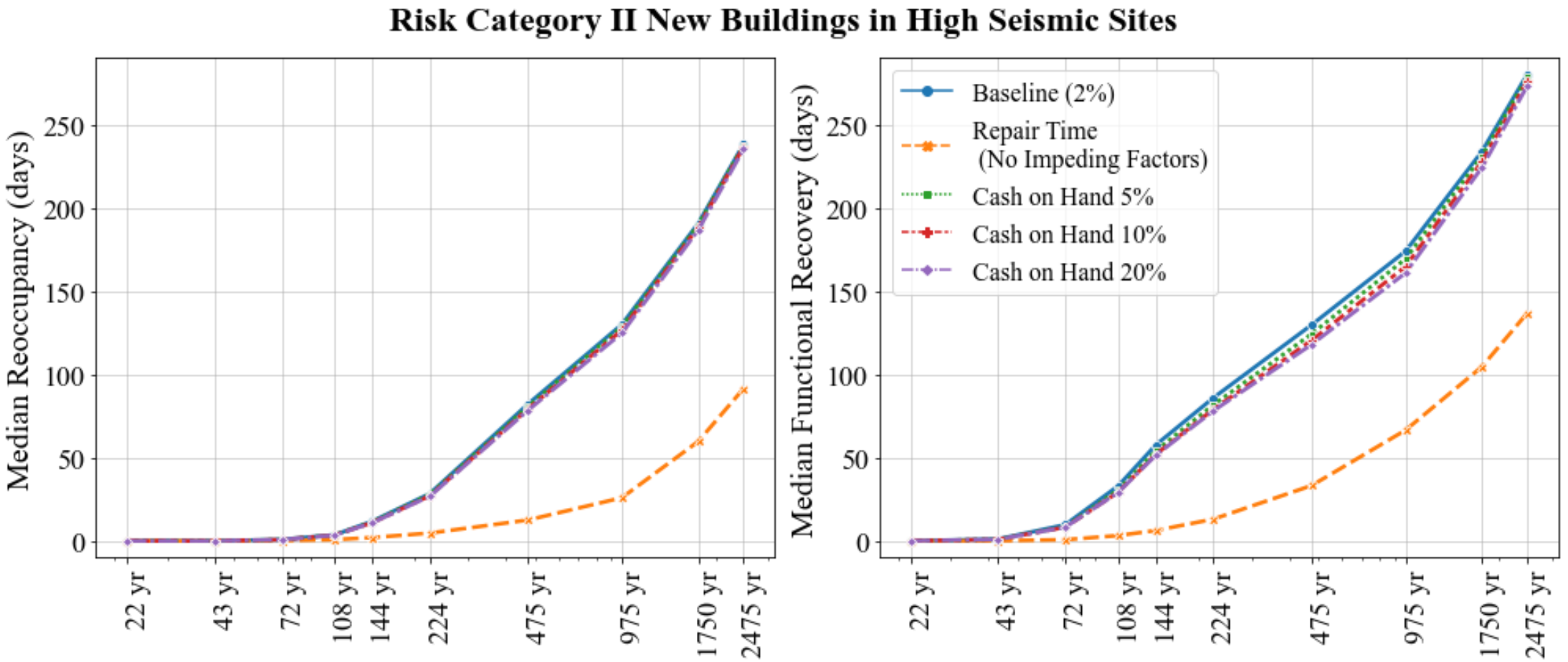
Sensitivity to Method Components: Specific Impeding Times

Take Away: Impeding factors are mostly in parallel, so you get most of the effect even if you turn some off.



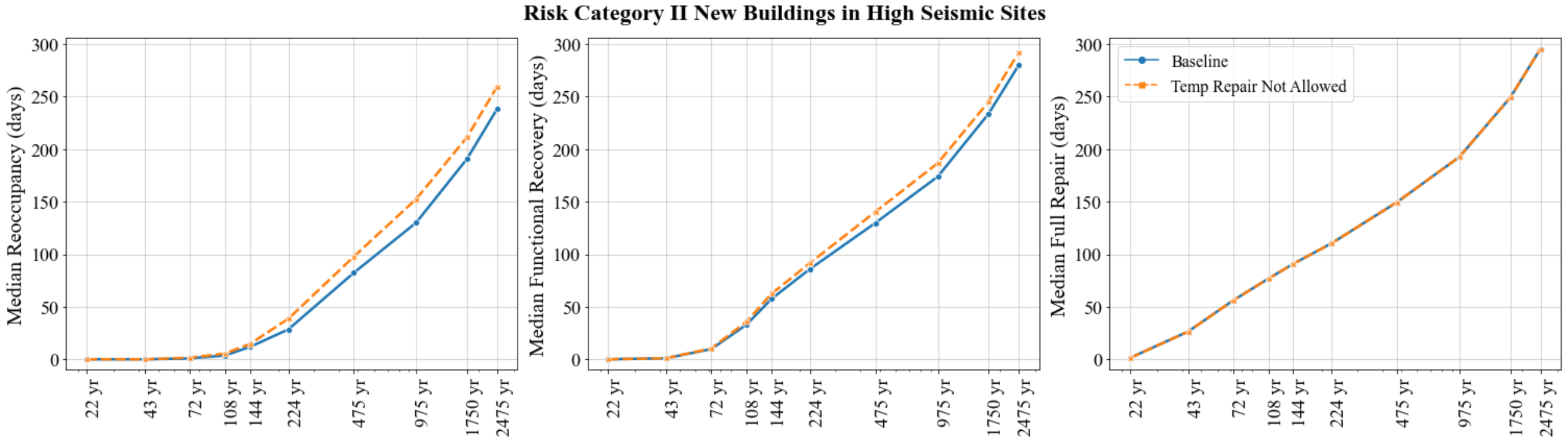
Sensitivity to Method Components: Cash-on-Hand Before Loan

Take Away: Financing details generally don't control (permitting/design/contracting does).



Sensitivity to Method Components: Temp. Repair Allowance

Take Away: Allowing temporary repairs reduce recovery times some. Important caveat is that the impact depends heavily on what is allowed to be temporarily repaired to regain basic function; if we are more permissible with what can be resolved with temp repair, then recovery times would be much lower between at SLE and even some DE levels.



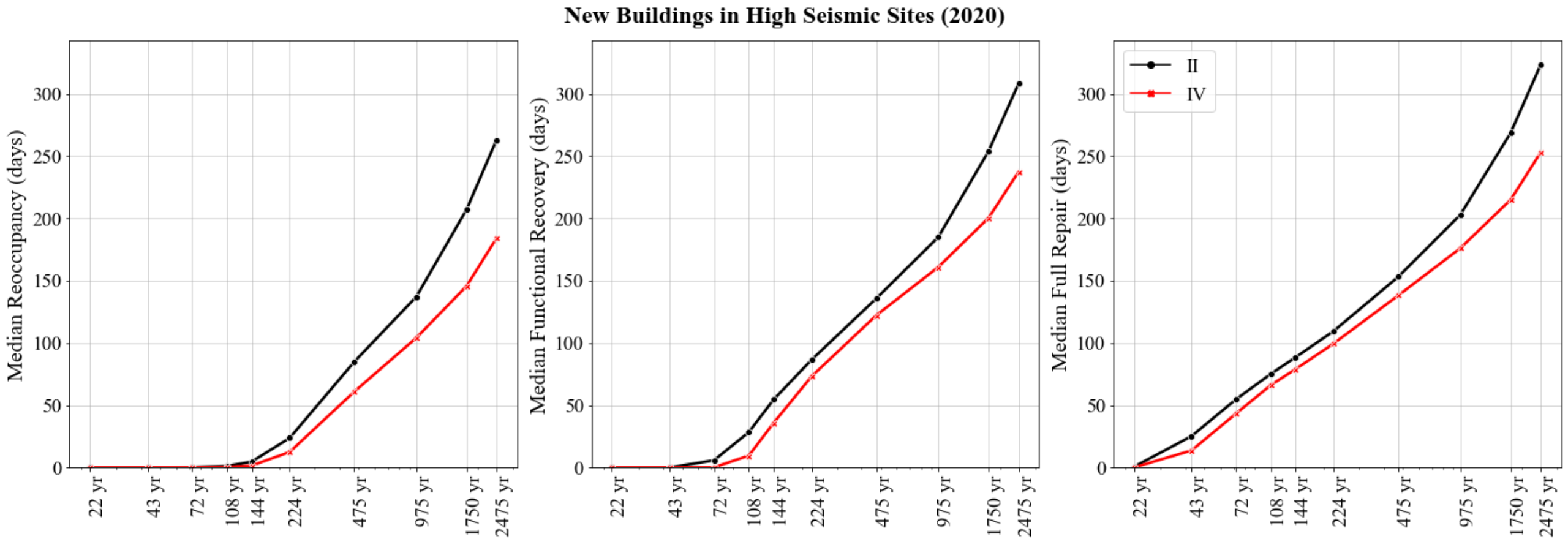
Trends for Building Design

What do some occupancy and design items affect results?

- RC II vs. IV
- New vs. Old buildings
- Occupancy (residential vs. commercial office)

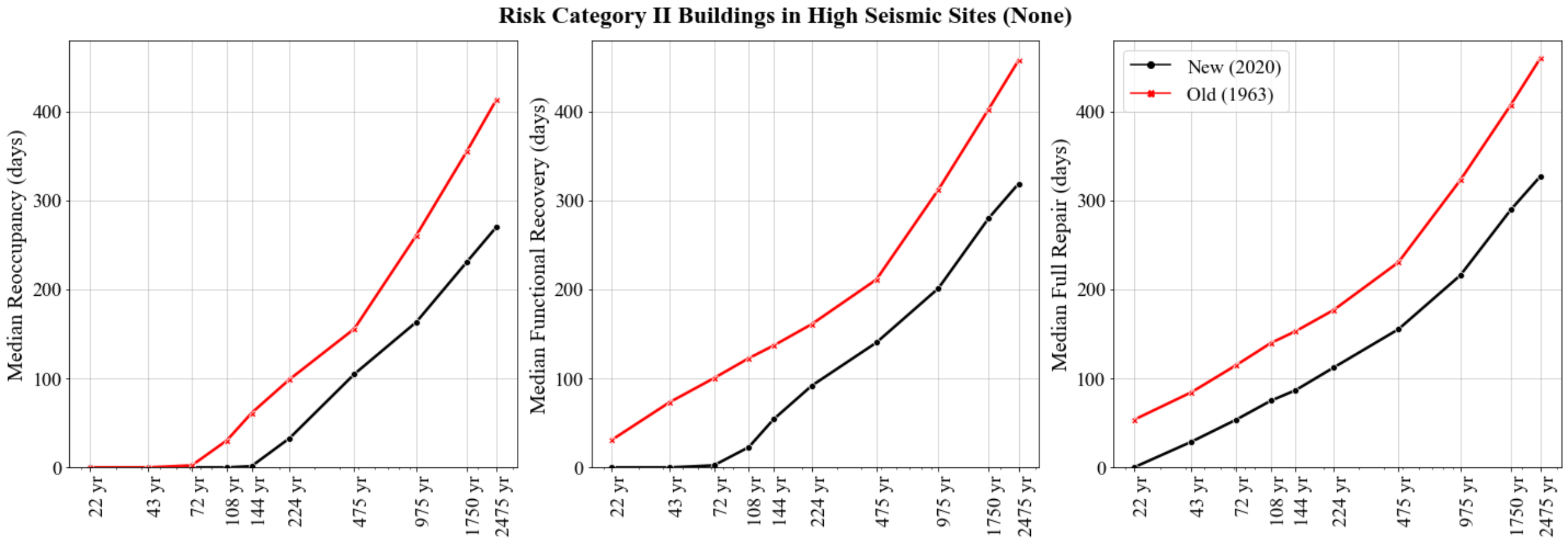
Trends for Building Design: Risk Category II versus IV

Take Away: RC IV delays onset of FR issues (near 72yr to 108yr), but then results are similar for DE and MCE.



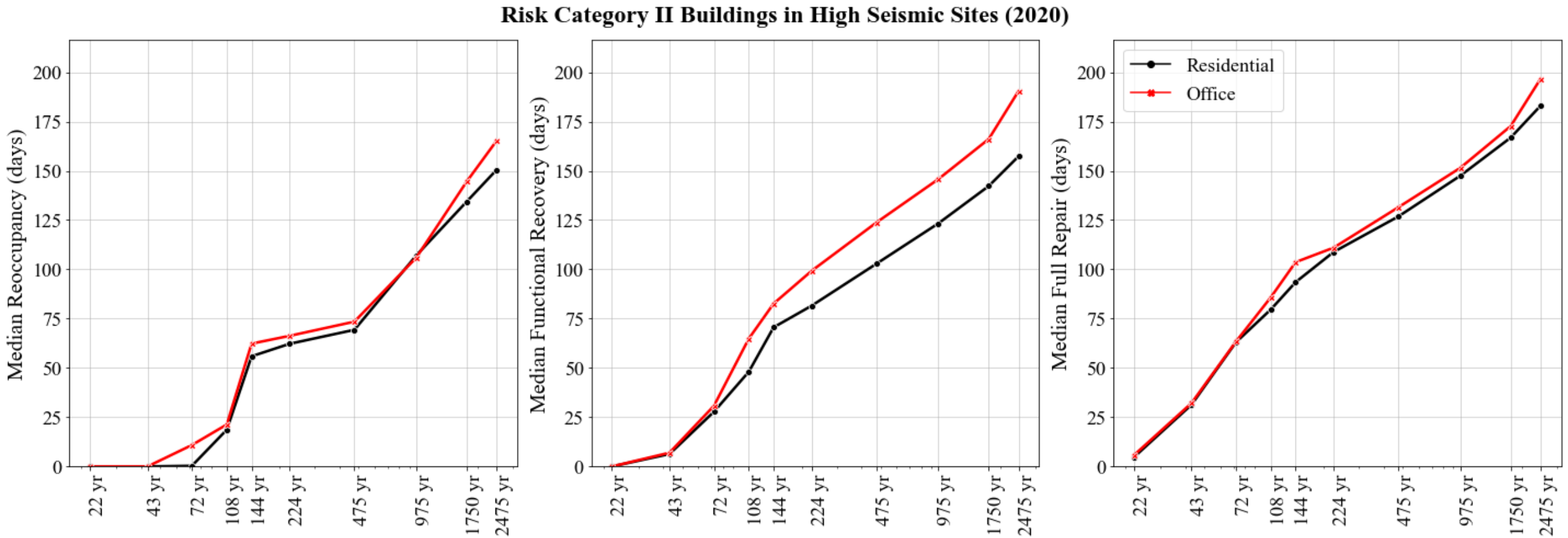
Trends for Building Design: Old vs. New Buildings

Take Away: New buildings are better (but we didn't need to tell you that).

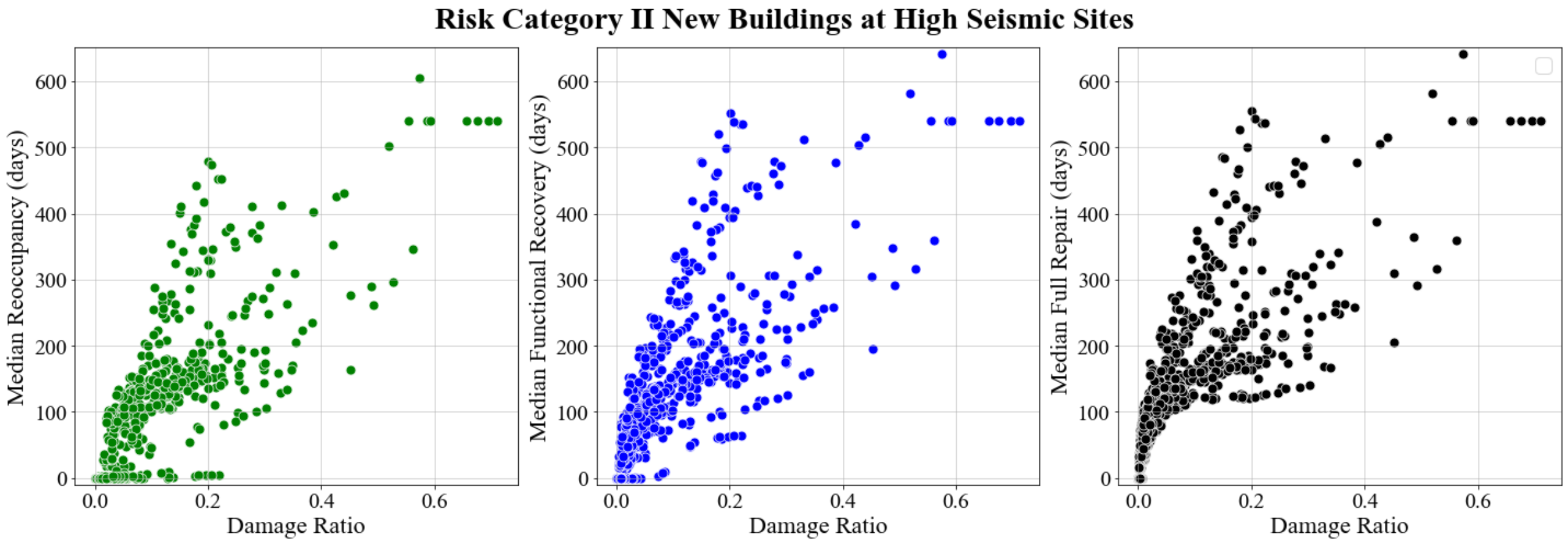


Trends for Building Design: Occupancy

Take Away: Similar results, with residential slightly better because more damage is allowed.



Recovery Times vs. Damage Ratio



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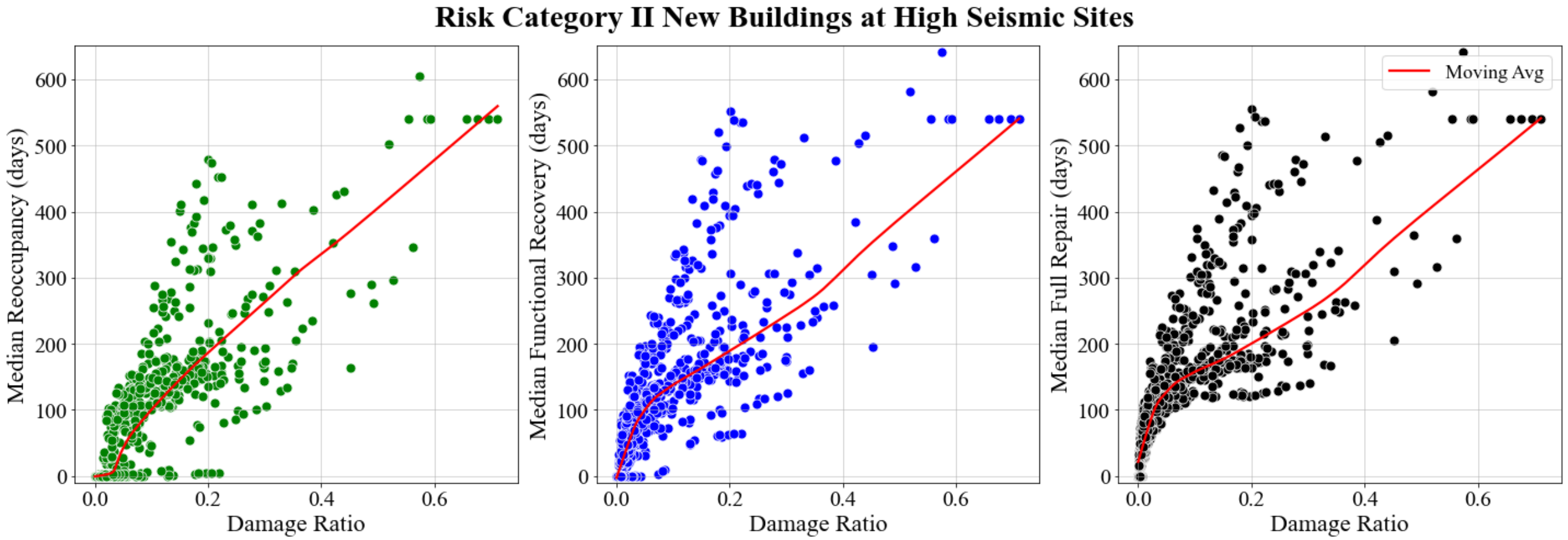

Results for a Real Project (Mar Structural Design)

Take Away: New practitioner design (RC wall lab building) was also taken through this process (full RHA). Results are comparable to what we have shown for main 592 building study. FEMA P-58/ATC-138 is enabling resilient design for this project by identifying which specific components need more resilient design.

Summary

- ATC-138 has extended the FEMA P-58 analysis method to now modeling/estimate functional recovery time (and reoccupancy times).
- Results for code-compliant buildings vary widely building-to-building and site-to-site (because the code doesn't try to design for function). Typical average values for high-seismic CA sites are:
  - ✓ SLE: Current code design delivers near-immediate occupancy/function for most systems
  - ✓ DE: Several months of recovery time (so need more resilient design to have quick recovery at DE)
  - ✓ MCE: Long recovery (but probably not the focus of FR design)
- Impeding factors have important influence in the estimated recovery times.
- Risk Category IV delays onset of damage and function issues (near SLE), but doesn't help much once we get to DE and MCE levels (more on this in Part II).
- Results are similar for a current practitioner design (and this methodology is already being used to inform resilient design as we speak).
- Looking toward the future, FEMA P-58/ATC-138 studies like this can be use to both inform FR acceptance criteria, and also to calibrate what prescriptive design requirements would meet FR goals.

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