APPLYING RESILIENT RATING SYSTEMS FOR PREDICTING CONTINUED OPERABILITY OF HOSPITALS AFTER EARTHQUAKES

Megan Boston
University of Waikato

Judy Mitrani-Reiser
Johns Hopkins University

Expectations of Hospitals

"It is the intent of the Legislature that hospital buildings that house patients who have less than the capacity of normally healthy persons to protect themselves, and that must be **reasonably capable of providing services to the public after a disaster**, shall be designed and constructed to resist, insofar as practical, the forces generated by earthquakes, gravity, and winds."

–Alfred E Alquist Hospital Facilities Seismic Safety Act of 1983

1. **Protect the lives of patients and health workers** by ensuring the structural resilience of health facilities.
2. Ensure that health facilities and health services are **able to function in the aftermath of emergencies and disasters**, when they are most needed.
3. Improve the emergency management capacity of health workers and institutions

-World Health Organization

Motivation

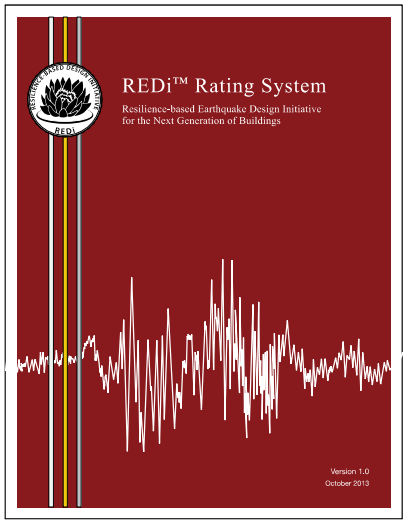
- When an earthquake hits, we expect our hospitals to remain functional….
- 1971: San Fernando
- 1985: Mexico
- 1994: Northridge
- 1999: Taiwan
- 2010: Chile
- 2011: Christchurch
- 2015: Nepal
- 2017: Mexico

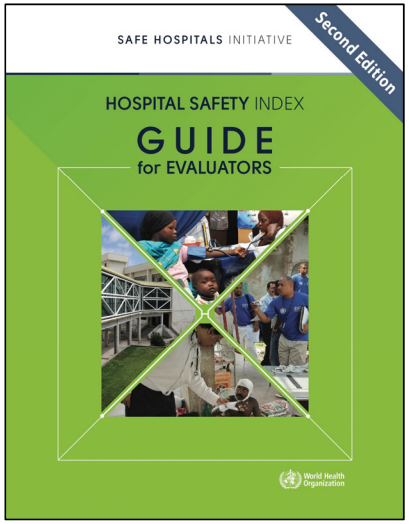
Photo: Kaiser Permanente Hospital, Jonathan Alcorn, LA Times

Resilient Rating Systems

U.S.RESILIENCY COUNCIL
Rating Building Performance in Natural Disasters

QuakeStar
BUILDING PERFORMANCE RATING

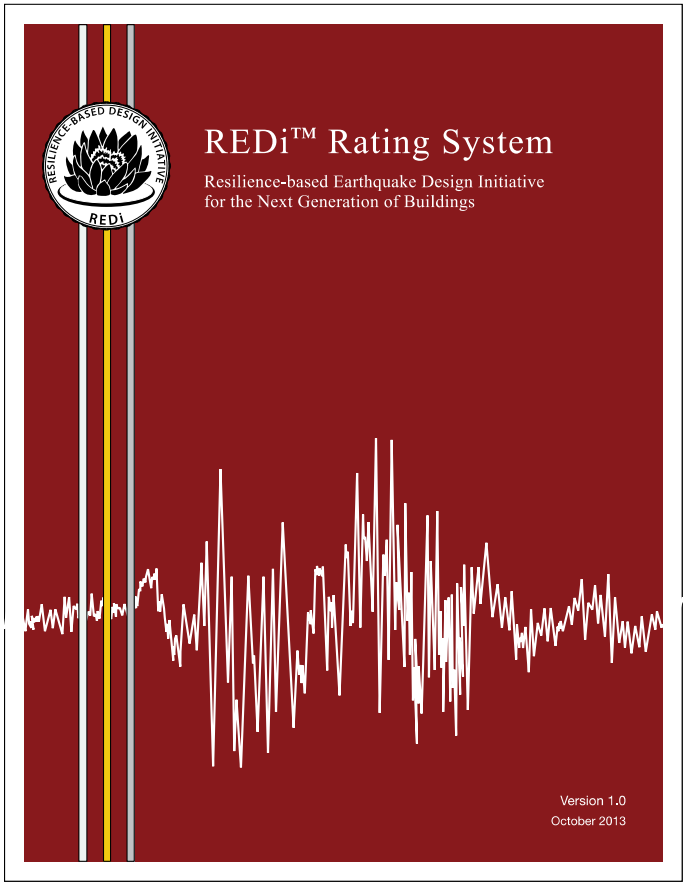


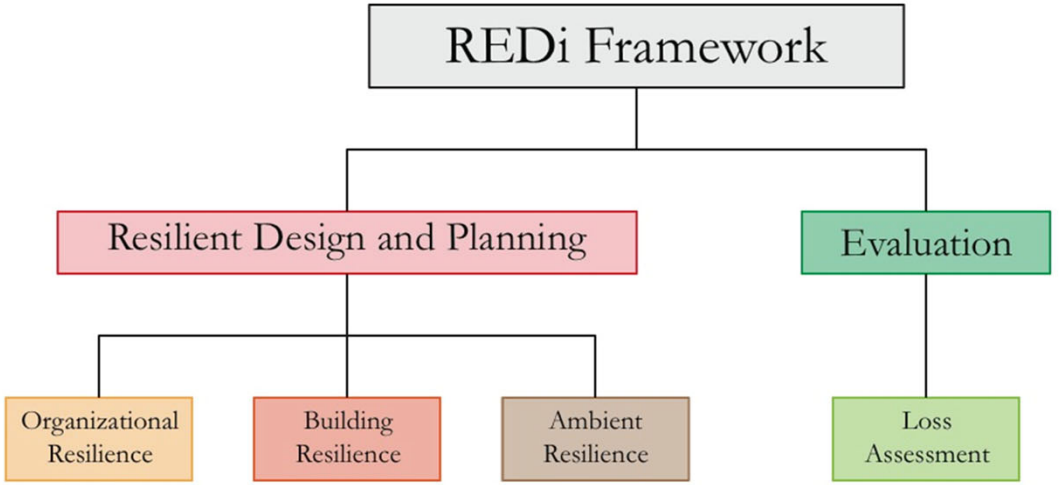


oshpd
Office of Statewide Health
Planning & Development

Structural Performance Categories		Non-structural Performance Categories	
SPC 1	Building poses significant risk of collapse, danger to the public	NPC 1	Equipment does not meet anchoring or bracing requirements
SPC 2	Compliance with pre 1973 building code. Meets life safety requirements but unlikely to be repairable or functional.	NPC 2	Bracing and anchoring of key systems such as: communication, emergency power, medical gases
SPC 3	Compliance with HSSA prior to 1994. Meets life safety requirements but unlikely to be repairable or functional.	NPC 3	NPC 2 and bracing and anchoring of nonstructural elements in critical care, clinical labs, pharmaceutical, radiology, and sterilization areas
SPC 4	Compliance with HSSA after 1994, may have structural damage that will hinder hospital services	NPC 4	NPC 3 plus proper anchoring and bracing of all architectural, mechanical, electrical, and medical equipment
SPC 5	Compliance with HSSA after 1994, reasonably capable of providing services after a major event	NPC 5	NCP 4 plus 72 hours of onsite water and holding tanks.

REDi Rating System





	Downtime: Re-occupancy	Downtime: Functional Recovery	Direct Financial Loss	Occupant Safety
Platinum	Immediate (green tag)	< 72 hours	< 2.5%	Injury unlikely
Gold	Immediate (green tag)	< 1 month	< 5%	Injury unlikely
Silver	< 6 months (yellow tag)	< 6 months	< 10%	Injury possible but structural collapse unlikely

STARS	SAFETY	DAMAGE	RECOVERY
★★★★★	**Injuries and blocking of exits unlikely** Fatality < $3x10^{-5}$	**Minimal Damage** Repair cost < 5%	**Hours to days** Recovery < 5 days
★★★★	**Serious injuries unlikely** Fatalities < $1x10^{-4}$	**Moderate Damage** Repair cost < 10%	**Days to weeks** Recovery < 4 weeks
★★★	**Loss of life unlikely** Fatalities < $4x10^{-4}$	**Significant Damage** Repair cost < 20%	**Weeks to months** Recovery < 6 months
★★	**Loss of life possible in isolated locations** Fatalities < $4x10^{-3}$	**Substantial Damage** Repair cost < 40%	**Months to 1 year** Recovery < 1 year
★	**Loss of life likely** Fatalities > $4x10^{-3}$	**Severe Damage** Repair cost > 40%	**More than 1 year** Recovery > 1 year

Rating	Risk of Harm (Safety)	Damage	Repair Time
★★★★★	Extremely Low	Minimal	Days
★★★★	Very Low	Moderate	Weeks
★★★	Low	Significant	Months
★★	Moderate	Substantial	> 6 Months
★	High	Severe	> 1 year

QuakeStar BUILDING PERFORMANCE RATING — **Worksheet 1** — **Commercial** — **Safety**

Overall Safety Rating ***

Notes (Replace with building-specific notes)

Building Details		
Name	Tower Block 7/5 Richter Street, Quaketown	
Assessor	ABC Consulting Engineers	
Reviewer	DEF Structural	

Overall combined	E-W	N-S	Building	Notes
Safety Ratings	***	***	***	Shows overall rating and safety score in each direction - based on the lowest individual scores in the relevant column.
Safety Scores	100	100	100	

	Item	Attribute	Measure (Capacity = at ULS; Demand = 500-yr at ULS)	IL2 NBS min	User input Building Scores E-W	N-S	Combined Ratings	E-W	N-S	Building	Notes
							Combined Ratings: Structure : Site : Building Stability	*** / 100	*** / 100	*** / 100	Shows the overall score in each direction without considering "Non-structural Elements"
Stability Assessment	Site	Overall site stability	Capacity / Demand	100	130	120	Combined ratings Site : Building Stability	*** / 130	*** / 120	*** / 120	Shows the results of examining the stability of the Site and of the Building as a whole. Including this means that these important issues are considered.
	Building	Building overall stability		100	140	120					
Structural Capacity Assessment	Primary Structure	Basic Capacity at ULS	Capacity / Demand (Figures used must take account of integrity, ductility, consequences of failure, capacity design, asymmetry and lack of separation from other buildings)	100	100	100	Rating for Primary Structure only	*** / 100	*** / 100	*** / 100	Shows the result of examining the Primary Structure on its own, including foundations, regardless of stability or floor/stair issues. Estimation of ULS Capacity / ULS Demand using the NZSEE Guidelines 2016 is deemed to have taken account of factors noted.
Structural Capacity Assessment	Floors and Stairs	Diaphragm action	Capacity / Demand	100	120	120	Rating for Floors and Stairs	*** / 120	*** / 120	*** / 120	A separate item for floors and stair recognises the particular issues with these items in the Canterbury Earthquakes
		Vertical support		100	120	120					
		Stair support		100	150	150					
Structural Capacity Assessment	"Non-structural" Elements	Cladding	Capacity / Demand	100	120	120	Rating for "Non-structural" Elements	*** / 120	*** / 100	*** / 100	These results need to be derived according to the scale of safety issues involved. Items that would "fail" which have no significant safety issues should be excluded. Insert "NC" (Not Critical) instead of number.
		Glazing		100	120	120					
		Ceilings		100	120	120					
		Partitions		100	NC	NC					
		Building Services		100	NC	NC					
		Appendages		100	120	100					

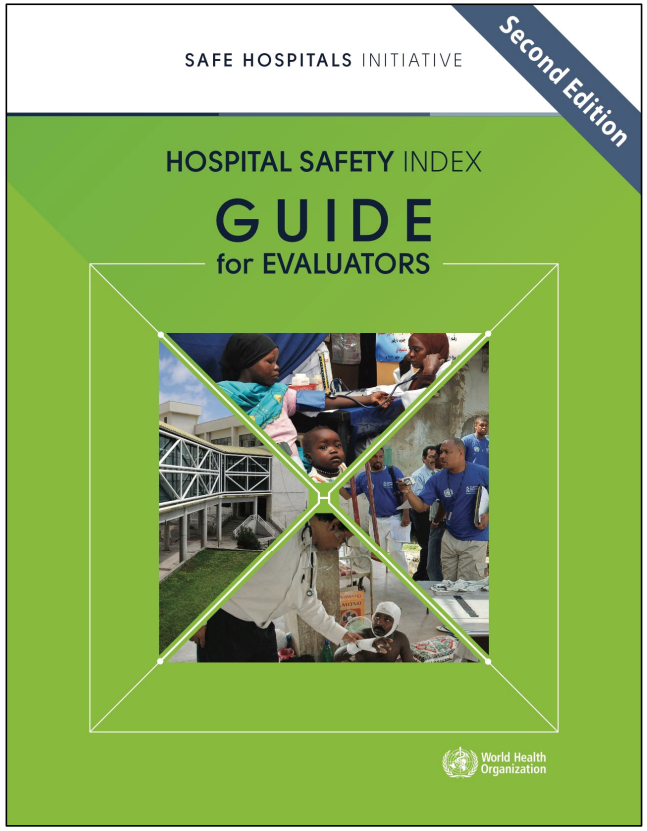
User Input: Items in red type require or allow user input. Items in green type are calculated or determined by worksheet.

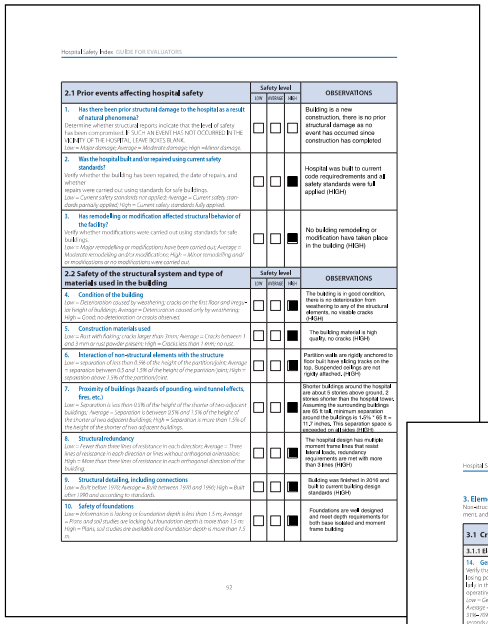
Note 1: A basic score of 100 represents *minimum* assessment for design-level performance of a new building of IL2 Category. With modifying factors an *average* new building of this type is expected to score about 130.

Note 2: Data for both directions is required. If an attribute is clearly not critical in one direction enter "NC" or a higher score for that direction and add a note.

Source: https://quakestar.org.nz/commercial-buildings/

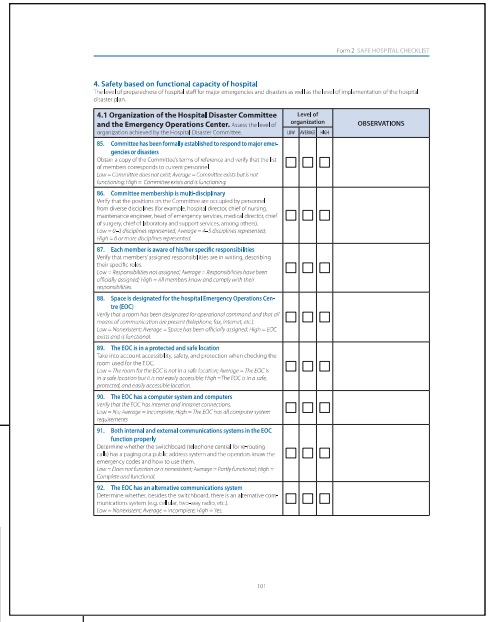
Hospital Safety Index





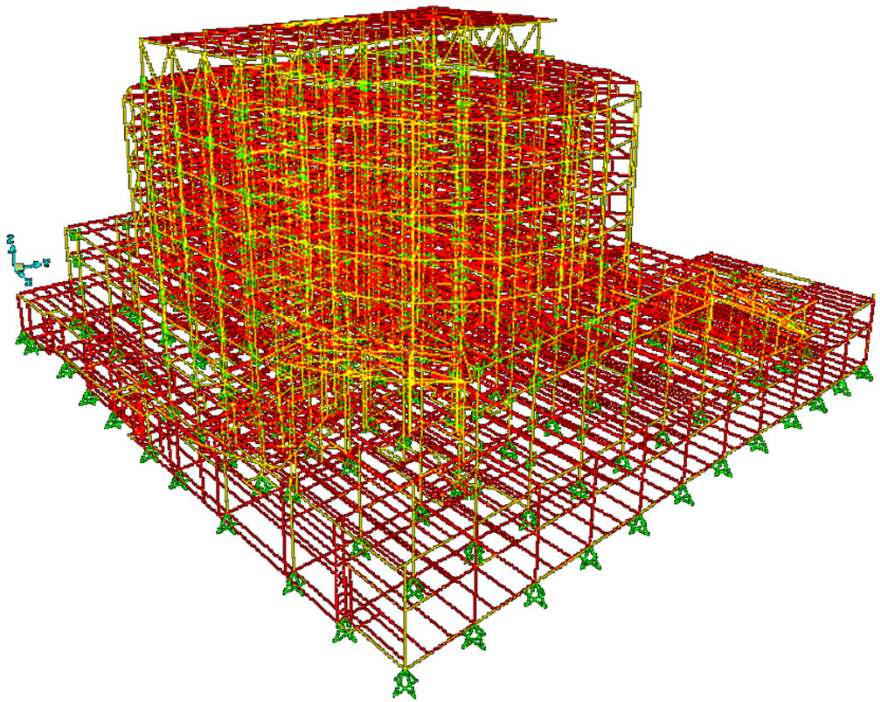
Nonstructural

Structural



Functional

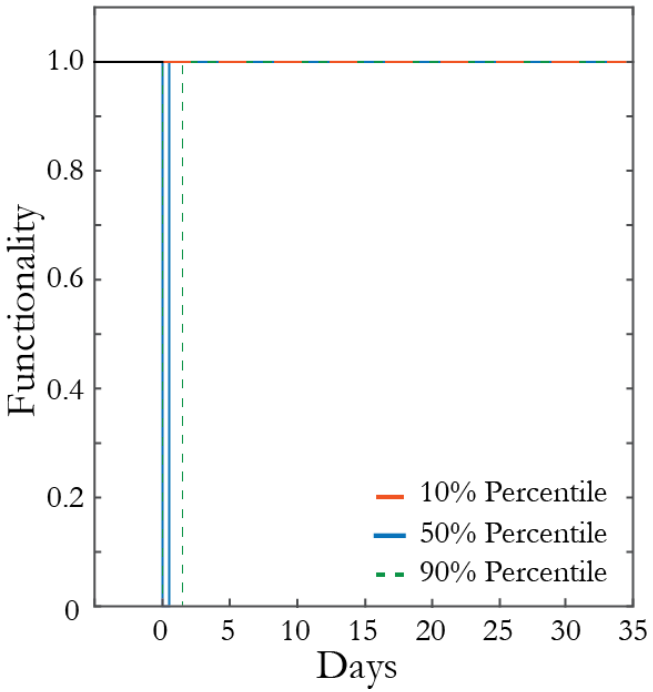
Hospital Rating Results



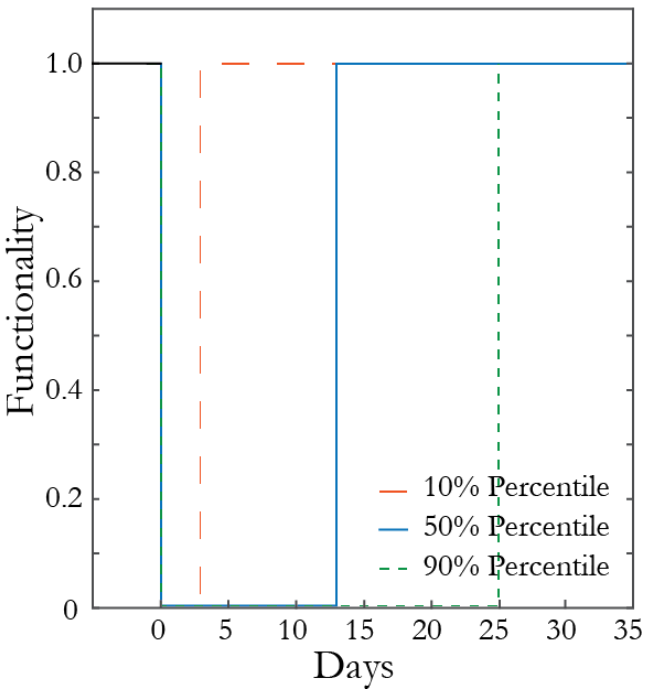
OSHPD	SPC: 5 NPC: 4
REDi	**SILVER** Downtime-Reoccupancy: 0 days Downtime-Functional: 114 days for repairs Direct Financial Loss: 0.4% Occupant Safety: No expected injuries
QuakeStar	
United States Resiliency Council	SAFETY ★★★★★ DAMAGE ★★★★★ RECOVERY ★★★★☆
Hospital Safety Index	**A** **0.91** Structural: 0.98 Nonstructural: 0.86 Functional: 0.81

Resilience: Elevators

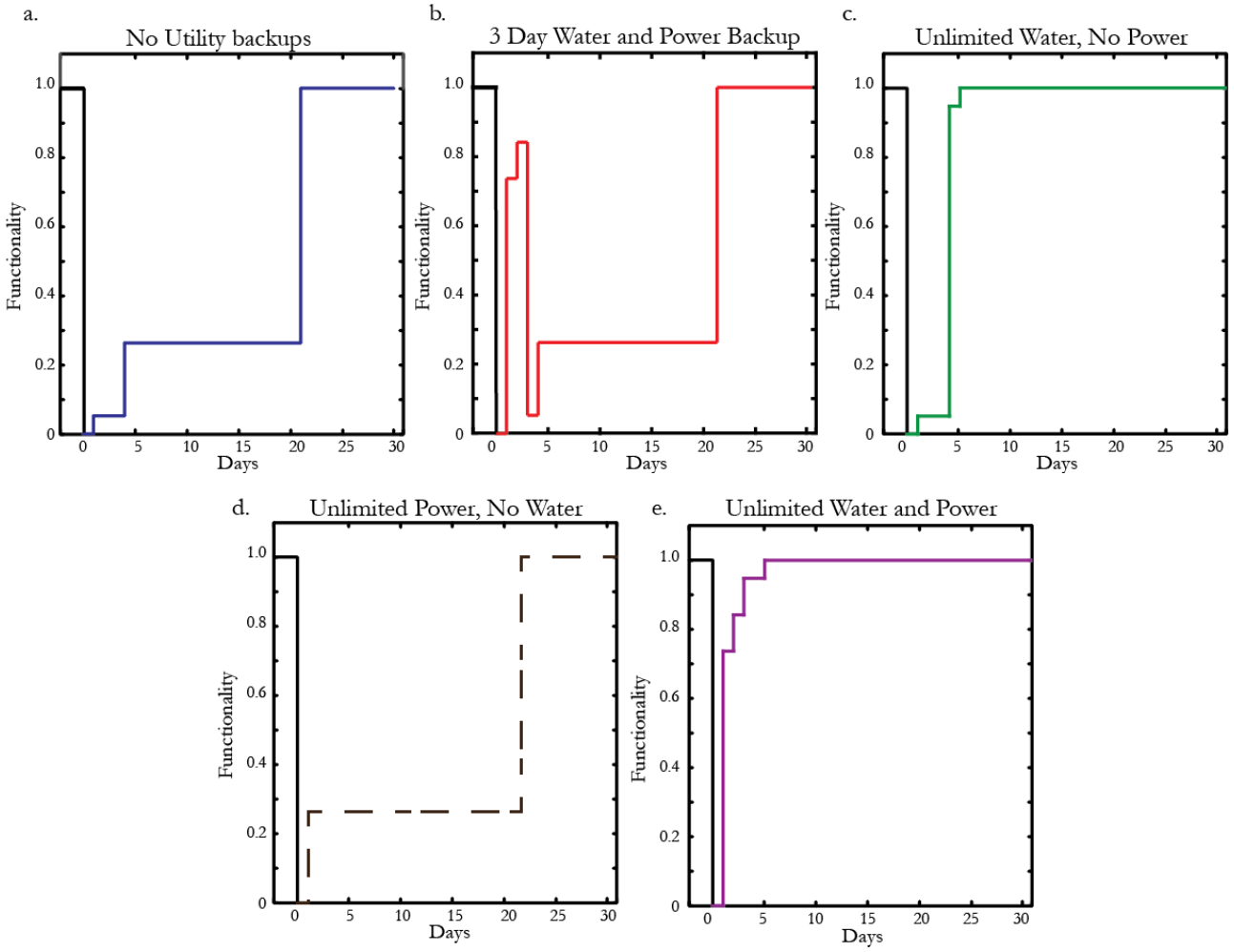
Base Isolated: Stairs or Elevators allowed for Egress



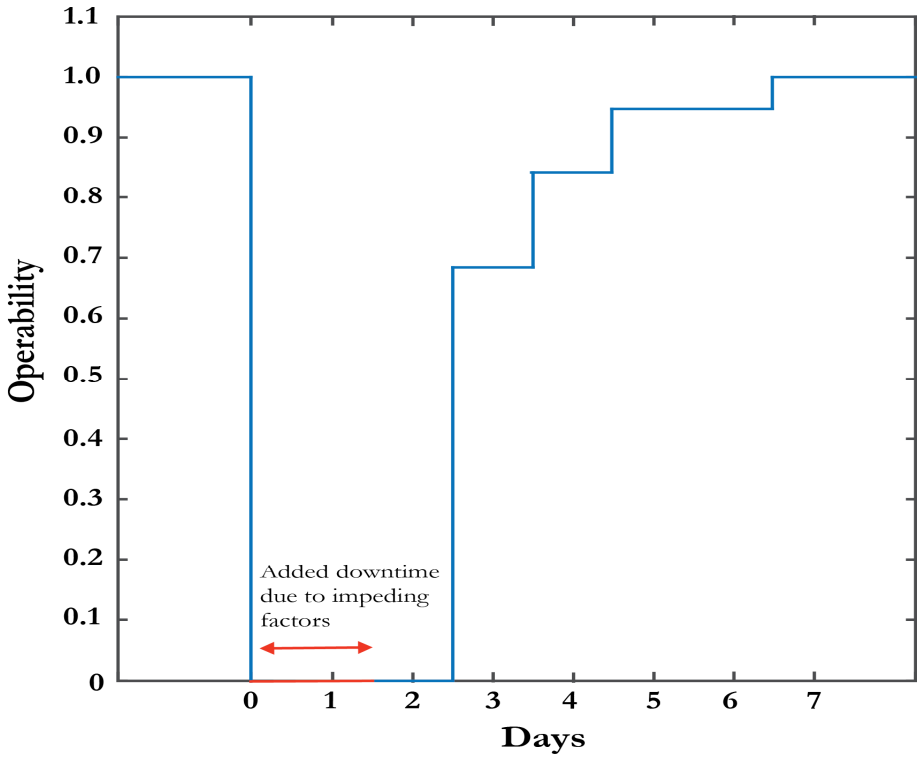
Base Isolated: Elevators **Required** for Egress



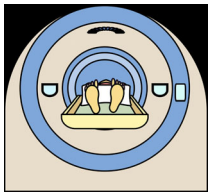
Functionality—Utilities

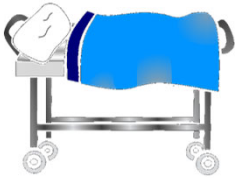


Functionality—Impeding Factors



Staff

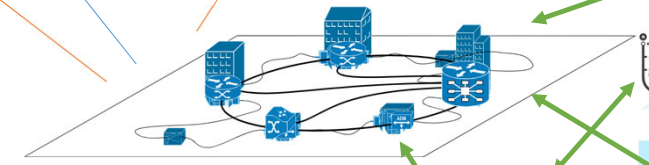




Stuff

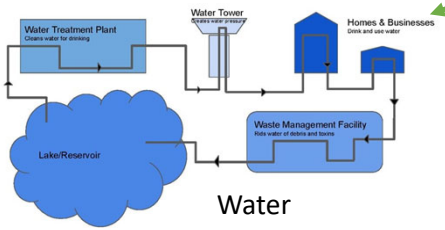
Space

Infrastructure Lifelines

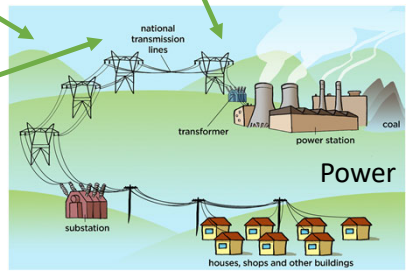


Communications

Transportation



Water



Power

Conclusions

- REDi, USRC, QuakeStar
  - Detailed comprehensive assessments that consider building performance and recovery levels
  - Inconsistency of criteria for rating systems
  - Nonspecific to building occupancy type
  - Disaster specific
- OSHPD
  - Generalized performance categories
- Hospital Safety Index
  - Quick assessment that requires limited calculations and only considers immediate impact
  - Specific to hospitals
  - Accounts for all hazards
- Overall
  - Rating Systems focus on the performance of the physical building, largely neglect business continuity
  - None of the rating systems provide enough detail in the immediate recovery time frame to provide emergency managers enough information to predict the immediate and short term operability of hospital after an earthquake