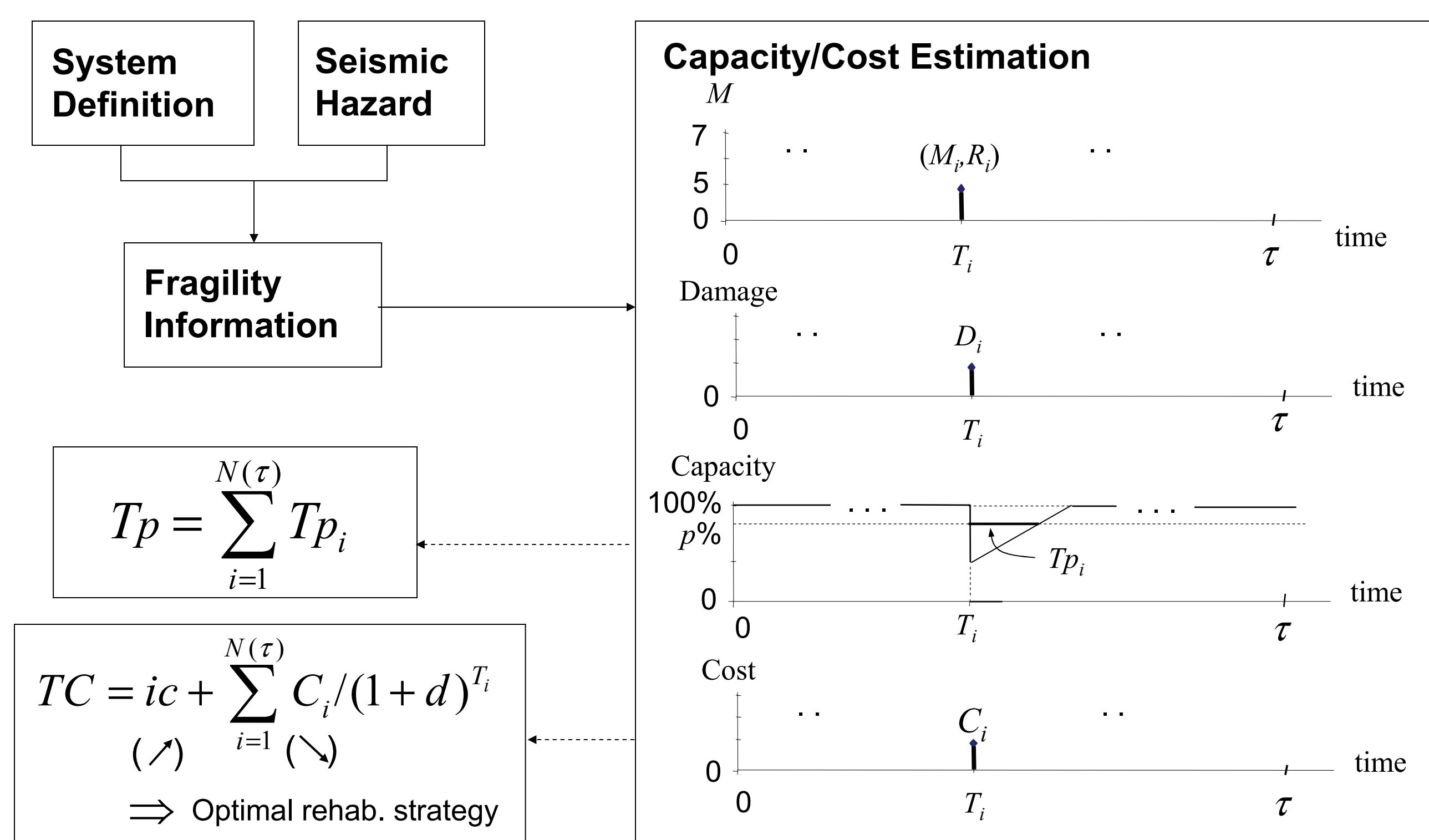


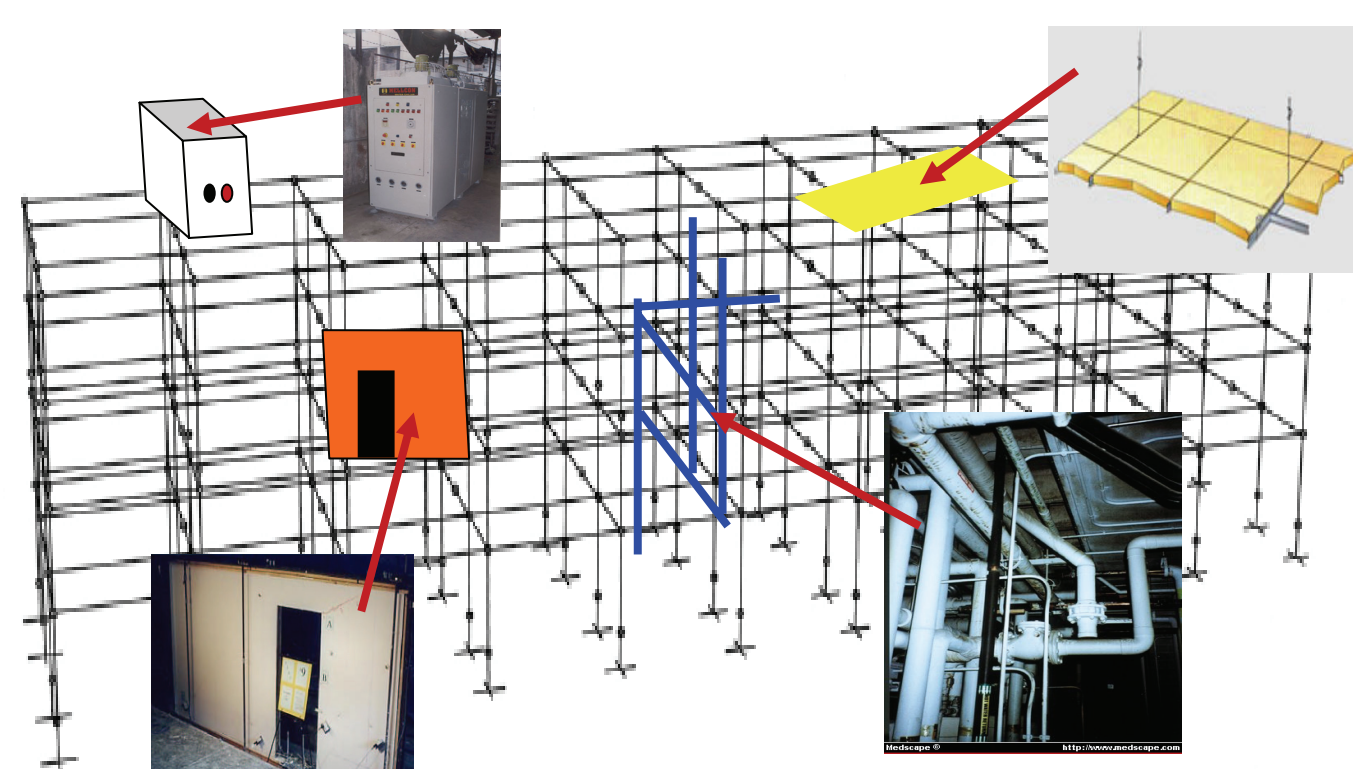
### ABSTRACT

A method is presented for assessing the seismic performance of structural/nonstructural systems and developing rational strategies for increasing the seismic resilience of these systems. The seismic performance is measured by fragility surfaces, that is, the probability of system failure as a function of moment magnitude and site-to-source distance, consequences of system damage and failure, and system recovery time following seismic events. The input to the analysis consists of (i) structural/nonstructural systems properties, (ii) seismic hazard, (iii) performance criteria, (iv) rehabilitation strategies, and (v) a reference time. Estimates of losses and recovery times can be derived using fragility information, financial models, and available resources. MCEER West Coast Demonstration Hospital is used to demonstrate the methodology. Fragilities are obtained for structural/nonstructural systems for several limit states. Also, statistics are obtained for life time losses and recovery times corresponding to different rehabilitation alternatives.

### METHODOLOGY



### SYSTEM DEFINITION



**Structural system:** MCEER West Coast Demonstration Hospital.

**Nonstructural systems:**

- HVAC: 2 chillers located at the roof

- Piping:

Floor	Length (ft)	Connections	Valves	Hangers
1	330	45	15	33
2	510	115	40	51
3	510	115	40	51
4	270	60	25	27

- Partition walls:

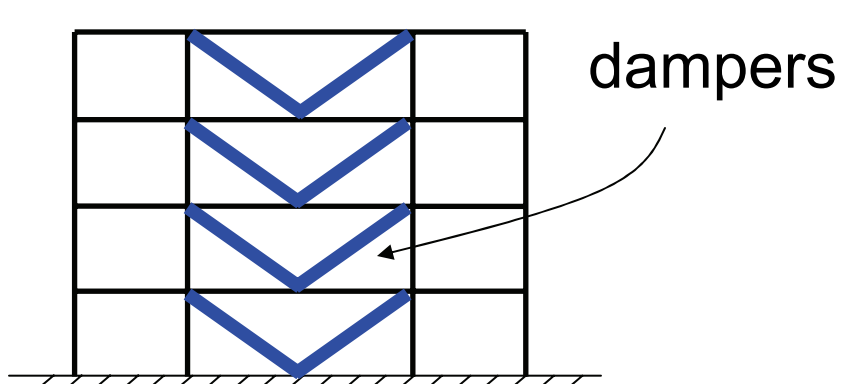
Floor	Walls	Effectuated # of beds						
		0	1	2	3	4	5	6
1	80	80	0	0	0	0	0	0
2	80	33	14	18	7	6	1	1
3	60	20	2	28	2	8	0	0
4	80	80	0	0	0	0	0	0

#### Assumptions:

- Cascade analysis applies
- Systems are brought to their initial state after each event

#### Rehabilitation alternatives:

- Structural system: Add linear viscous dampers (same stiffness as the existing system)
  - . rehab.alt.1 = 20% damping (1<sup>st</sup> mode) [ $ic = \$109,000$ ]
  - . rehab.alt.2 = 25% damping (1<sup>st</sup> mode) [ $ic = \$133,000$ ]
  - . rehab.alt.3 = 30% damping (1<sup>st</sup> mode) [ $ic = \$180,000$ ]
- Piping system: Add transverse and longitudinal braces ( $ic = \$120,000$ )



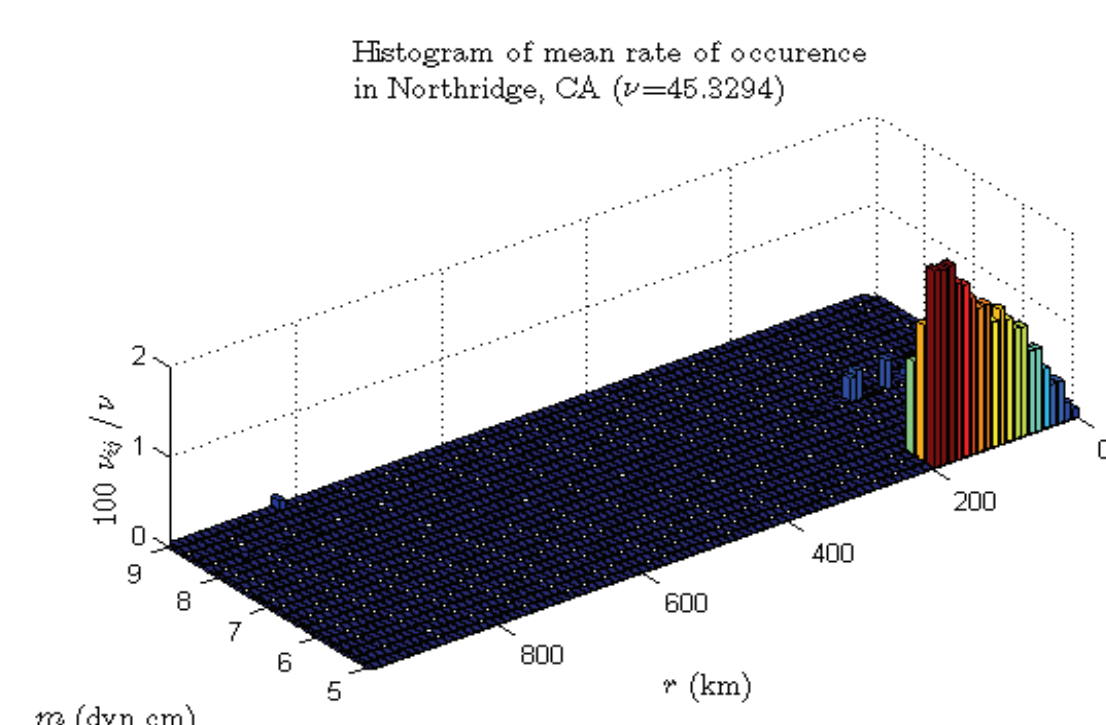
### SEISMIC HAZARD

**Location:** Northridge, CA

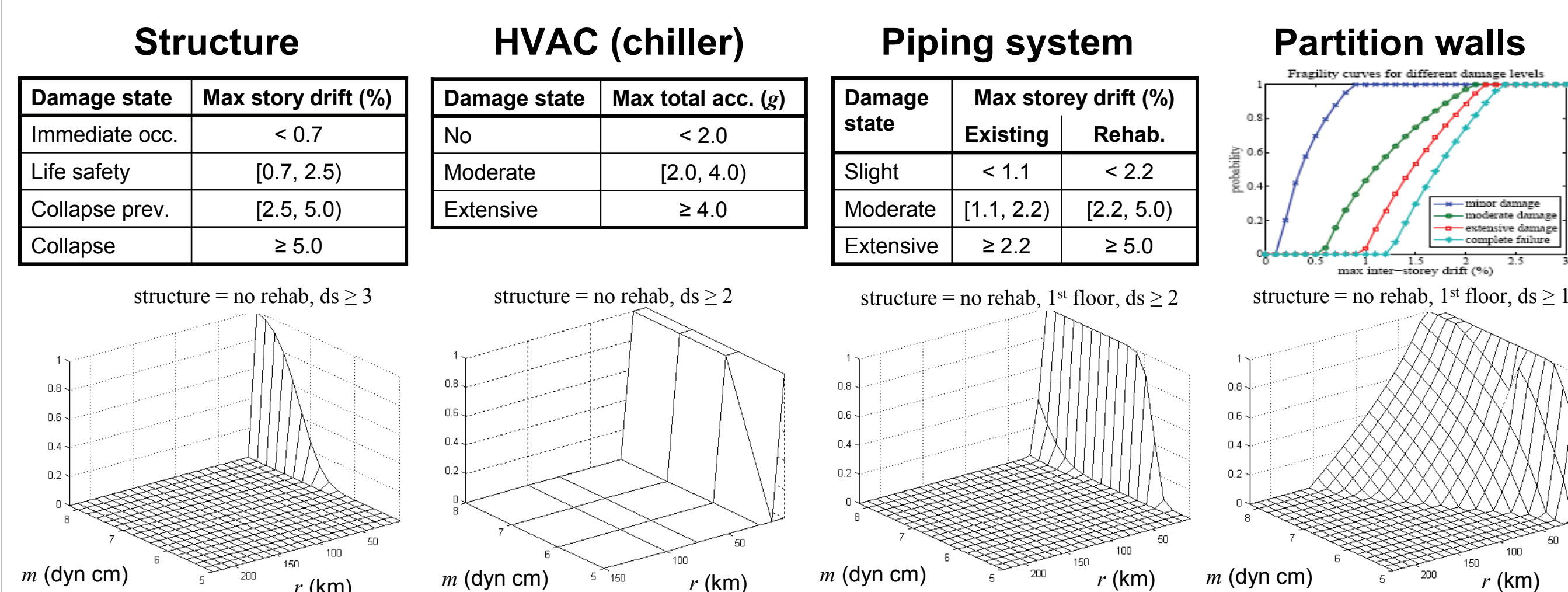
**Soil type:** Stiff soil (NEHRP site class D)

**Lifetime:** 50 years

**Ground motion model:** Specific barrier model



### FRAGILITY INFORMATION



### CAPACITY and COST ESTIMATION

**Structure:** 93 acute care beds (43 on 2<sup>nd</sup> and 50 on 3<sup>rd</sup> floors). Net revenue = \$1,500/bed/day

Damage state	Repair/replacement cost (\$)	Consequences
Immediate occupancy	280,000	Hospital is 100% operational
Life safety	1,512,000	2 years of repair with 5% capacity loss
Collapse prevention	67,500,000	4 years of reconstruction
Collapse	67,500,000	4 years of reconstruction

**HVAC:**

Damage state	Repair/replacement cost per HVAC (\$)	Consequences per HVAC
No	0	No capacity losses
Moderate	90,000	50% of the beds are lost for 2 days
Extensive	500,000	50% of the beds are lost for 20 days

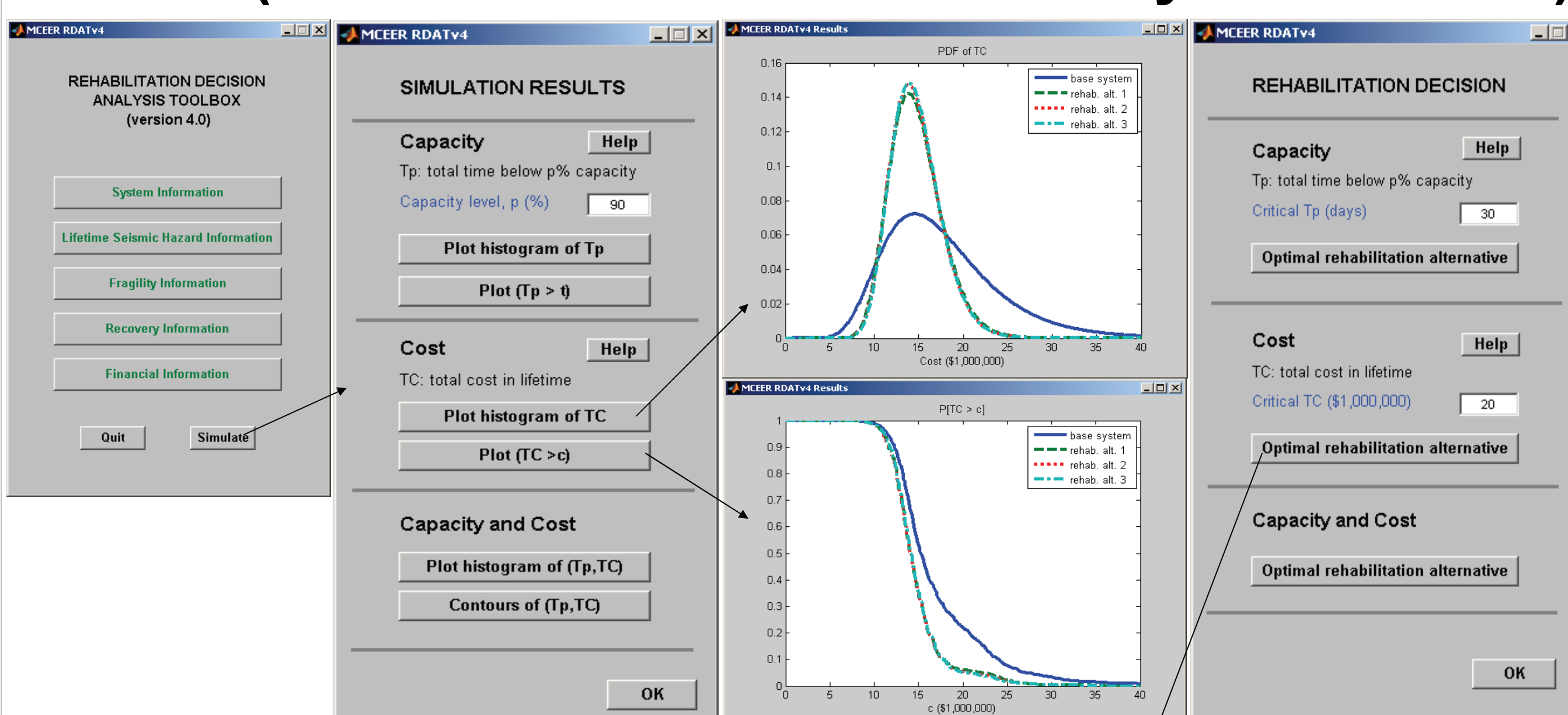
**Piping system:**

Damage state	Repair/replacement cost per wall (\$)	Consequences per wall
No	0	No capacity losses
Minor	230	Effectuated beds are unavailable for 1 day
Moderate	460	Effectuated beds are unavailable for 2 days
Extensive	690	Effectuated beds are unavailable for 3 days
Complete failure	920	Effectuated beds are unavailable for 3 days

**Partition walls:**

Damage state	Repair/replacement cost per floor (\$)				Consequences per floor
	1	2	3	4	
Slight	1,100	1,690	1,690	900	No capacity losses
Moderate	1,720	4,380	4,380	2,290	10% of the beds are lost for 7 days
Extensive	1,860	4,950	4,950	2,290	25% of the beds are lost for 30 days

### RDAT (Rehabilitation Decision Analysis Toolbox)



### CONCLUSIONS

A method was developed to identify an optimal retrofitting technique for structural/nonstructural systems. The method is based on Monte Carlo simulation, probabilistic seismic hazard, fragility surfaces and capacity/cost analyses and applied to the MCEER West Coast Demonstration Hospital.

### ACKNOWLEDGEMENTS

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