The 4 R’s of Resilience and Multi-Hazard Engineering

(The Meta-Concept of Resilience)

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MCEER Vision

“The overall goal of MCEER is to enhance the disaster resilience of communities through improved engineering and management tools for critical infrastructure systems.”
Dimensions, Components, or Properties of Resilience

- **Robustness**: Inherent Strength, Resistance
- **Redundancy**: System Properties That Allow for Alternative Options, Choices, Substitutions
- **Resourcefulness**: Capacity to Mobilize Needed Resources
- **Rapidity**: Speed With Which Disruption Can Be Overcome & Service, Income, etc., Restored
Lack of Robustness:

Bam Earthquake, 2003: Adobe Construction

Hurricane Katrina: Levee Breaks, 2005
Lack of Redundancy:

Hurricane Katrina, 2005: Auto-Dependent Evacuation

World Trade Center Attack, 2001: No Alternate EOC
Lack of Resourcefulness:

Pakistan Earthquake, 2005: Disaster Far Exceeds Societal Capacity

Indian Ocean Tsunami, 2004: No Effective Warning System
Lack of Rapidity:

Katrina Victims Await Help
General Framework for Quantification: Extent of Disruption and Recovery Time

Quality of Infrastructure (percent)

0
50
100

t_0

time

EARTHQUAKE ENGINEERING TO EXTREME EVENTS
General Framework for Quantification: Extent of Disruption and Recovery Time

Loss of Resilience

Quality Of Infrastructure (percent)

$0 \\ 50 \\ 100$

t$_0$

time

EARTHQUAKE ENGINEERING TO EXTREME EVENTS
General Framework for Quantification: Extent of Disruption and Recovery Time

- Quality Of Infrastructure (percent)
  - 100
  - 50
  - 0

- Loss of Resilience

- Resilience Triangle

- t₀

- Time
General Framework for Quantification: Extent of Disruption and Recovery Time

Community Resilience

Quality Of Infrastructure (percent)

Resilience Triangle

t₀

Time
General Framework for Quantification: Extent of Disruption and Recovery Time

Community Resilience

Quality Of Infrastructure (percent)

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General Framework for Quantification: Extent of Disruption and Recovery Time

Community Resilience

Quality of Infrastructure (percent)

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$t_0$

Time
Adding Resourcefulness Dimension
Adding Redundancy Dimension

Hospital #1

Hospital #2

Linkages
General Framework for Quantification: Extent of Disruption and Recovery Time
General Framework for Quantification: Extent of Disruption and Recovery Time

Quality Of Infrastructure (percent)

0 50 100

t₀
time

resilience
THE CONCEPT OF

r^4

resilience
The Four Fundamental Properties of Resilience

- Robustness
- Redundancy
- Resourcefulness
- Rapidity
MCEER Resilience Framework

- Understand resilience (multidisciplinary perspectives)
- Define resilience and dimensions of resilience
- Models to quantify resilience
- Incorporate resilience measures into Decision Support Systems
- Test and analyze resilience models, with an emphasis on selected critical infrastructures (MCEER Testbeds)
Further Elaboration: Resilience Domains

- **Technical**: Physical Systems—Location-Based & Distributed Critical Facilities
- **Organizational**: Attributes, Dynamics of Organizations & Institutions
- **Social**: Attributes, Dynamics of Communities and Populations
- **Economic**: Attributes, Dynamics of Local and Regional Economies & Their Constituent Units (e.g. Businesses)
## Resilience Property Space & Examples

<table>
<thead>
<tr>
<th>Dimension/Domain</th>
<th>Technical</th>
<th>Organizational</th>
<th>Social</th>
<th>Economic</th>
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</thead>
<tbody>
<tr>
<td><strong>Redundancy</strong></td>
<td>Capacity for Technical Substitutions, “Work-Arounds”</td>
<td>Alternate Sites for Managing Disaster Operations</td>
<td>Availability of Housing Options for Disaster Victims</td>
<td>Ability to Substitute, Conserve Needed Inputs</td>
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<td><strong>Resourcefulness</strong></td>
<td>Availability of Materials for Restoration, Repair</td>
<td>Capacity to Improvise, Innovate, Expand</td>
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<td>Extensiveness of Emergency Operations Planning</td>
<td>Social Vulnerability/Resilience Indicators</td>
<td>Extent of Economic Diversification</td>
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**Social Sciences Challenge** *(Inherently Multi-hazard)*
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Interdependency of R’s

- Structural Engineering:
  - Greater “Robustness” typically result in enhanced “Rapidity”
  - Redundancy positively impact Robustness

- Organizational
  - Redundancy and Resourcefulness impact Rapidity
  - Etc.
Multi-hazard solution

- A true multi-hazard engineering solution is a concept that simultaneously has the desirable characteristics to protect and satisfy the multiple (contradicting) constraints inherent to multiple hazards
- Needs holistic engineering design that address all hazards in integrated framework
- A single cost single concept solution (not a combination of multiple protection schemes)
- Pay-off: Reach/protect more cities/citizens
Conclusions

- Rigorous system-level multi-hazard design is a new challenge – an emerging field

- Objective of Symposium:
  - Review emerging developments in multi-hazard engineering – work of researchers and practicing engineering in this new field
  - Identify multi-hazard engineering community
  - Identify benefits of multi-hazard engineering
  - Identify (from engineering perspective) the path(s) forward for multi-hazard engineering (implementation, public-policy, etc.)
Thank you!

Questions?