It’s Not Just About Buildings:
Earthquakes and People

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‘It’s not just about buildings’ example

NICU patient evacuation at NYU in Superstorm Sandy (no access to elevators, electronic medical records, or telephone service; 3-6 staff required/infant to evacuate).
‘It’s not just about buildings’ example

Bucket brigade at Bellevue in Superstorm Sandy by social workers, nurses, medical students, radiology technicians, physicians, and secretaries. The flooding of the basement took out pumps required to get diesel fuel to backup generator on 13th floor.

(Khithani et al., 2014)
‘It’s not just about buildings’ example

Onsite staff quarters in Nepal ensured staff were available after the earthquake. Example above are doctors’ and Director’s housing at Gorkha District Hospital.
‘It’s not just about buildings’ example

Several conflicting physical inspections of the Mexicali General Hospital and hospital staff’s fear to inhabit a possibly damaged structure led to the closure of the hospital.
To the surprise of this engineer, maintaining hospital functions is clearly not just about buildings.

How do we account for human infrastructure to manage mass care needs?
Surge after Disasters

Kelen and McCarthy (2006) define surge as a “sizable increase in demand of medical or public health resources compared with a baseline demand” and composed of the following components:

- Patient influx (volume rate)
- Event (type, scale, and duration)
- Resource demand (consumption and degradation)

Surge Capacity

Barbisch and Koenig (2006) correctly state that *surge capacity* is not simply about beds and ventilators, but:

- **Staff** (trained personnel)
- **Structure** (functional facilities)
- **Stuff** (comprehensive supplies and equipment)
- **Systems** (integrated policies and procedures)

Functional Failure of Hospital Services

Simplified emergency department is disabled.

Emergency department staff are unavailable
10

Emergency department space is unavailable
11

Emergency department space cannot be accessed
4

Emergency department space is damaged
5

Critical infrastructure fails
6

Physicians are unavailable
1

Nurses are unavailable
2

Non-Clinical Staff are unavailable
3

Critical infrastructure is damaged
4

Capital Equipment (Clinical)
5

Re-useable Equipment (Clinical)
6

Supplies (Clinical)
7

Clinical capital equipment is unavailable
7

Clinical re-useable equipment is unavailable
8

Clinical supplies are unavailable
9

Licensed Staff (Physicians)
1

Licensed Staff (Nurses)
2

Non-Licensed Staff (Non-clinical)
3

Coordination area severely damaged
1

Exits unavailable
2

Structural damage occurs
3

Non-structural damage occurs
4

Basic Event: a failure in a system component and corresponds to data collected in the field study.

Intermediate and Top Events: The failure (e.g., complete or partial loss of function of a hospital service) that is being assessed and the system states that contribute to the top failure.

OR Gate: The output event associated with this gate is true if at least one of the input events exist (e.g., means of egress are impacted if either horizontal or vertical means of egress are severely damaged).

AND Gate: The output event associated with this gate is true if all input events exist (e.g., water infrastructure fails when the municipal water and the back-up water systems fail).
Functional Failure of Hospital Services

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- **Nurses are unavailable**
- **Non-Clinical Staff are unavailable**
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- **Emergency department space is damaged**
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Service-Specific Fault Tress

Jacques (2016) developed a survey tool to determine topology of fault-trees for major clinical and non-clinical support services for acute-care hospitals in the US, including five areas:

- **Staff**
- **Infrastructure**
- **Capital equipment**
- **Reusable equipment and supplies**
- **Interdependencies**

Experts were interviewed across 16 service areas at JHMI, and were asked to identify required resources for daily and surge (disaster) conditions of their specific service area.
Figure 4.10. Staff needs of interviewed services at Johns Hopkins Hospital by category

Black lines: the staff are needed both under normal conditions and in emergencies
Green lines: the staff are only needed under normal conditions
Red lines: the staff are only needed in emergencies
Fault Tress for Single Staff Type

[Diagram of fault tree for single staff type in adult emergency department physicians]
Functioning of Single Healthcare Facility
Functioning of Single Healthcare Facility

**Graph:**
- **Title:** Q_f for Christchurch Hospital - Comparison
- **Axes:**
  - Y-axis: Functional Resilience Metric Q_f
  - X-axis: Time (days)
- **Legend:**
  - Real
  - Simulated

**Inset:**
- **Title:** Exponential recovery
- **Axes:**
  - Y-axis: Functionality Q_f [%]
  - X-axis: Time (t)
Functioning of Multiple Networked Healthcare Facilities
Network structure for the healthcare system in the Canterbury region based on staff sharing agreements, including the facilitation provided by the CDHB.
Network structure excluding the facilitation provided by the CDHB. Black lines indicate that directed edges exist in both directions. Gray arrows indicate directed edges exist only in that direction.
Network structure based on staff sharing agreements, including the facilitation provided by the CDHB, with Christchurch Hospital and Christchurch Women’s Hospital removed.
Network structure based on staff sharing agreements, excluding the facilitation provided by the CDHB, with Christchurch Hospital and Christchurch Women’s Hospital removed.
Concluding Remarks

- People matter A LOT, so we need occupancy-specific models that incorporate human infrastructure in order to assess continued functionality of healthcare facilities and systems.
- Incorporate features of “ready-willing-able” framework and Witte’s Extended Parallel Process Model (EPPM) to better predict personnel reporting to work after an event.
- Need to capture the ‘networked’ system of buildings that provides specific community services.
- Need performance metrics that are relevant to the entire system and to the stakeholders managing these institutions.
- These tools, considering failures in personnel of an organization, are not simply an academic exercise – we developed a one-day workshop for Utah’s Department of Health where these fault trees were used as an activity for an earthquake scenario exercise.
Thank You
Critical infrastructure-Based Societal Systems (ClbSS)
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Population Displacement

Photo: Andrea Booher/FEMA

Food Security

Photo: ShamSuddin Ahmed/IRIN

Economy Security

Photo: Canterbury Earthquake Recovery Authority (CERA)

Healthcare Delivery

Photo: Judith Mitrani-Reiser/JHU