FRAMEWORK OF SEISMIC RESILIENCE AND RECOVERY OF HOSPITAL CLUSTER

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Purpose

- Understand hospitals functionality and the hospitalization service.
- Study community resilience and recovery after major seismic events.
- Investigate the factors causing the reduction of the hospitalization service after the EQ hazard.

Significance

- Introduce enhanced framework to estimate hospitalization service in a community.
- Evaluate the dependence of community infrastructure on the seismic performance of a hospital building.
- Introduce a community recovery model for essential infrastructure while accounting for interdependencies between lifelines.

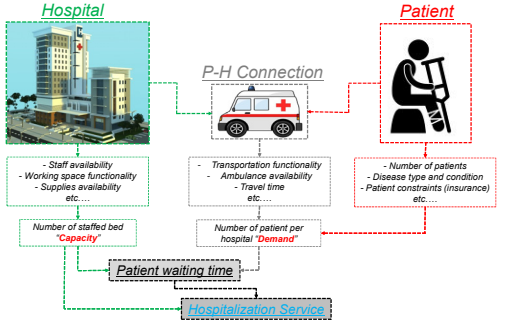
Patient received the hospitalization service in the street (Central Mexico earthquake 2017)

Patient transferred from St. John's Regional Medical Center, Missouri (2011)

Methodology

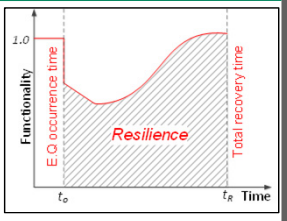
Hospitalization service:

The main components controlling the availability of service: *Hospitals capacity, Demand* and P-H Connection



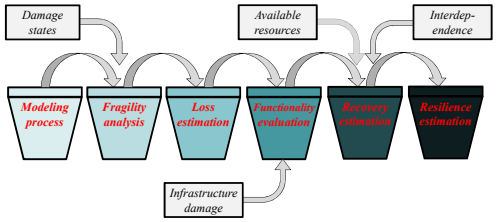
Resilience definitions:

1. Capacity to recover quickly from disruptions.
2. Ability to provide required level of functionality for a building.
3. *Area under the functionality curve.*



Resilience framework:

- Analytical resilience framework implemented to estimate infrastructure resilience.



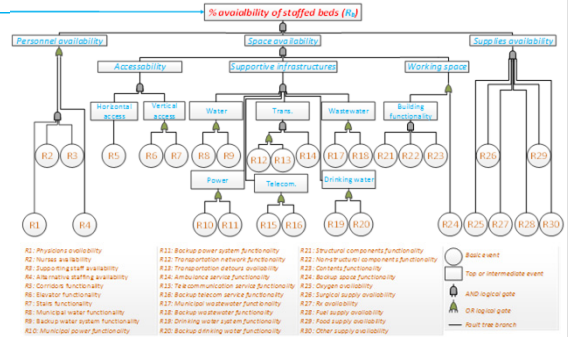
Hospital Functionality Assessment

Hospital Capacity $B_a(t)$:

- Hospital capacity expressed in terms of number of staffed beds available $B_a(t)$.
- Every staffed bed required: Personnel, space and supplies availability to run.

- Fault tree analysis consists of *And* & *Or* gates, top or intermediate events and basic events selected to evaluate staffed beds availability.

$B_a(t) = B_0 * R_a(t)$ "Fault tree analysis"

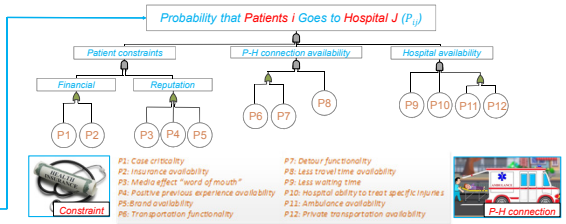


Hospital Demand $N_a(t)$:

- Hospital demand is estimated based on patient selection or case criticality *(patient-driven model)*.
- Fault tree analysis implemented to estimate the probability of a patient going to each hospital.

$N_a(t) = \sum [\max P_{ij} \mid j=J]$ "Patient-driven model"

$P_{ij} = [P_{i1}\ P_{i2}\ P_{i3}\ \ldots\ P_{in}]$ "Fault tree analysis"



Patient waiting time $W_t(t)$:

- *Time to receive the hospitalization service.*

$W_t(t) = \boldsymbol{a_0} + \boldsymbol{T_{tvl}}(t) + a_t[B_0 - B_a(t)]/B_0 + a_e[N_a(t) - N_0]/N_0$

- *Function on travel time, hospital capacity and demand.*

Hospitalization service $F_t(t)$:

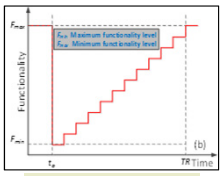
- *Function on hospital capacity and patient waiting time.*

$Q_v(t) = B_a(t)$

$Q_S(t) = [W_{t,max} - W_t(t)]/[W_{t,max} - W_0]$

$F_t(t) = Q_S^{\alpha_S} * Q_V^{\alpha_V}$

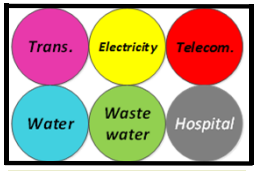
Infrastructure Recovery



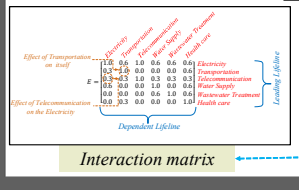
Functionality stages

Markov chain process (stochastic model)

$$Q_n(k\,\Delta\,t) = Q_n(0) * \prod_{j=0}^{k-1} A_n P_n(x_n \mid j\,\Delta\,t)$$



Six different lifelines investigated

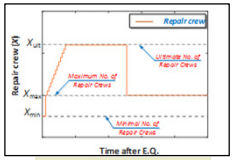


Interaction matrix

Optimization was conducted to distribute the limited resources to maximize income return (R)

$Maximize\ R(t) = \sum Rn$
Subjected to: $X(t) = \sum x_n$
and: $x_n \leq x_{max}$

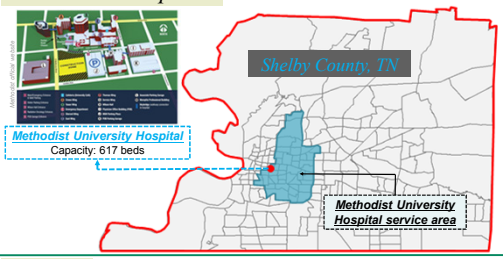
Optimization



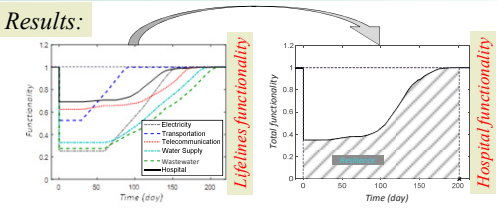
Repair resources

Case Study (Shelby County, TN)

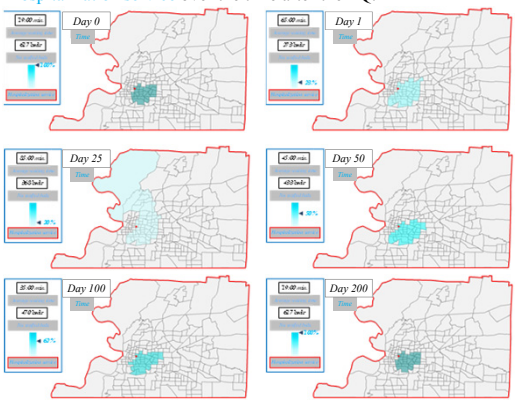
Problem Description:



Results:



- Change in service area, waiting time, number of staffed beds and hospitalization service over the time after the EQ.



Conclusion

- Hospitalization service depends on personal, space and supplies availability in addition to the demand on the hospitals.
- Patient's selection of the hospital is sensitive and changes with time.
- The backup systems are essential for the hospitals to ensure acceptable level of the hospitalization service after the EQ hazard.

Future Research

- Validate the introduced frameworks for both the hospitalization service functionality and EQ recovery against field data.
- Apply the frameworks to Memphis Metropolitan Area, which is considered a larger scale testbed.
- Introduce recommendations for healthcare managements to enhance hospitalization service during and after the EQ hazard.