Capturing Socio-Physical Interaction Towards Reducing the Impact of Extreme Events

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NASEM Workshop: Compounding and Cascading Events
Mitigating Impacts: Developing Solutions and Avoiding Unintended Consequences

Levers to Reduce Impact

Examples of how we can intervene short-term and long-term to reduce the impact of extreme events

Infrastructure and Space

- *Arrange for additional/temporary spaces (S)*
- *Plan for quick mobilization of repair crews (S)*
- *Retrofit existing structures or use enhanced structures (L)*
- *Reduce interdependencies among infrastructure (L)*
- *Provide backup systems and temporary housing (L)*

Supplies

- *Consider alternative supplies (S)*
- *Provide immediately supplies (S)*
- *Facilitate transfer of supplies (S)*
- *Consider alternative suppliers (S/L)*
- *Provide redundant supply-chain (L)*

People & Personnel

- *Educate the public and communicate expectations (S)*
- *Accessibility of personnel to infrastructure (S)*
- *Facilitate staff transfer (S)*
- *Arrange additional/trained personnel and volunteers (S/L)*
- *Relocate Population (land use / zoning) (L)*

Capturing ***Socio-Physical Interaction*** is key to determine effective **short-term and long-term strategies** for mitigating the impact of compounding and cascading hazards prior **to the events and during recovery**

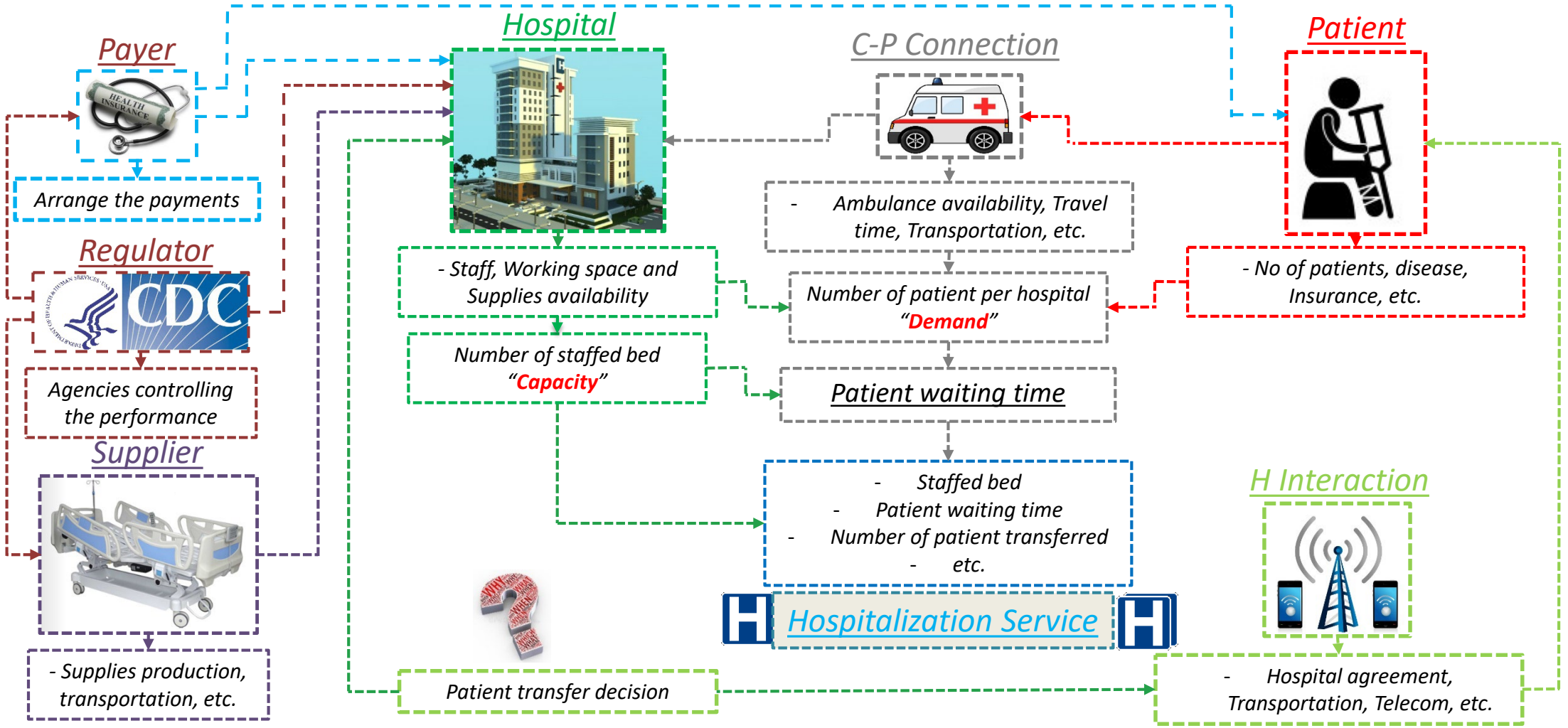
S = few days to a month
L = few months to year(s)

Capturing Socio-Physical Interaction

Healthcare Resilience

Understanding Healthcare Service

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



Hassan and Mahmoud (2019), ***Eng. Struct.***

Hospital Demand

Patients classification:

- *Regular* patients
- *Event-related* patients

Different severity levels:

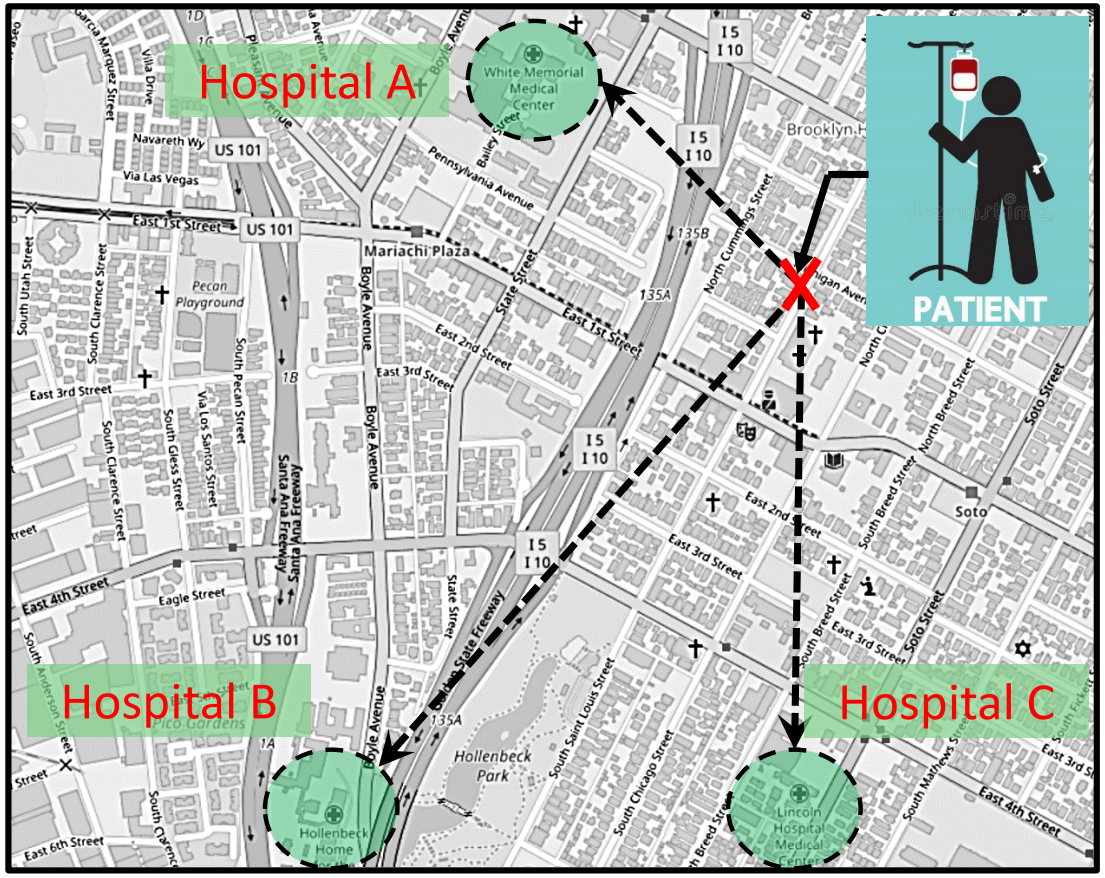
- Severity 1 (*no medical* care needed)
- Severity 2 (*some medical* care needed)
- Severity 3 (*immediate medical* care needed)
- Severity 4 (*death*)

Normal operating conditions:

- Calculated based on: *Statistical data*
- Distributed using: *Hospital service areas*

Emergency operating conditions:

- Calculated based on: *Social losses*
- Distributed using: ***Patient driven model***



Hassan and Mahmoud (2020), ***Rel. Engr. & Sys. Safety***.

Hospital Interaction

Hospital interaction includes:

- *Change in number of patients*
- *Transfer resources*

Hospital can transfer:

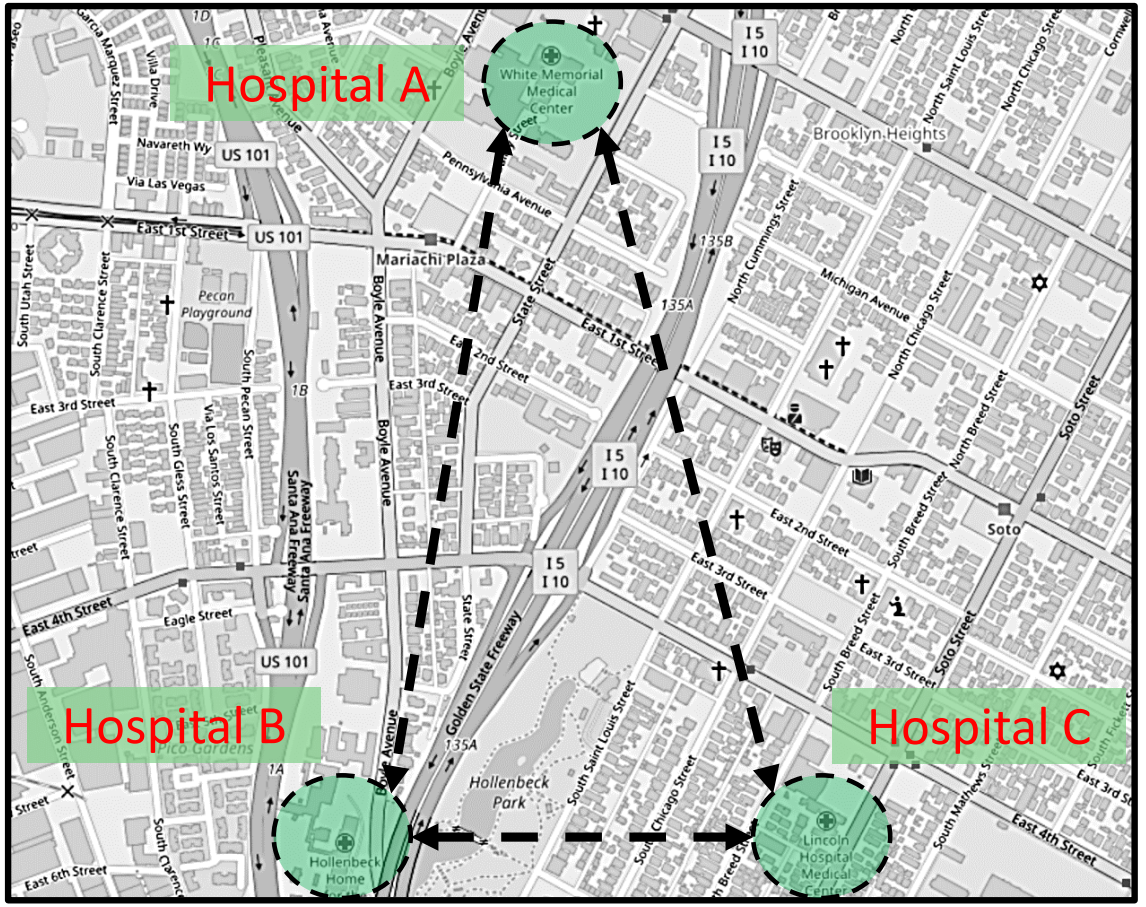
- *Patients*
- *Patients' records*
- *Staff*
- *Supplies*
- *Repair resources*

Transfer process is function of:

- *Patient constraints and hospitals connection*
- *Capability of the receiver hospital to treat the patient*

Hospitals will transfer patient if:

- *Hospital reaches the capacity*
- *Patient case cannot be treated*



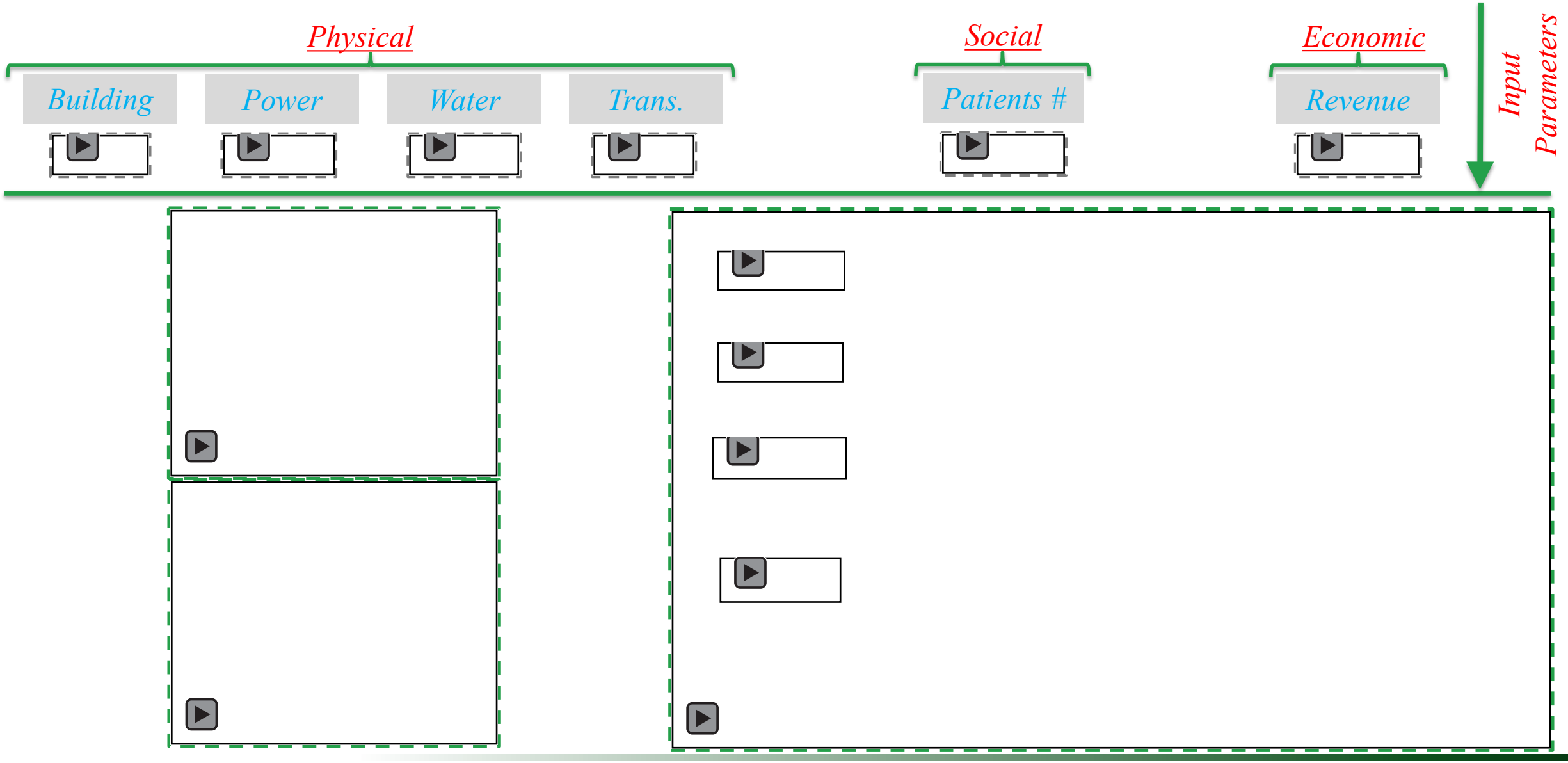
Hassan and Mahmoud (2020), ***Rel. Engr. & Sys. Safety***.

Mainshock – Aftershock Sequences

Healthcare Resilience - ***Impact is driven mainly by*** ***infrastructure Damage***

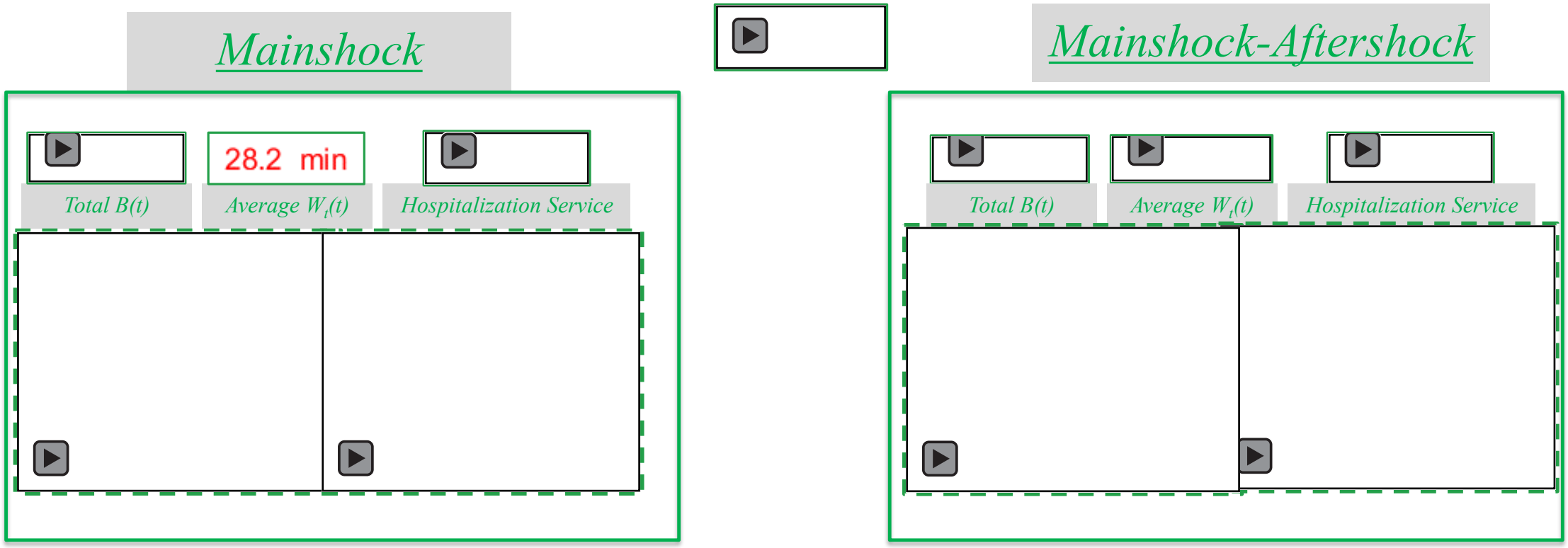
Response to a Single Event

Motivation | Socio-Physical | Cascading | Compounding



Response to Cascading Events

- The main Aftershock assumed to strike the community after 18 days from the Mainshock



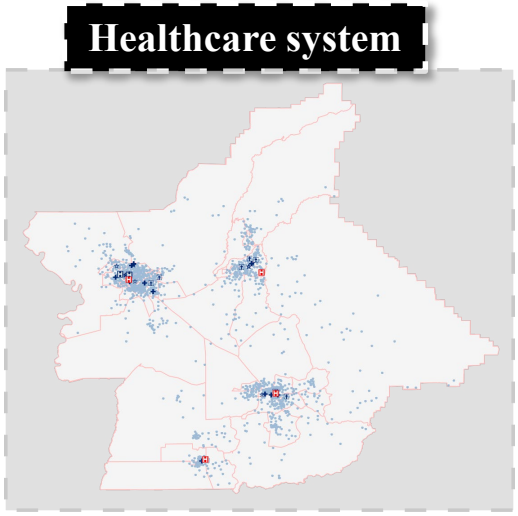
- The healthcare service resilience was reduced in the case of the Mainshock and Aftershock
- The recovery time of most of the hospitals' functionality increased in the case of the Mainshock and Aftershock

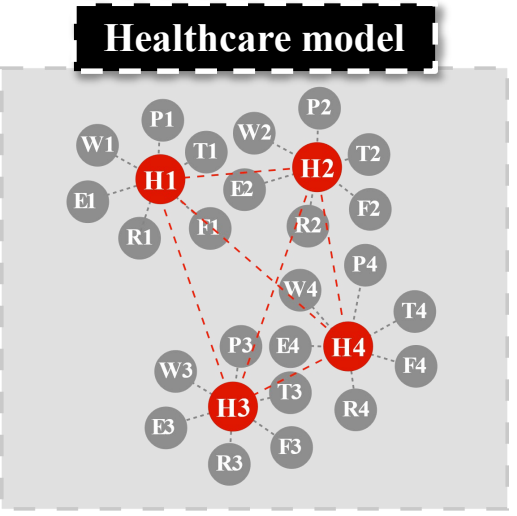
Wildfire and Pandemic

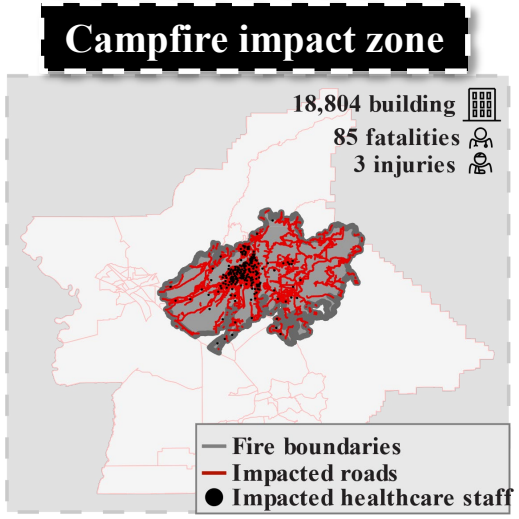
Healthcare Resilience - *Impact is driven by* *Human Losses and Infrastructure Damage*

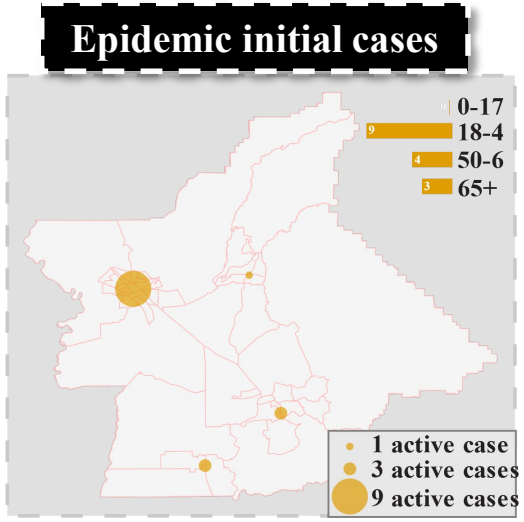
Pandemics and wildfires – Demand Distribution

- Area of interest is *Butte County, CA*
- The 2018 *Camp Fire* that occurred in Paradise is combined with the 2020 *COVID-19 pandemic*
- How a *healthcare system* might be impacted by *wildfire* striking during *epidemic*?
- *What strategies* can be used *and when* to lower the impact of the compounding events?



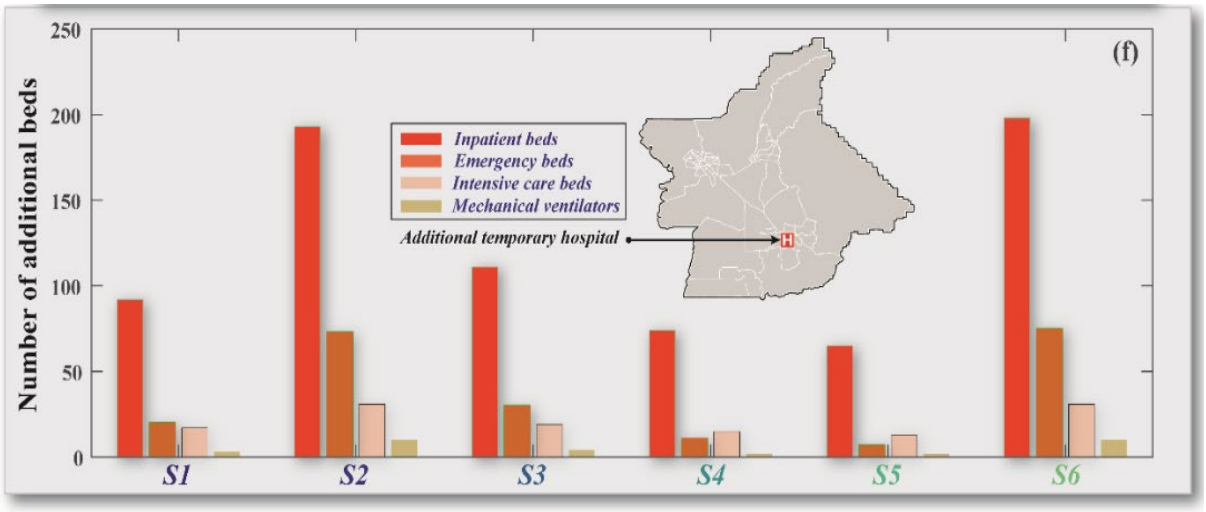


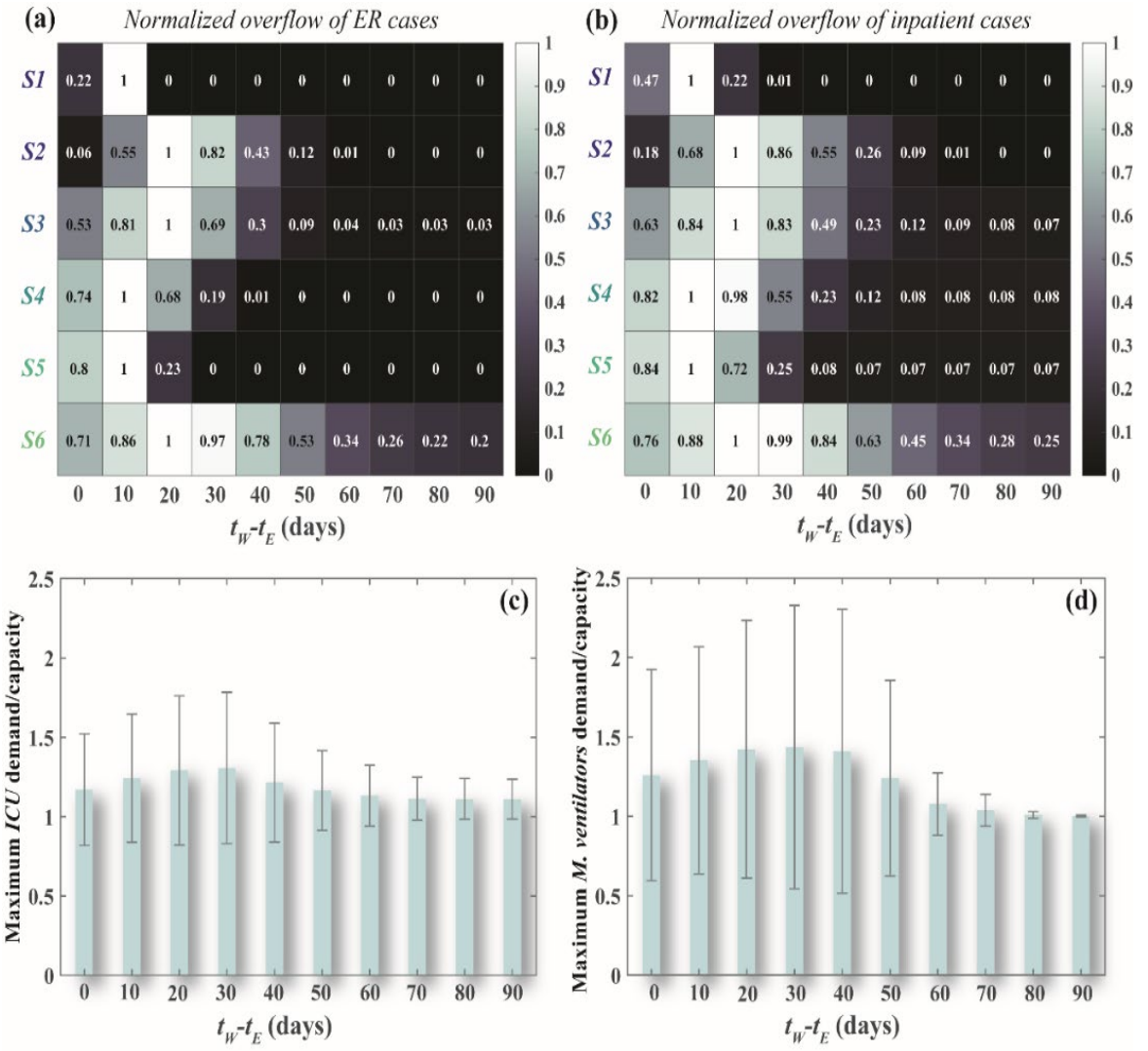




Resource Allocations for the Compounding Events

- The highest value of *ER and inpatient overflow when* wildfire is 10 to 20 days after the outbreak
- The *ICU and mechanical ventilator* demand can increase by *31% and 44%, respectively*
- *Optimization* for the *location and number of different staffed beds* are shown





Hassan and Mahmoud (2021), ***Nat. Commun.***

Summary

- Short-term and long-term strategies will vary depending on the nature of the events
- The spatio-temporal characteristics of the hazards will dictate whether the focus should be on short-term or long-term strategies or both
- Critical to the development of successful strategies is to understand the system of systems behavior
- Strategies should entail a combination of solutions that entail infrastructure, personnel and supplies

NIST National Institute of Standards and Technology U.S. Department of Commerce
NSF
RAPID NHERI Natural Hazards Reconnaissance
NATURAL HAZARDS CENTER
NCDMPH National Center for Disaster Medicine & Public Health

My Students, Visiting Scholars and Collaborators