NIST National Construction Safety Team Investigation of Hurricane Maria

NCST Advisory Committee Meeting – June 14, 2023

Cross-Project Panel Theme 3: Infrastructure Dependencies

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NIST | NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Infrastructure Dependencies Theme: Motivation

- Hurricane Maria's infrastructure impacts included:
  - Complete electrical outage across Puerto Rico
  - Severe physical damage to electric power generation, transmission and distribution systems, including utility-scale solar and wind power generation
  - Cascading effects of electrical outage: water, wastewater, communications
  - Near complete loss of digital communications
  - Severe physical damage to tower- and building-mounted cellular communications equipment
  - Damage to miles of fiber optic cable, impacting wireless and wireline communications
- Infrastructure serves as an important connection across all seven technical projects

Infrastructure Dependencies Theme: Integration of Data Streams

Emergency Communications:

Post-storm accessibility issues for infrastructure reported by households

Morbidity and Mortality:

Transportation accessibility of healthcare

Lack of power and water for deceased

Lack of infrastructure to hospitals

Recovery of Infrastructure:

Networks geodatabase

Transportation events, power crew assignments, and aerial imagery for damage assessment

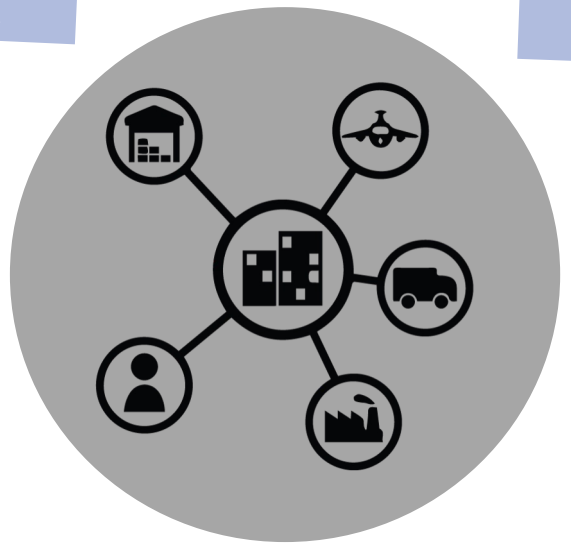
Time to recover services

Critical Buildings:

Infrastructure disruptions and performance of backup systems for hospitals and shelters

Recovery of Business and Supply Chains:

Disruption of power, water, cell, internet, transportation for businesses



Hazard Characterization:

Impact of power loss on measurement of wind, rainfall

Hazard exposure of various infrastructure (e.g., towers, bridges, transmission lines)

Recovery of Social Functions:

Disruption of power, water, cell, internet, transportation for schools and hospitals

Infrastructure Dependencies Theme: Integration of Analysis

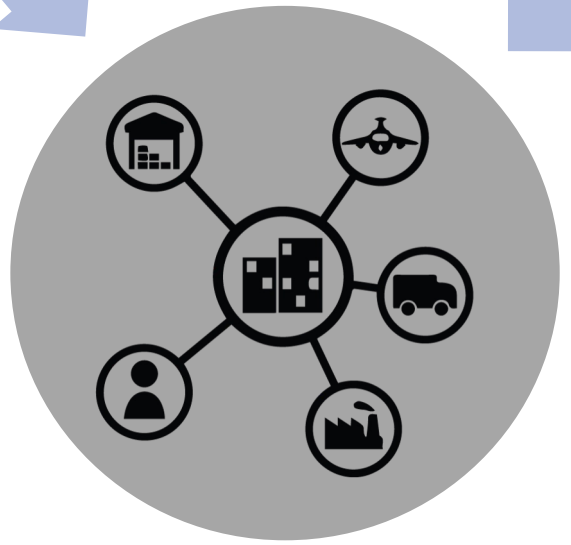
Emergency Communications:
How did the loss of infrastructure impact emergency communications and evacuation?

Morbidity and Mortality:
How did the loss of infrastructure impact mortality?

Recovery of Infrastructure:
What slowed recovery of infrastructure services?

Critical Buildings:
How did infrastructure disruptions affect building function for hospitals and shelters?

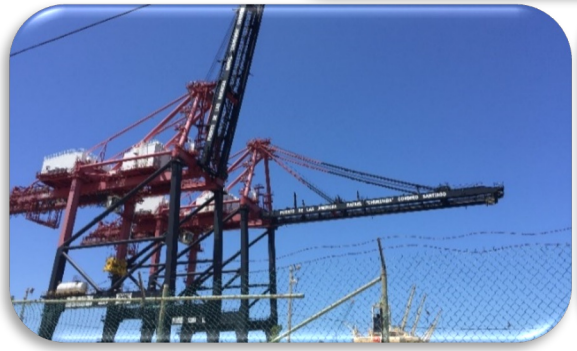
Recovery of Business and Supply Chain:
How did infrastructure disruptions for businesses affect recovery?



Hazard Characterization:
How were hazard measurement systems impacted by loss of infrastructure?

Recovery of Social Functions:
How did infrastructure disruptions for schools and hospitals affect recovery?

Infrastructure Dependencies – Highlighted Projects



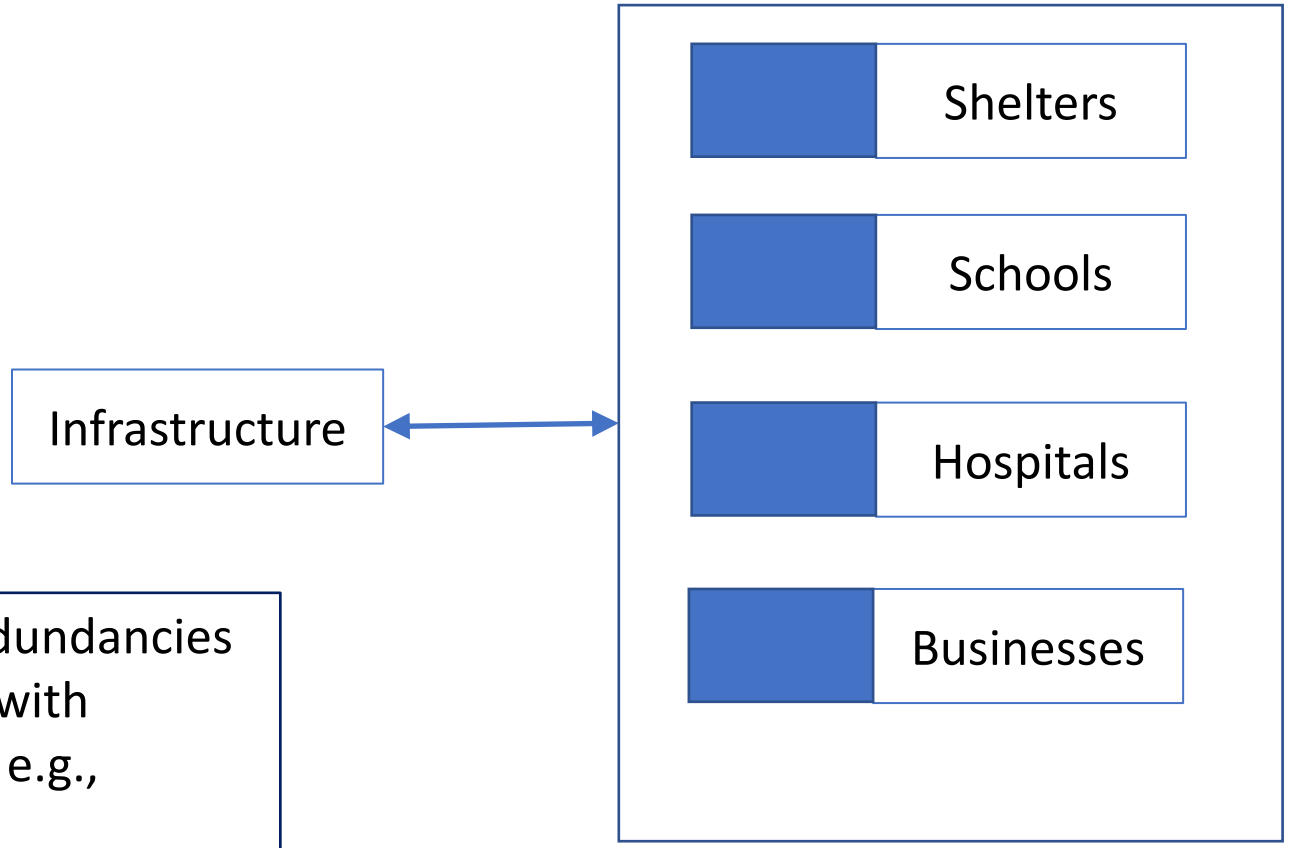
- Impacts to and Recovery of Infrastructure
- Morbidity and Mortality
- Recovery of Business and Supply Chains & Recovery of Social Functions

Infrastructure Dependencies – Highlighted Projects

- **Impacts to and Recovery of Infrastructure**
- Morbidity and Mortality
- Recovery of Business and Supply Chains & Recovery of Social Functions

Role of Infrastructure

- **Infrastructure supports critical building functionality**
- **Buildings can endure temporary loss of infrastructure service**



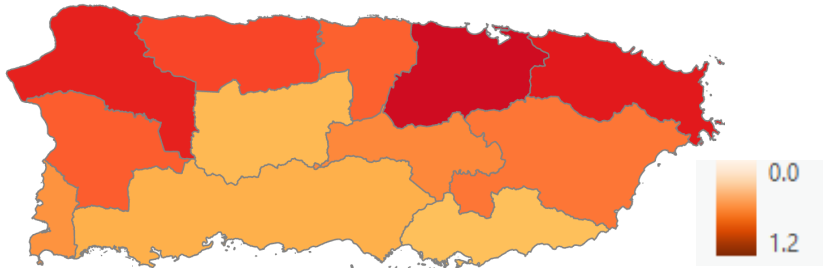
= Storage and other redundancies to maintain function with disruptions in inputs, e.g.,
- Power generators
- Tanks (e.g., potable water)
- Redundant service lines (e.g., multiple access roads)

Hurricane Maria Damage to Infrastructure

- Wireless: damage to cell towers
- Power: repair intensity is less in south central part of PR, as measured by work effort per km of distribution system; work effort proxied by number of PREPA crew assignments after HM
- Transportation: highest incidence rate on secondary roads in interior municipios not served by a primary road; for primary roads, higher incidence rate in more remote areas

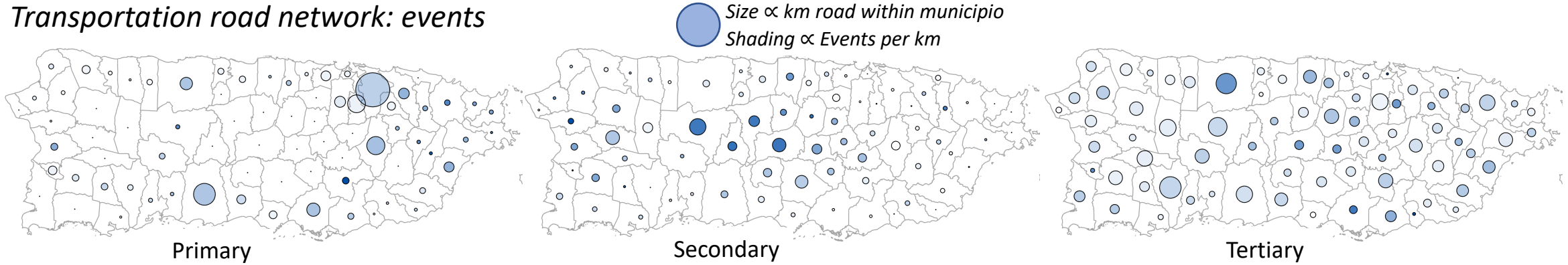
Wireless comm: cell tower collapse

Power: crew assignments per km distrib.



PRELIMINARY DATA ANALYSIS

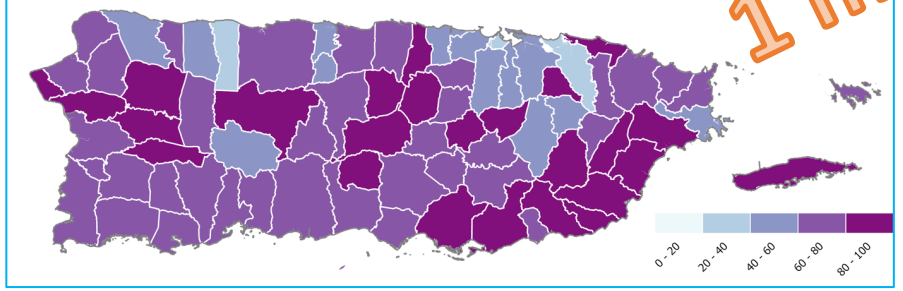
Transportation road network: events



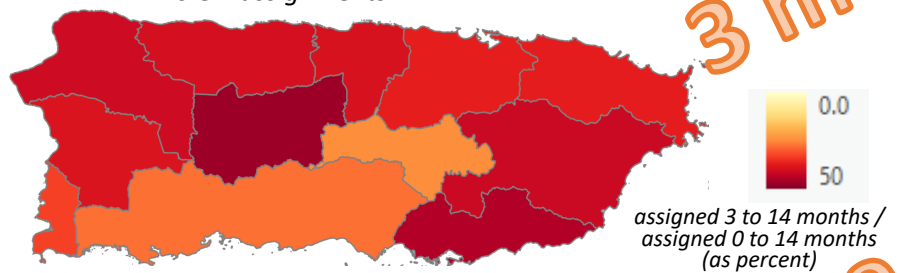
Recovery of Infrastructure

- Wireless and Transportation at 1 month:
  - In most municipios, more cell sites *out-of-service* than *in-service*
  - Nearly all primary and secondary roads are either fully or partially clear; tertiary road status is unknown
- Power at 3 months:
  - Depending on region, 25 to 50%, of HM PREPA crew assignments occur after three months

Wireless communications:
Percent Cell Service Sites Out-of-Service - 10/24/2017

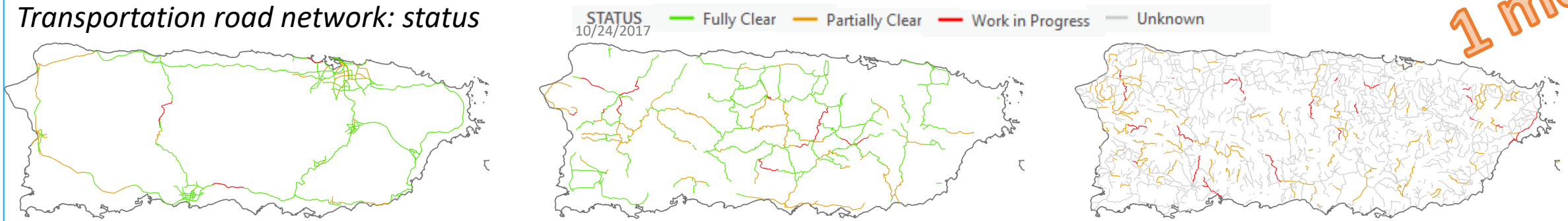


Power: *Work effort remaining 3 months out, as measured by PREPA crew assignments*

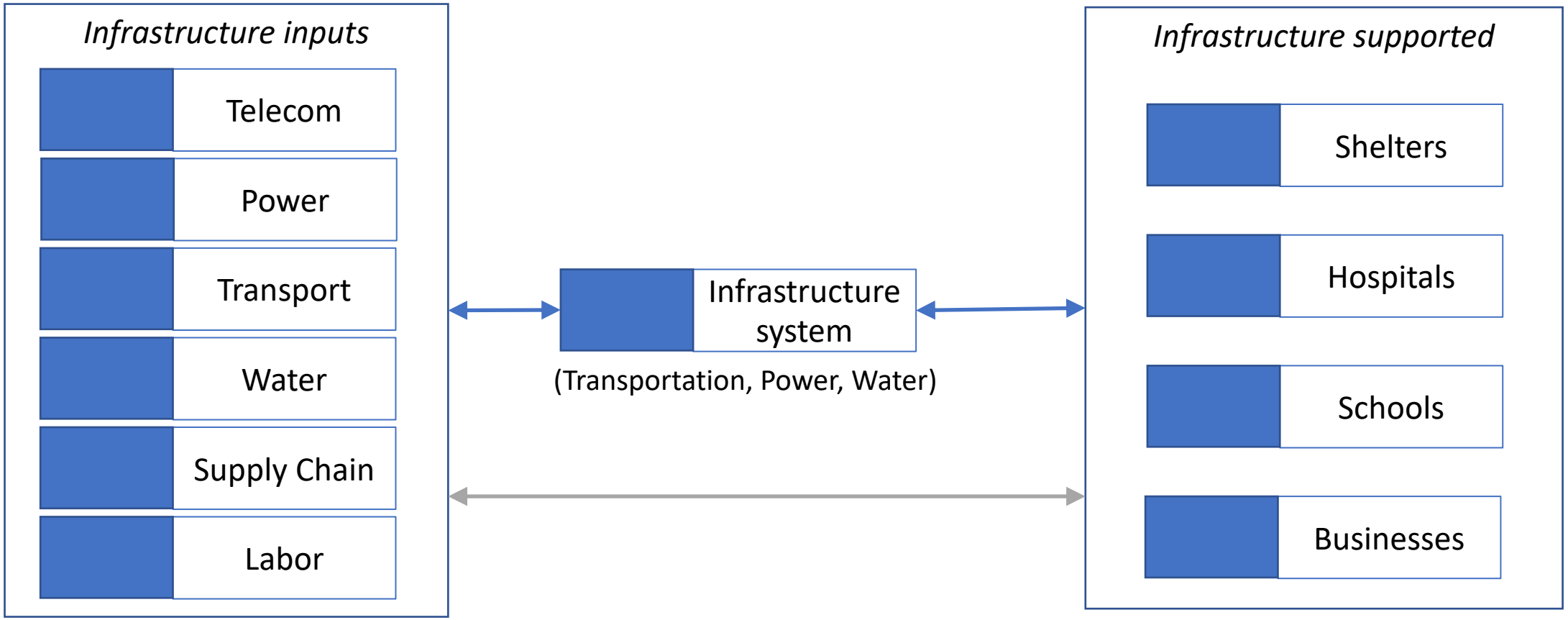


PRELIMINARY DATA ANALYSIS

Transportation road network: status



Infrastructure Recovery Dependencies



- Interviews to reveal impediments to recovery of infrastructure services at municipio, regional and commonwealth level (Status: data collection in progress)
- Additional study components include wireless communications and the role of vegetation in infrastructure failure

Infrastructure Dependencies – Highlighted Projects

- Impacts to and Recovery of Infrastructure
- **Morbidity and Mortality**
- Recovery of Business and Supply Chains & Recovery of Social Functions

Infrastructure Disruption and Mortality

- The verbal autopsy (VA) captures information about the cause of death, provided by a source different from those already available (death certificates, police reports, medical records).
- The socio-environmental questionnaire (S´E) captures the conditions that may affect the occurrence of the death.

  Infrastructure questions include →
- The integrated database includes geospatial data from other sources that can support the analysis of excess mortality.

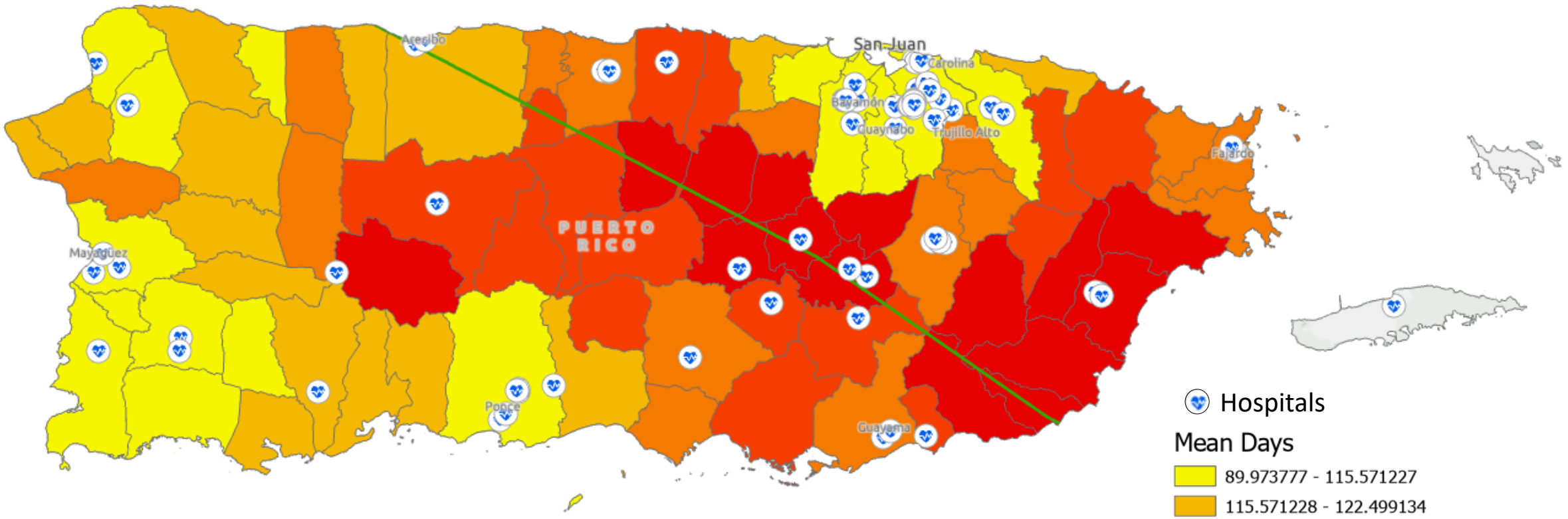
Was there active electricity supply from their public electrical utility?

How many days was he/she without an active electricity supply?

Was there a fully functioning electric portable generator to cover the electricity demand?

How many hours a day, on average, did the portable electric generator run?

Average Days without Power by Municipio Derived from NASA Black Marble Days without Power Dataset

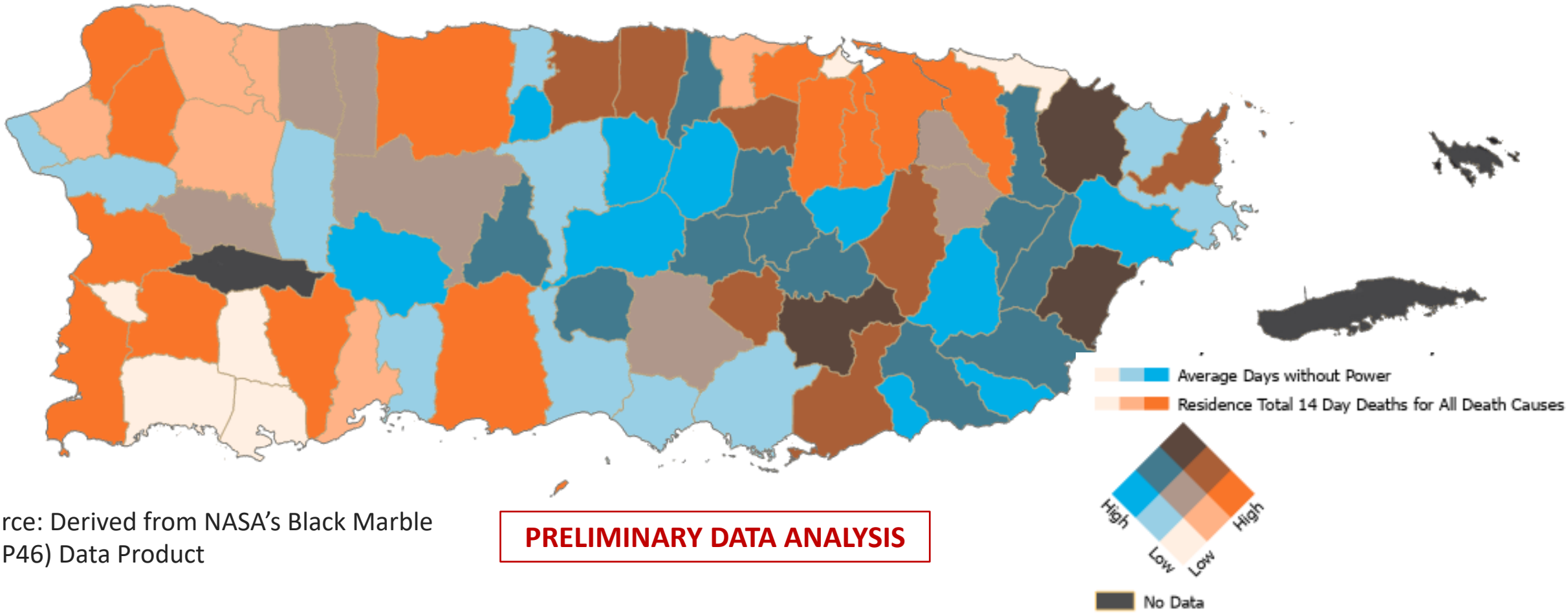


Source: Derived from NASA's Black Marble (VNP46) Data Product

PRELIMINARY DATA ANALYSIS

Milken Institute School of Public Health
THE GEORGE WASHINGTON UNIVERSITY

Relationship between Average Days without Power and Total 14 Day Deaths by Place of Death



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PRELIMINARY DATA ANALYSIS

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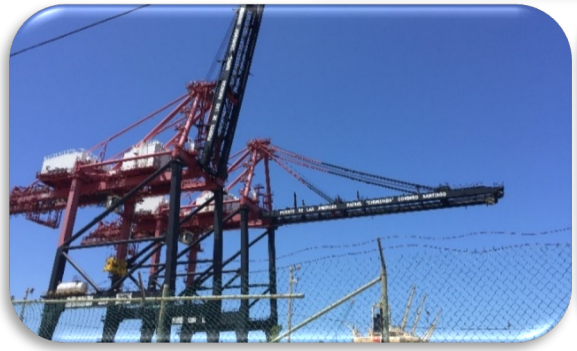
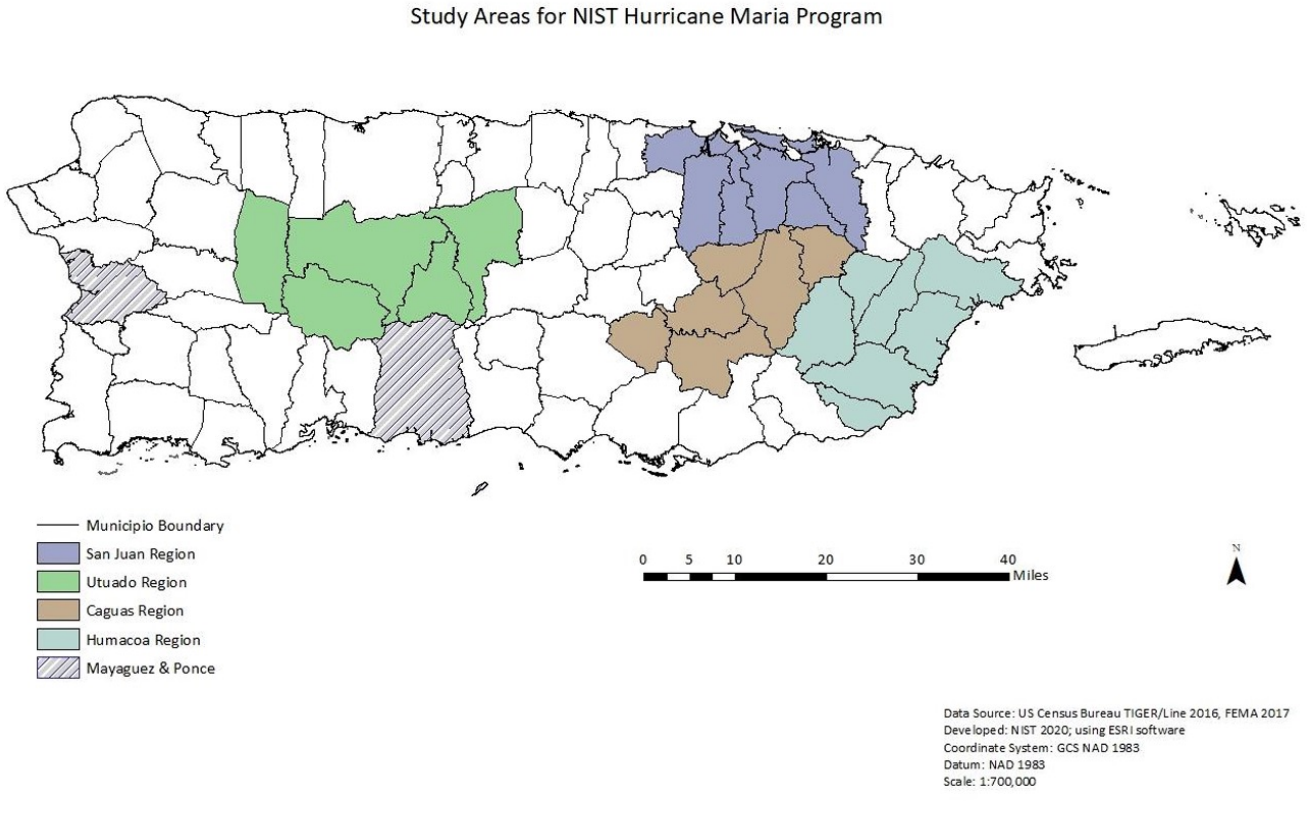
Infrastructure Dependencies – Highlighted Projects

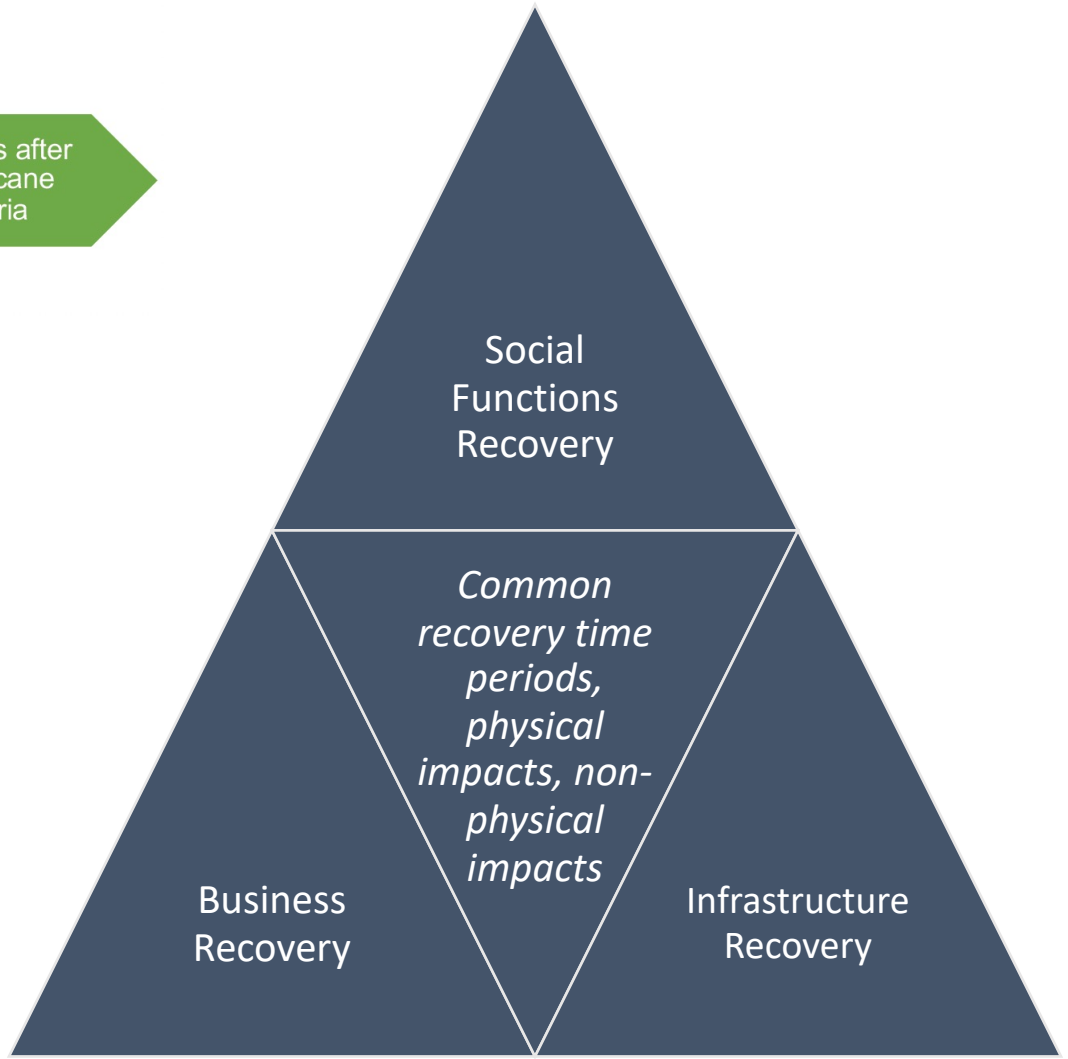


- Impacts to and Recovery of Infrastructure
- Morbidity and Mortality
- **Recovery of Business and Supply Chains & Recovery of Social Functions**

Infrastructure and the Recovery of Business, Education and Healthcare

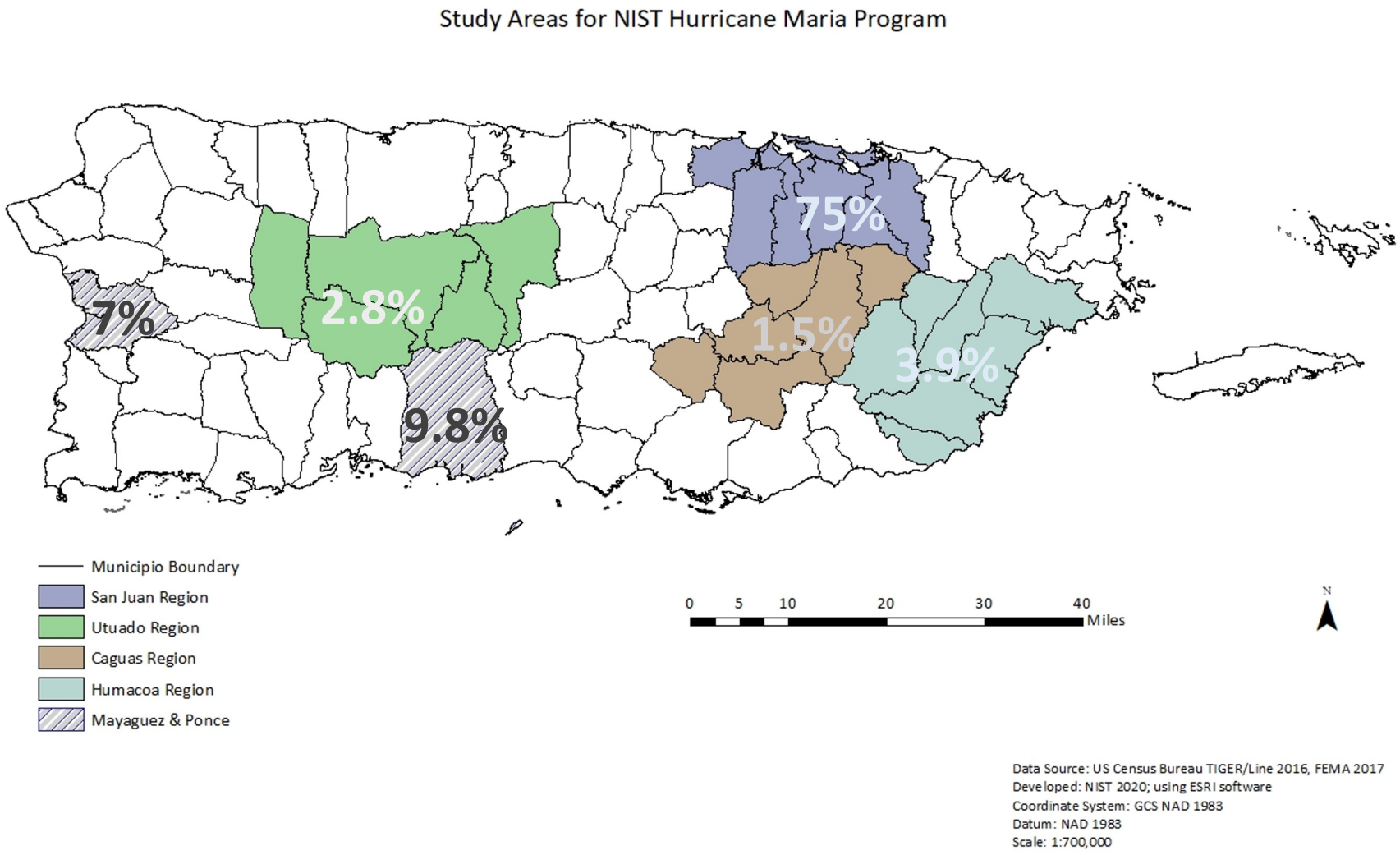
Time Periods:





Distribution of Businesses

- Municipios selected within the six shaded regions shown below
  - Four common regions across all projects
  - Addition of Mayagüez and Ponce (concentration of manufacturers)
- Business sample selected by zip codes
- Percentage of businesses that responded displayed on the map



Disruptions in Infrastructure for Businesses

- Of the responding businesses, the vast majority experienced disruptions of multiple infrastructure services.
- **Highlighted cells show the percent of businesses that experienced a loss of service.**

CRITICAL INFRASTRUCTURE – DISRUPTIONS

CATEGORIES FOR ASSESSMENT Critical Infrastructure	0-No Disruption	1-Minor Disruption	2-Moderate Disruption	3-Severe Disruption	4-Complete/Major Disruption
Electrical Power, % of businesses that experience loss of service	0%	1% to 24%	25% to 50%	51% to 75%	76% to 100%
Water/sewer, % of businesses that experience loss of service	0%	1% to 24%	25% to 50%	51% to 75%	76% to 100%
Landline telephone, % of businesses that experience loss of service	0%	1% to 24%	25% to 50%	51% to 75%	76% to 100%
Internet/IT, % of businesses that experience loss of service	0%	1% to 24%	25% to 50%	51% to 75%	76% to 100%
Cellphone, % of businesses that experience loss of service	0%	1% to 24%	25% to 50%	51% to 75%	76% to 100%

PRELIMINARY DATA ANALYSIS

Preparedness in Infrastructure for Businesses

- Back-up systems and redundancies in critical infrastructure are important indicators of the preparedness of regions, which is a key factor for recovery.
- **Highlighted cells show the percent of businesses that had a back-up for service.**

CATEGORIES FOR ASSESSMENT

Back-up systems

	CRITICAL INFRASTRUCTURE - PREPAREDNESS			
	1-Unprepared	2- Somewhat Prepared	3- Prepared	4-Very Prepared
Electrical Power, % of businesses that had back-up at the time of HM	0% to 25%	26% to 50%	51% to 75%	76% to 100%
Water/sewer, % of businesses that had back-up at the time of HM	0% to 25%	26% to 50%	51% to 75%	76% to 100%
Landline telephone, % of businesses had back-up at the time of HM	0% to 25%	26% to 50%	51% to 75%	76% to 100%
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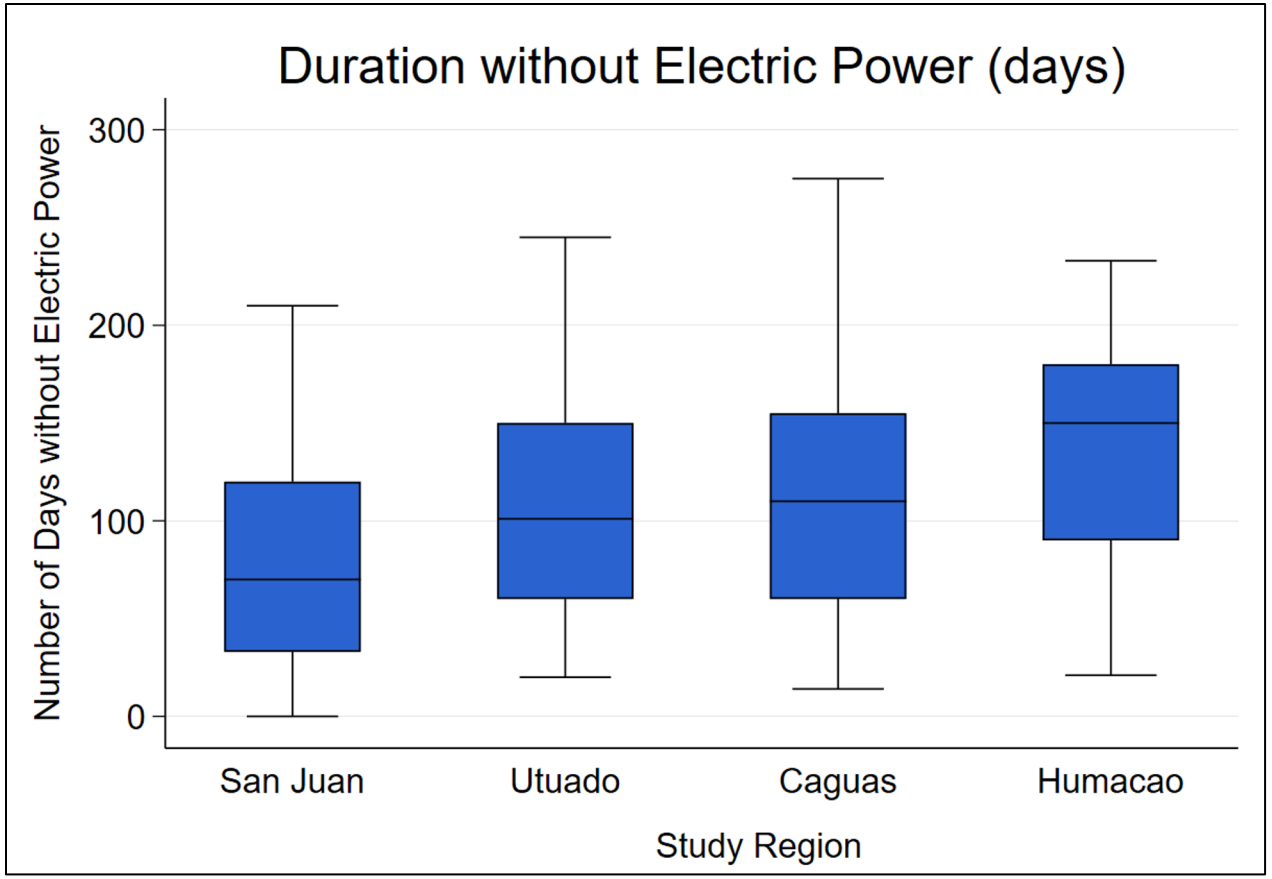
PRELIMINARY DATA ANALYSIS

Disruptions and Preparedness in Infrastructure for Schools and Hospitals

- Of the responding schools and hospitals, the vast majority experienced disruptions of multiple infrastructure services.
- Nearly all experienced the loss of electrical power, telephone and internet; loss of water/sewer services impacted just over half of responding schools and hospitals.
- There was limited availability of backup systems across power and communications-related utilities.



Note: *Outliers excluded from box plot.*

PRELIMINARY DATA ANALYSIS

Questions?

Theme 1: *Hospitals*

DongHun Yeo, Joseph Main, Judith Mitrani-Reiser

Theme 2: *Sheltering*

Marc Levitan, Katherine Johnson, Maria Dillard

Theme 3: *Infrastructure Dependencies*

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