NIST National Construction Safety Team Investigation of Hurricane Maria

NCST Advisory Committee Meeting – March 6, 2024

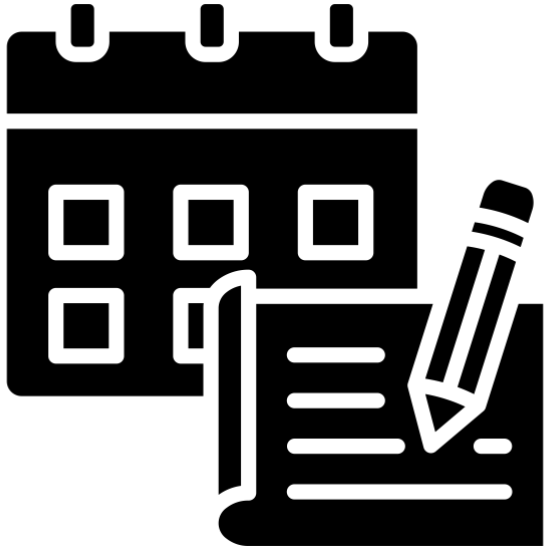
Cross-Project Panel Theme 3: Protective Action and Preparedness

Jennifer Helgeson, Katherine Johnson, Judith Mitrani-Reiser, Marc Levitan

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

Motivation

- The Hurricane Maria NCST Investigation goals include characterizing the performance of emergency communications systems and the public's response to such communications.
- Understanding the preparations and protective actions taken by households and organizations ahead of and during Hurricane Maria is important to understanding the context for the impacts, including physical damage, deaths, injuries, and the provision of critical services like healthcare and shelter.
- This information is also central to understanding which protective actions would have resulted in the greatest reduction of impacts.



Created by Good Father from Noun Project

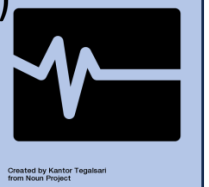
Integration of Data Streams

Data streams featured in Cross-Project Panel Theme 3:

Emergency Communications
Surveys with households (1523 households)
Interviews with information providers (35 providers)

Critical Buildings
Interviews with shelter representatives (5 shelters)

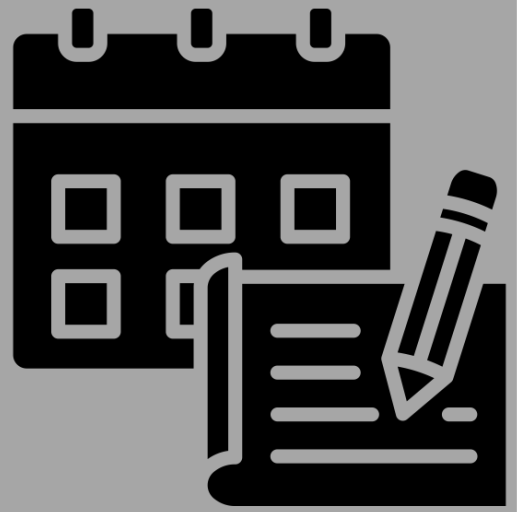
Morbidity and Mortality
Interviews with hospital administrators and clinical staff (6 hospitals, 30 respondents)
Surveys with next of kin of deceased (410 deceased persons)
Medical records of deceased from hospital functionality assessment (139)



Recovery of Social Functions
Surveys with hospital administrators (16 hospitals)
Surveys with school administrators (277 schools)

Recovery of Business
Surveys with businesses (451 businesses)

Integration of Analysis



Created by Good Father from Noun Project

Communications

What communications did the public receive about protective actions?

What was the trust and preference for communications received?

Protective Actions and Preparedness

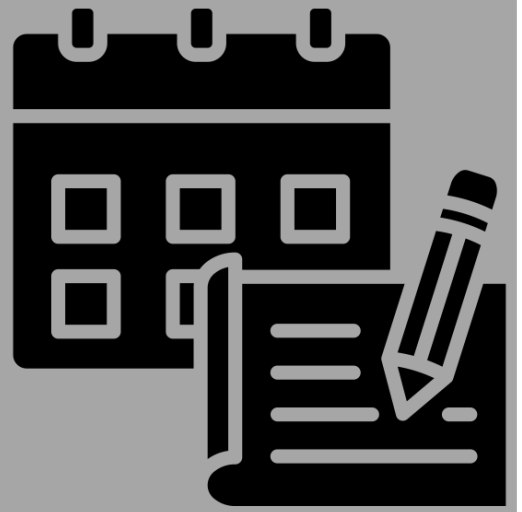
What evacuation decisions were made?

What actions were taken to plan for emergencies?

What actions were taken to avoid damage to physical structures?

What actions were taken to avoid disruption of utility service?

Integration of Analysis



Created by Good Father from Noun Project

Communications

What communications did the public receive about protective actions?

What was the trust and preference for communications received?

Protective Actions and Preparedness

What evacuation decisions were made?

What actions were taken to plan for emergencies?

What actions were taken to avoid damage to physical structures?

What actions were taken to avoid disruption of utility service?

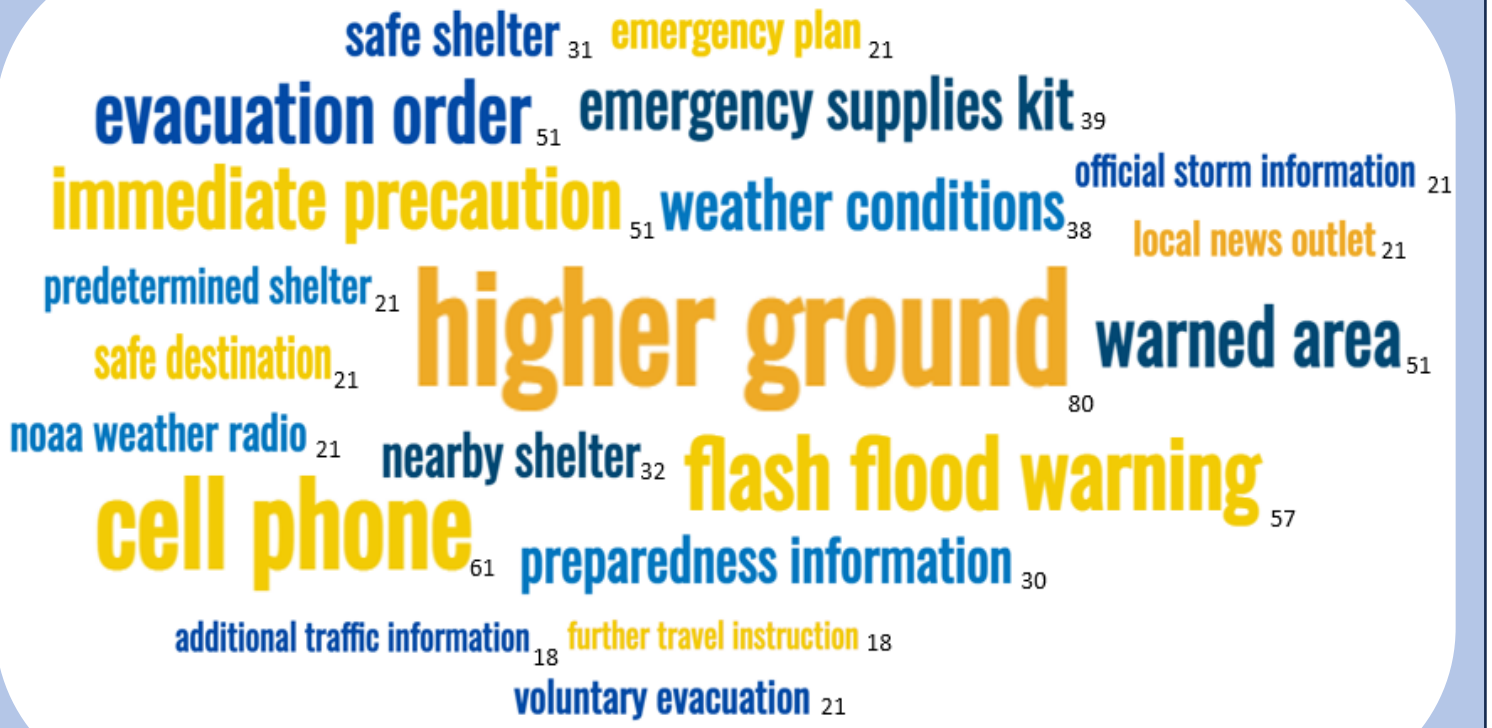
Messages Distributed

Emergency Communications

NOAA Weather Radio Messages

- Move to **higher ground** due to flood risk
- Charge cell phone and use sparingly
- Follow locally-issued evacuation orders
- Prepare emergency supplies kit

Phrases used for preparedness instruction:

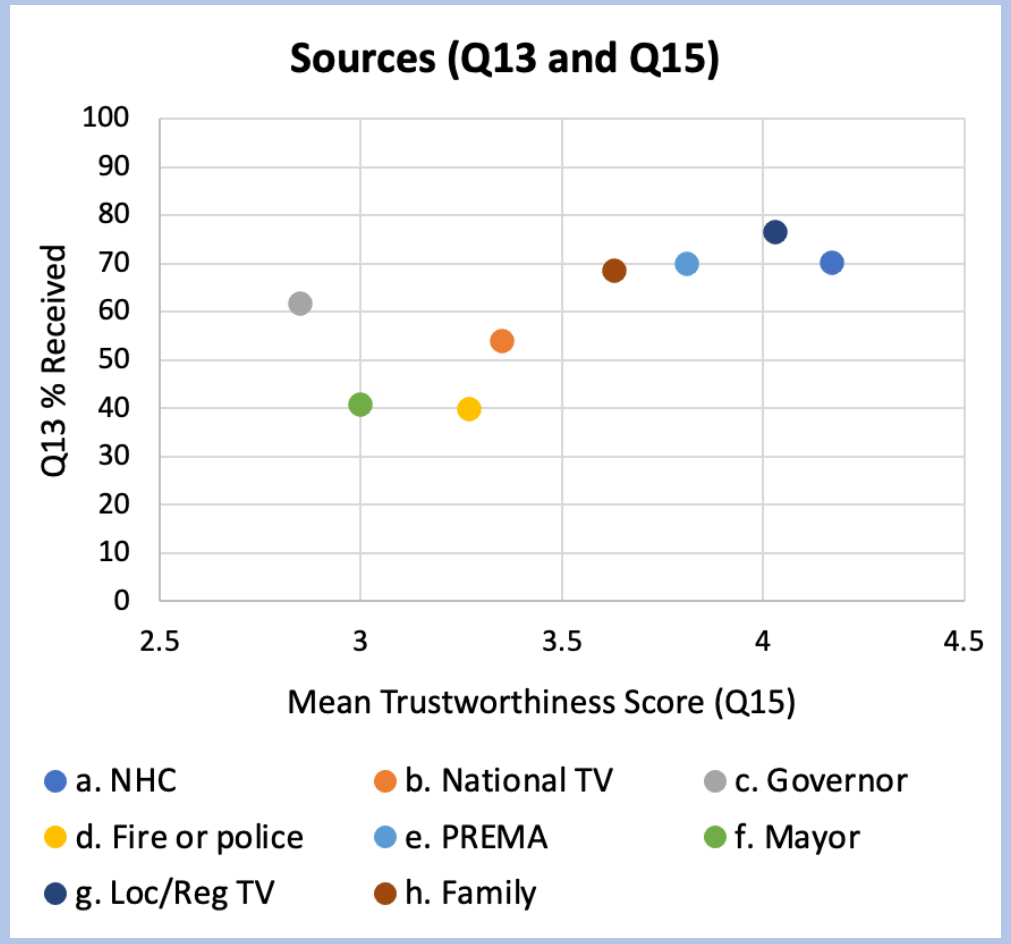


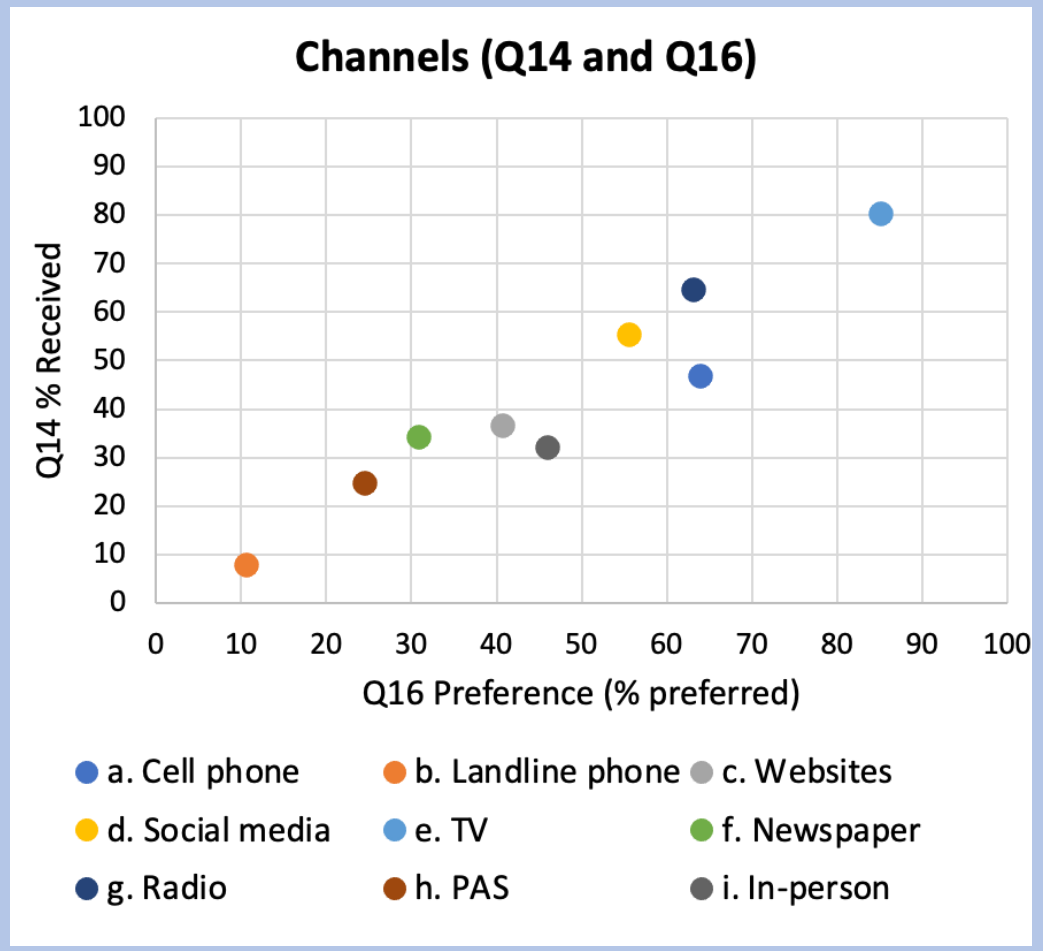
PRELIMINARY ANALYSIS

Trust and Preference for Messages Received

Emergency Communications

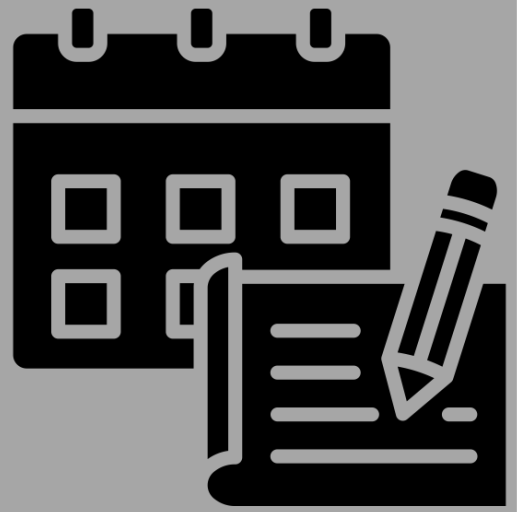
Household survey results:





PRELIMINARY ANALYSIS

Integration of Analysis



Created by Good Father from Noun Project

Communications

What communications did the public receive about protective actions?

What was the trust and preference for communications received?

Protective Actions and Preparedness

What evacuation decisions were made?

What actions were taken to plan for emergencies?

What actions were taken to avoid damage to physical structures?

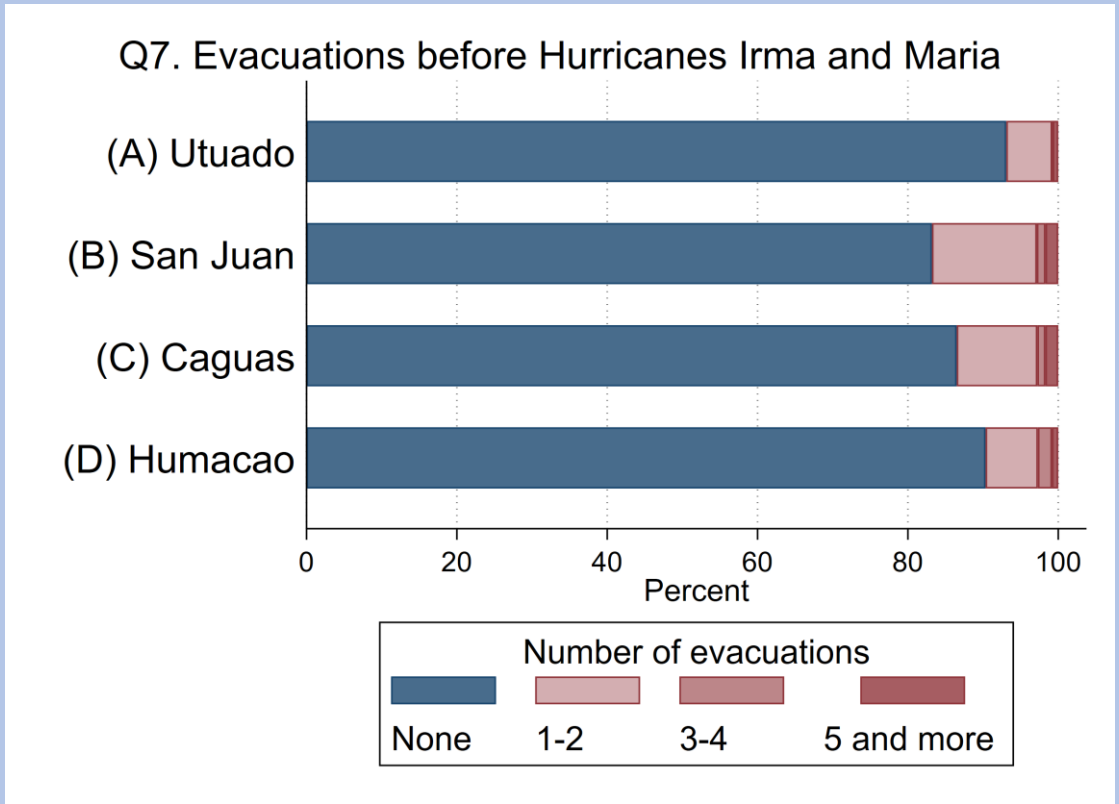
What actions were taken to avoid disruption of utility service?

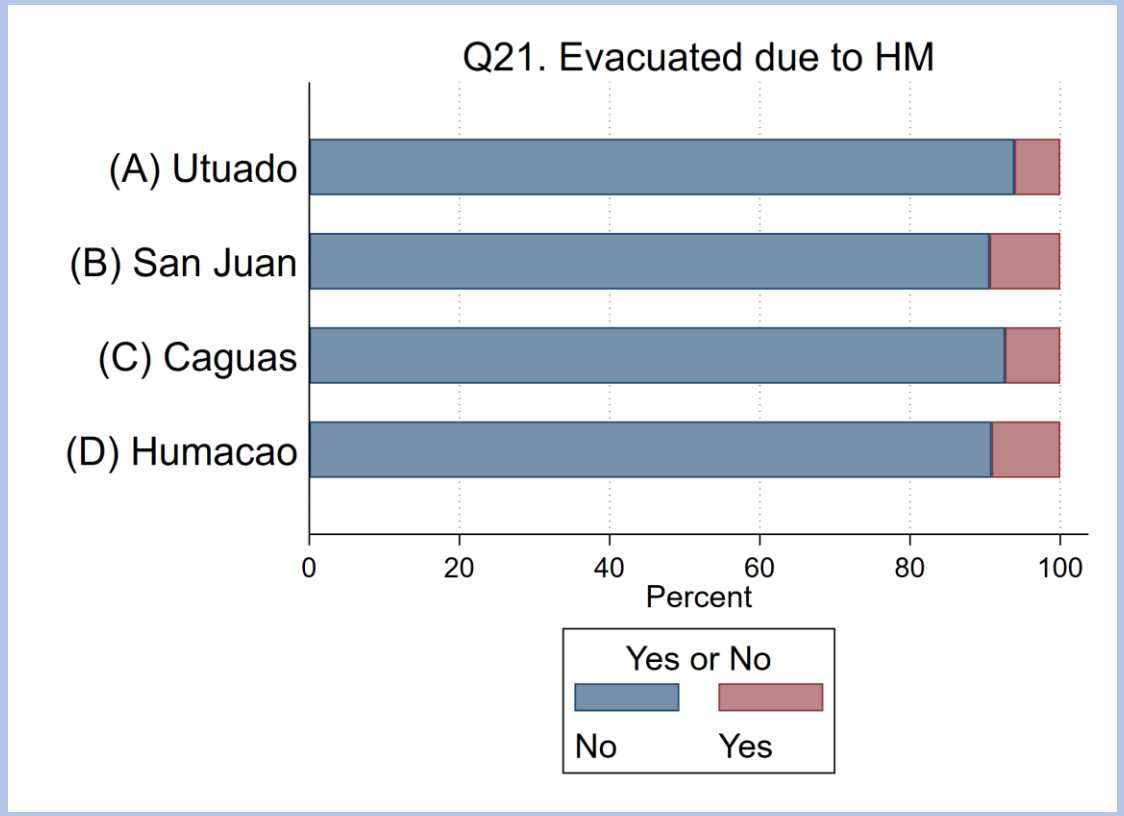
Evacuation Decisions

Emergency Communications

Household survey results:

- Most Puerto Ricans did not have evacuation experience from a prior hurricane.
- Most did not evacuate for Hurricane Maria.





PRELIMINARY ANALYSIS

For Emergencies in Households

Morbidity and Mortality

Verbal autopsy survey results:

- Over half of the deceased represented in the verbal autopsy and socio-environmental survey had an emergency plan in place.
- Few (~15%) had identified the shelter they would go to in an emergency.

Top 3 Emergency Plan Actions Taken	%
Stock of Food and Water	97%
Stock of Medicines/ Medical Supplies	93%
Had batteries and flashlights	92%

Emergency Communications

Household survey results:

- 4 or more protective actions were taken by 58% of the population.
- Approximately 3% of the population did not take any protective actions.

High Ranking Actions Taken before Hurricanes Irma and Maria	%
Set aside food, water, medicine, or other supplies	93%
Talked with others about hurricane preparation	70%
Made a plan for evacuation (such as where to go)	42%
Had insurance coverage for a natural hazard (any)	34%

PRELIMINARY ANALYSIS

For Emergencies in Schools, Shelters & Hospitals

Recovery of Social Functions

School survey results:

- 82% of schools in the sample had an emergency plan in place for natural hazard events such as hurricanes.

Implementation of the emergency plan during Hurricane Maria	%
Very Poor	0.9%
Poor	3.1%
Acceptable	28.3%
Good	40.3%
Very Good	27.4%
Total	100.0%

Critical Buildings

Shelter personnel interviews:

- None (n=5) of the facility POCs had access to Shelters Operations Plans.

Morbidity and Mortality

Hospital personnel interviews:

- The 6 hospitals had developed emergency plans ahead of the 2017 hurricane season; implementation of these plans varied.

Recovery of Social Functions

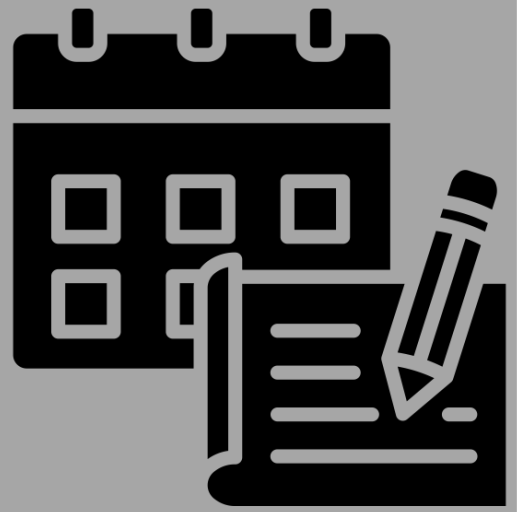
Hospital survey results:

- 100% of hospitals in the sample had an emergency plan in place for natural hazard events.

Implementation of the emergency plan during Hurricane Maria	%
Very Poor	0.0%
Poor	0.0%
Acceptable	6.2%
Good	25.0%
Very Good	68.8%
Total	100.0%

PRELIMINARY ANALYSIS

Integration of Analysis



Created by Good Father from Noun Project

Communications

What communications did the public receive about protective actions?

What was the trust and preference for communications received?

Protective Actions and Preparedness

What evacuation decisions were made?

What actions were taken to plan for emergencies?

What actions were taken to avoid damage to physical structures?

What actions were taken to avoid disruption of utility service?

For Physical Protection of Households

Morbidity and Mortality

Verbal autopsy survey results:

- Protective actions were reported to be taken by more than 50% of the deceased's households.
- Most of the deceased had taken 1 to 3 actions; however approximately one third did not take any protective action for their structure.
- No significant differences found in the number of structural protective actions taken by the household by geographic regions.

Top Protective Actions for Home	%
Protecting windows/openings with shutters	49%
Didn't leave any garbage, debris, or trash outside	48%
Protecting windows/openings with plywood	45%
Disconnected electrical appliances	38%
Pruning trees	20%

Emergency Communications

Household survey results:

- 77% of households reported taking home-protection action before Hurricanes Irma and Maria.
- Assessment of risk is complex, and depends on many factors:

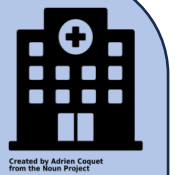
"Well, I stay at home because my house is safe. We don't live near any river or creek. We have storm shutters. Our house is made of concrete. We have a cistern. We have the power generator. We are well prepared." (ID21)

PRELIMINARY ANALYSIS

For Physical Protection of Shelters & Hospitals

Critical Buildings

Shelter and Hospital personnel interviews:



Protective Actions for Shelters	# of Shelters
Had operable hazard mitigation systems, e.g., storm shutters, impact-resistant door systems, sump pumps	0 of 5
Cleared drains and gutters	3 of 5
Secured and protected school materials and equipment	1 of 5
Placed sandbags for flood protection	0 of 5

Protection Actions for Hospitals	# of Hospitals
Deployed storm shutters	5 of 5
Cleared roof drains	5 of 5
Anchored rooftop equipment	4 of 5
Placed sandbags for flood protection	3 of 5

Morbidity and Mortality

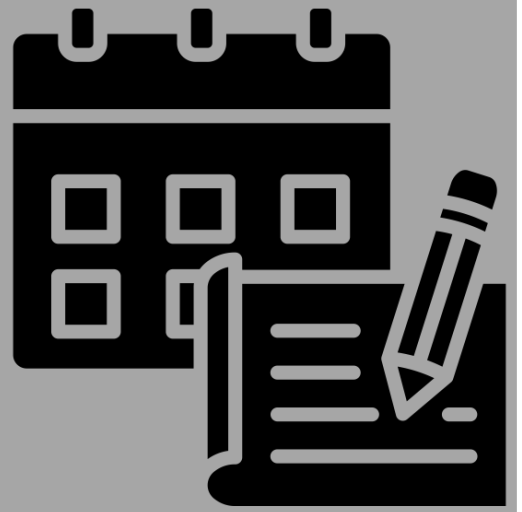
Hospital personnel interviews:

Protective Actions for Hospitals

- 5 of 6 hospitals reported significant physical and structural damage to facilities with impacts to patient rooms and flooding and destruction in various parts of the hospital (including ICUs and Emergency Departments).
- Future actions recommended by hospital personnel include pruning trees to prevent blocking the hospital's entrances.
- Physical protective actions ahead of Hurricane Maria were not emphasized by respondents for any of the 6 hospitals.

PRELIMINARY ANALYSIS

Integration of Analysis



Created by Good Father from Noun Project

Communications

What communications did the public receive about protective actions?

What was the trust and preference for communications received?

Protective Actions and Preparedness

What evacuation decisions were made?

What actions were taken to plan for emergencies?

What actions were taken to avoid damage to physical structures?

What actions were taken to avoid disruption of utility service?

For Utility Service Disruptions in Shelters & Schools

Recovery of Social Functions

School survey results:

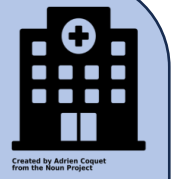
- 95.3% of schools lost power
- Average days without power for schools in the sample is 102.2 (SD=74.7)

Backup Infrastructure Services	% Had	% Used
Electrical Power	22.0%	27.8%
Water/Sewer	43.7%	31.4%
Landline Telephone	15.2%	18.8%
Internet/ IT	7.9%	10.1%

SC34374: *"Yes, in that case, we had to emphasize to students that they needed to bring their water because, after a hurricane, the water, or when there is no running water for a while, then the water is not safe."*

Critical Buildings

Shelter personnel interviews:



Power: All 5 shelters lost external power;
4/5 shelters had emergency power generators

Water: All 5 shelters had cisterns;
4/5 shelters had issues with potable water supply

Shelter	Had Generator	Used	Worked as Intended	Issue
1	Yes	Yes	Yes	-
2	Yes	Yes	Yes	challenge obtaining fuel
3	No	-	-	-
4	Yes	Yes	No	malfunctioning part
5	Yes	Yes	Yes*	water intrusion damaged component

**Generator failed around same time shelter was closed.*

PRELIMINARY ANALYSIS

Protective Action and Preparedness:

For Utility Service Disruptions in Hospitals

Morbidity and Mortality

Hospital personnel interviews:

Created by Kantor Tegalsari from Noun Project

- 4 of 6 hospitals reported a redundant electric power generator system with the capacity to supply the facility's electricity needs during the two weeks after Hurricane Maria's landfall.
- However, the power generators of 2 of the 4 hospitals with backup power were not able to provide the amount of electricity needed.
- This impacted patient movement via elevators, among other functions.

H-4: There was concern over the possibility that the power generators, which had been operating for many days, might fail or break down, and that the power supply would be interrupted, affecting the medical care of patients connected to medical equipment.

Recovery of Social Functions

Hospital survey results:

Created by Matthias Hartmann from Noun Project

H154: *"There was an electrical issue caused by the river water because, when it got flooded...the pumps were submerged under water, something we didn't expect either, and we lost power. ...we had neither electricity nor running water."*

Backup Infrastructure Services	% Had	% Used
Electrical Power	100.0%	87.5%
Water/Sewer	87.5%	56.2%
Landline Telephone	56.2%	37.5%
Internet/ IT	50.0%	37.5%
Oxygen	93.8%	50.0%

PRELIMINARY ANALYSIS

For Utility Service Disruptions in Businesses

Recovery of Business

Business survey results:

- 97.1% of businesses lost power
- The average days without power for businesses in the sample is 98.2 (SD=110.6)

Backup Infrastructure Services	% Had	% Used
Electrical Power	49.4%	43.2%
Water/Sewer	33.7%	26.4%
Landline Telephone	20.0%	16.2%
Internet/ IT	17.5%	15.7%
Cellphone	6.9%	5.5%

Shipping and Transportation Interviews

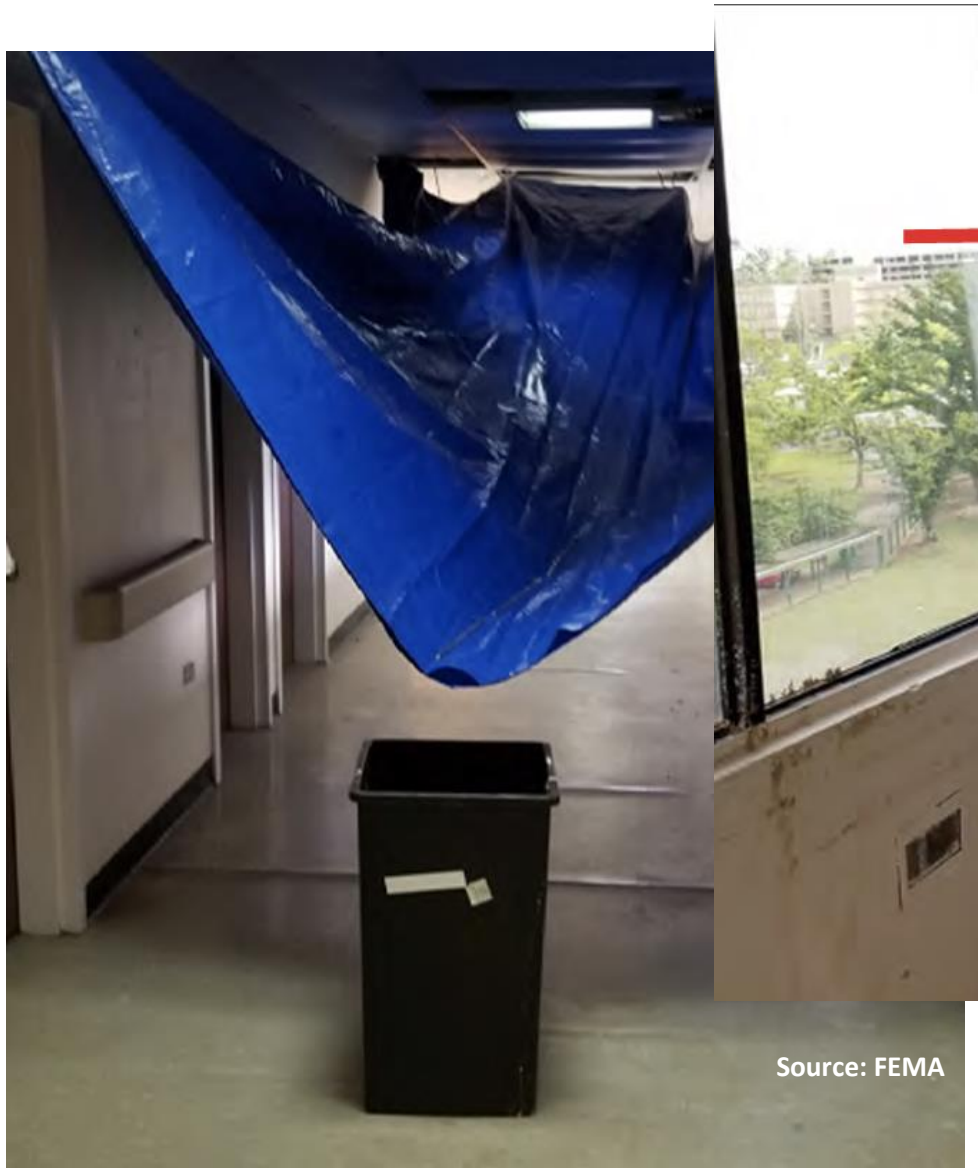
50% ranked interruptions to "Utilities, telecommunications, and IT" systems as the most impactful during the aftermath of Hurricane Maria.

ID# 126: "The problem, obviously, was with the energy because the fuel was not accessible all the time. It was a challenge for us, finding fuel with different suppliers, obviously to supply our employees, but also to supply our generator, which uses diesel. That was the challenge…"

ID# 125: "…there was zero communication…got a satellite phone…but my company services a company and it was an uphill battle to communicate with them…their merchandise was inside the port; we couldn't get it out."

PRELIMINARY ANALYSIS

Influence on Impacts



1. **Physical damage, e.g., rainwater intrusion through broken windows**
2. Loss of power and water
3. Operational challenges to providing service in shelters, hospitals, schools, businesses
4. Injuries and Deaths

Influence on Impacts

1. Physical damage, e.g., rainwater intrusion through broken windows
2. **Loss of power and water**
3. Operational challenges to providing service in shelters, hospitals, schools, businesses
4. Injuries and Deaths

Influence on Impacts

1. Physical damage, e.g., rainwater intrusion through broken windows

2. Loss of power and water

3. **Operational challenges to providing service in shelters, hospitals, schools, businesses**

4. Injuries and Deaths

Influence on Impacts

1. Physical damage, e.g., rainwater intrusion through broken windows
2. Loss of power and water
3. Operational challenges to providing service in shelters, hospitals, schools, businesses
4. **Injuries and Deaths**

Questions?

Theme 1: *Hazard Exposure*

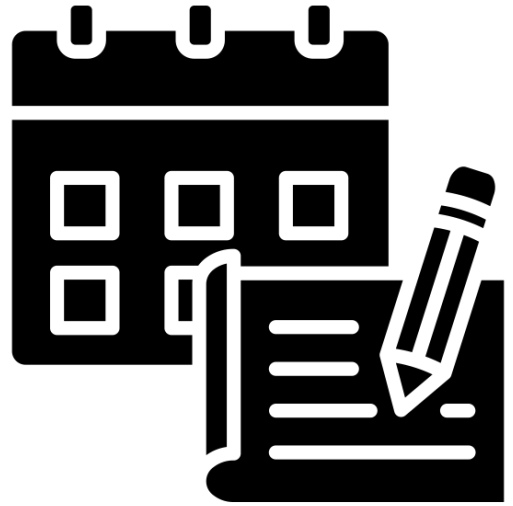
Created by Arthur Shlain
from the Noun Project

DongHun Yeo, Marc Levitan, Maria Dillard

Theme 2: *Hospital Functionality & Infrastructure Dependencies*

Maria Dillard, Joseph Main, Ken Harrison

Theme 3: *Protective Action & Preparedness*



Created by Good Father
from Noun Project

Jennifer Helgeson, Katherine Johnson, Marc Levitan, Judith Mitrani-Reiser

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