Critical Infrastructure and the Resilient-Sustainable Reconstruction of Puerto Rico After Hurricane Maria

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Introduction

Critical infrastructure poses a substantial risk in the face of hazardous natural phenomena. Hurricanes, storms, earthquakes, heavy rains and other natural disasters are the most likely and most impacting events. Puerto Rico's location greatly exposes the island to these phenomena and makes it vulnerable to extreme damages, as was the case of Hurricane Irma and María. Category 5 Hurricane Irma skirted the northeastern side of Puerto Rico on September 6, 2017, causing damages to part of the Island. Two weeks later, Category 4 Hurricane María made landfall in Puerto Rico through the southeast region in the early morning of September 20, 2017. The event caused severe damages to the Island's critical infrastructure which was determined to be in poor condition and mostly below updated and adequate engineering resilient design standards. For its reconstruction, increasing the resilience of Puerto Rico's infrastructure is of upmost importance. As a response, objectives are set forth to identify design and construction concepts that apply to the Island's critical infrastructure. Furthermore, recommendations to work with the interdependence of critical systems are paramount for this investigation.

Approach / Methodology

CISA Critical Infrastructure Sectors

https://www.cisa.gov/critical-infrastructure-sectors

Puerto Rico's Multi-Hazards Exposure

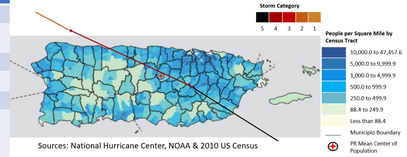
Hurricanes/Storms /Tropical Cyclones	• Winds • Storm Surges • Waves • Tides
Earthquakes	• Tsunamis • Landslides • Mudflows • Subsidence
Rainfall	• Droughts • Riverine Flash Floods • Urban Floods • Scour
Others	• Ambient Temperature • Cold and Warm Fronts • Orographic Effects • Wildfires

Structures Within 1 km of the Coast

(Díaz, 2021; Pagán Trinidad et al., 2019)

Coastal Assets at Risk	Public and Private Infrastructure
Ports	12
Airports	11
Hospitals	3
Schools	36
PR Power Generation Plants	7 (5 Public – 2 Private)
PR Aqueducts and Sewers Authority	200 km potable water network 260 km sanitary infrastructure 28 wastewater treatment plants
PR Industrial Developments Co.	81 Industrial Parks

Hurricane Maria Trajectory



Sources: National Hurricane Center, NOAA & 2010 US Census

Outcomes / Results

Grading Scale for Puerto Rico's Infrastructure

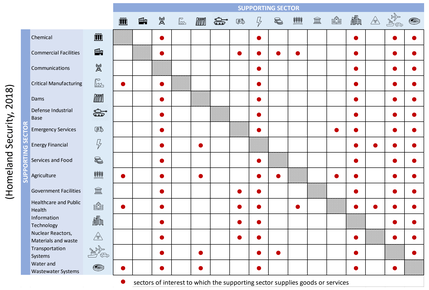
(ASCE, 2019)

Dams	D+
Bridges	D+
Drinking Water	D
Energy	F
Ports	D
Roads	D-
Solid Waste	D-
Waste Water	D+
G.P.A.	D-

A	Excpetional, Fit for the Future
B	Good, Adequate for Now
C	Mediocre, Requires Attention
D	Poor, At Risk
F	Failing/Critical Unit for Purpose

Critical Infrastructure Dependency Matrix

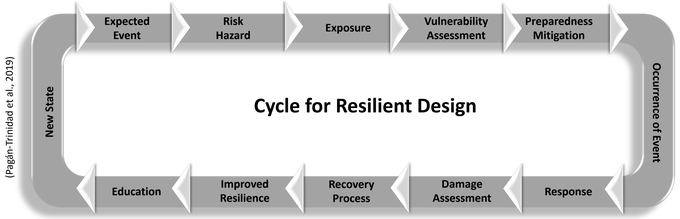
(Homeland Security, 2018)



Damages caused by Hurricane Maria

Sources: FHWA.

(Pagán-Trinidad et al., 2019)



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Conclusions

Sector's Damages and Repairs

(HSOAC, 2020)

Dams	Bridges	Ports	Wastewater	Roads	Energy
Failure of Guajataca Dam	Severely Damaged: 27%	Over $11.2 million was obligated to the PRPA work that includes repairs to 12 piers	PRASA pump station Damage: ~$75 millions (FY 2018 dollars)	Estimated damage value in millions of dollars (roads and bridges): 646.7	Downed or damaged transmissions: 115 kV – 1,482 (27%), 230 kV – 511 (21%)
Reparations are estimated to go as high as 500 millions	Moderately Damaged: 63%		Damaged stormwater pump stations: 17	Less than 8% of the roads were open a month after Maria	Downed towers and poles: 115 kV – 648 (12%), 230kV – 107 (4%)
	Collapsed or destroyed: 50		70% of potable water treatment and distribution systems were affected	PRHTA estimates that it will need $3.1 billion of capital expenditures	Damaged insulators and other components: 115kV – 834 (15%), 404 (17%)
			A total of $551 is needed for renewal and replacement		

Main Resiliency Recommendations for Puerto Rico's Infrastructure

(ASCE, 2019)

Dams	Bridges	Ports	Wastewater	Roads	Energy
• Implementation of a yearly dredging plan • Hydraulic barrier system • Increase funding • Increase capacity and lifespan • Rehabilitate, maintain and maximize the use of hydropower resources in the system	• Higher weight allowance. • Considerations of stronger side effects caused by natural disasters or extreme events for new designs • Life cycle approaches • Preventive maintenance programs	• Repair and rehabilitate Piers 11-14 • Invest in resiliency improvements for critical piers throughout the island.	• Implementation of sewer line replacement and renovation programs • Improve detection and repair of infiltration and exfiltration • Consider the use of alternate energy systems in wastewater treatment facilities	• Improve pavement conditions • Establish an effective and systemic pavement preventive program • Encourage collection, dissemination, and processing of real-time data for day-to-day benefits and long-term planning	• Adopt ASCE 7 codes and standards or consensus industry standards with at least a 160-mph design wind speed • Utilize smart grid technologies, redundant power delivery, and hardened communications • Increase use of readily available solar and wind generation

- Critical infrastructure requires conscientious operation and consistent, adequate maintenance investments to provide the levels of service and protection developed by the designer and expected by the customer and affected public.
- Design criteria needs to always consider how the performance of individual components affects the overall performance of a system.
- Puerto Rico needs to increase infrastructure investment by $1.3 to $2.3 billion annually in order to reach a desired range of 2.5%-3.5% of GDP (ASCE, 2019).

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