The Use of Hybrid Modelling to Examine the Elasticity of Cargo Movement Following a Natural Disaster

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ABSTRACT

Resilient infrastructure is imperative especially following natural or manmade disasters. The ability to move food, water, and relief supplies using multiple modes of transportation to areas recently affected by major disasters is oftentimes very difficult. Following Hurricane Maria's landfall on Puerto Rico in 2018, 10,000 shipping containers were stranded in just one port of Puerto Rico unable to traverse the island to reach those in need. The lack of resilient infrastructure caused a delay in repair to normalcy for the entire island and delayed supplies that were already late to their destination even longer.

The goal of this research is to model the elasticity of cargo arrival and departure under resilient infrastructure. The objective of this research is to determine the responsiveness of a mode of transportation to change under demand and restrictions.

PROBLEM

On September 20, 2017 Hurricane Maria made landfall on Puerto Rico as a category four hurricane, the strongest storm to pass over the island in 85 years.[1] The island, whose infrastructure was already deteriorating, came out in an inhabitable state in many areas. It took until September 23rd for the Port of San Juan to reopen and allow 11 cargo ships to bring water, foods, cots, and generators.[2] On September 28th, eight days after landfall, 10,000 shipping containers containing food and supplies were still stuck in the Port of San Juan.[2]


Cargo containers filled with supplies stuck in the Port of San Juan unable to leave due to lack of gasoline and damaged infrastructure following Hurricane Maria. [3]

In 2017, NOAA reported that 17 named storms formed in the Atlantic, 10 of which were hurricanes, and six of which were major hurricanes (category three or higher.)[4] Since 1851, 27 storms have directly hit Puerto Rico, 11 of which were major storms.[5] In the past 20 years the number of major hurricanes in the Atlantic has increased 74 percent.[6] As the number of major hurricanes increases, the need to ensure resilient infrastructure to aid in preparation and repair efforts on an island with aging infrastructure is ever present. The National Science Foundation (NSF) defines resiliency as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events.[7]"

STORMS IN THE ATLANTIC BASIN 1851-2015
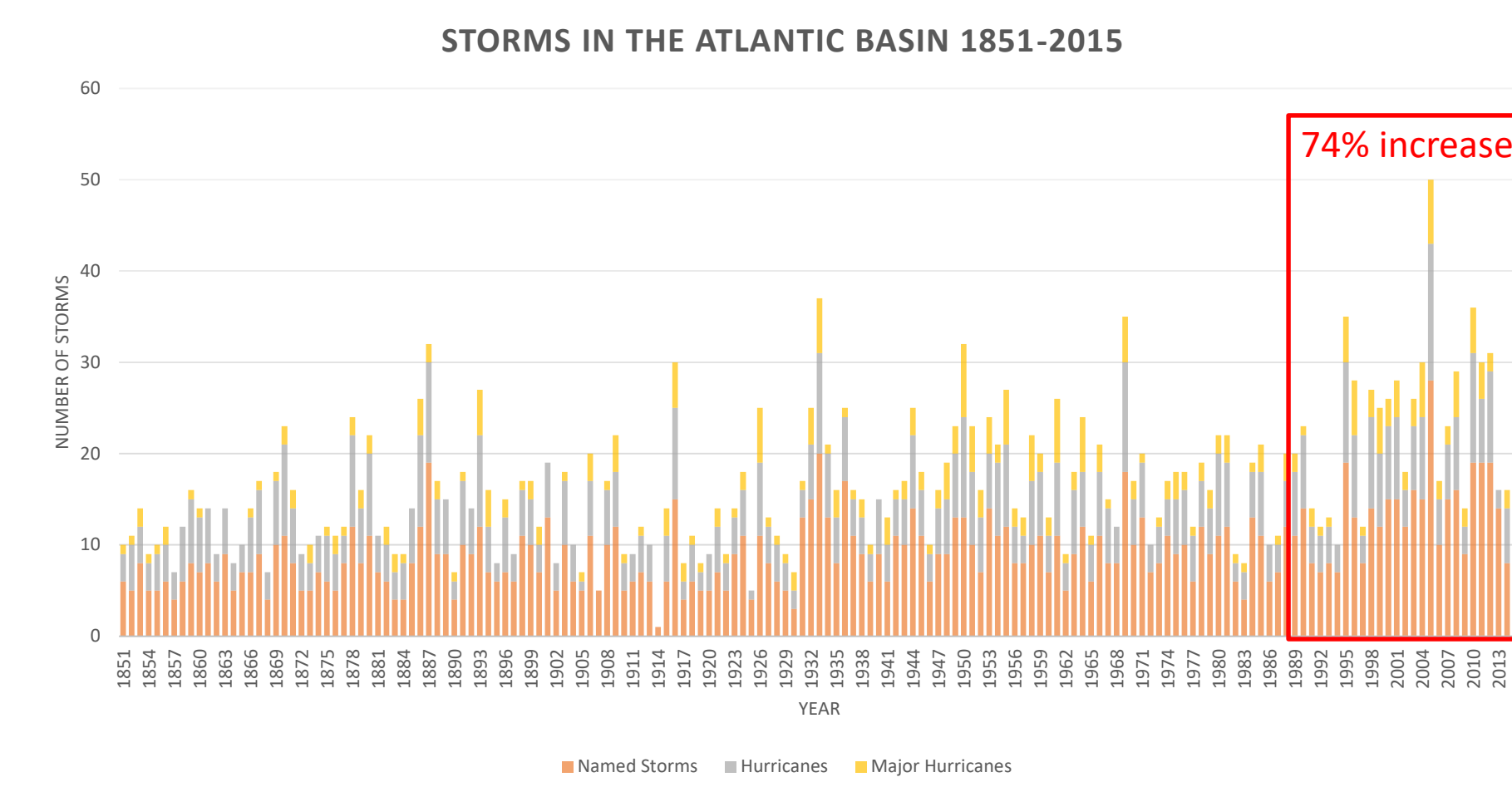
Named storms, hurricanes, and major hurricanes in the Atlantic Basin from 1851-2015. [6]

A Time-Dependent Resiliency Plot shows the functionality of the system being examined during a disruptive event. It includes the time leading up to the event, the occurrence of the event, the absorption state, disruptive state, and recovery state. During the absorption state it measures the system's ability to absorb the disruptive event. The disruptive state shows the system has now been affected by the event and is unable to function as it once it due to these circumstances. The recovery state shows the time period in which a system begins to be up and running and returning to normalcy. [8]
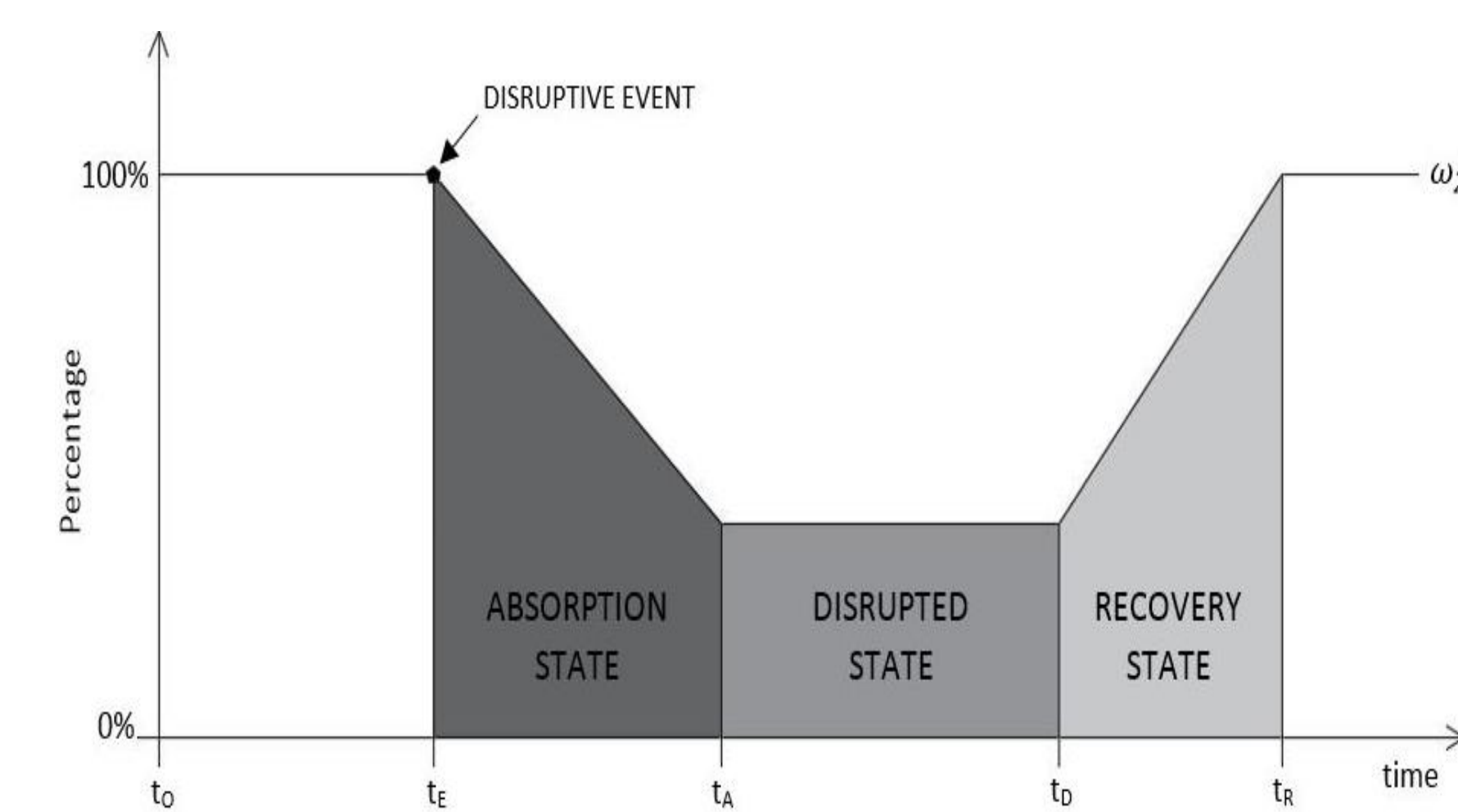
Time-Dependent Resiliency Plot[8]

Following Hurricane Irma also in September 2017, the resiliency of various airports in Florida were examined. Tampa (TPA) airport went through a disruption due to this event. The airport experienced 4 days of preparation before the event and 6 days in an absorption state. During the two days the storm made landfall the system operated in a disrupted state in which no or minimal flights occurred at this location. It took an additional 5 days in the recovery state before the system reached pre-event functionality.
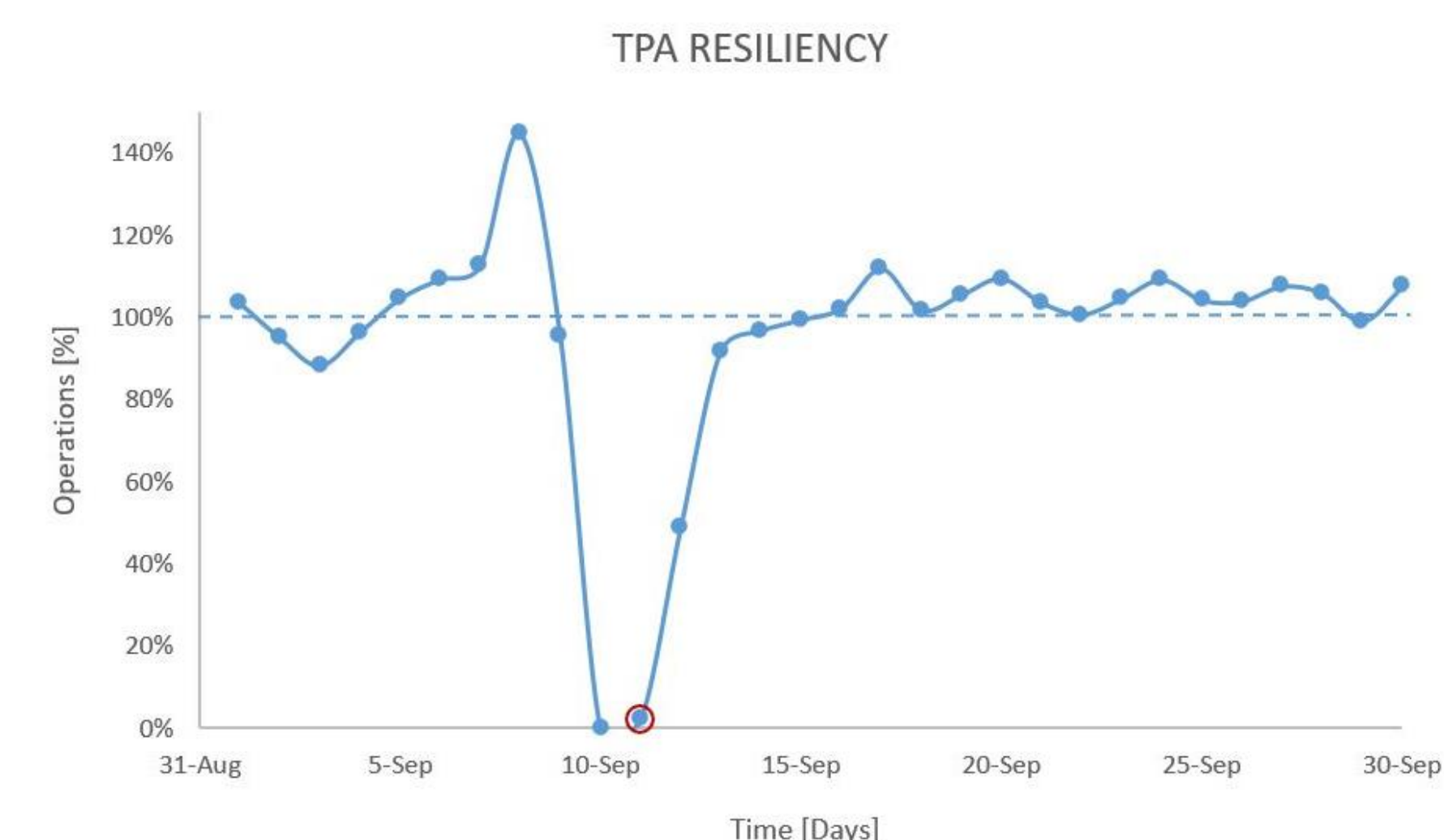
TPA RESILIENCY

Example of a Time-Dependent Resiliency Plot using data for Tampa International Airport during Hurricane Irma.[8]

METHODOLOGY

Modeling of Hybrid Mesoscopic/Microscopic Network in VISSIM

A base model will be established under normal operations using data collected over a given timeframe. An Inverse Transform Sampling will be applied to simulate vessels within the port. Once vessel arrival and dwell times are estimated they can be analyzed using a Graphical User Interface. Simulated vessel operation will be examined and compared to historical data for calibration and validation purposes. A developed simulation model will allow the evaluation of various disruptive scenarios such as Hurricane Maria, flooding, and port labor disputes. This approach to analyzing port operations will be integrated with a landside model of surface transportation cargo distribution facilities.

**Example of VISSIM Network for a Container Terminal.[9]**

An integrated microscopic traffic simulation platform will be used to model the surface transportation network. Within this platform, the developed port model will be integrated to link the travel modes within a unified architecture. Microscopic analysis will be conducted on the port facility and regional transportation network for the three major cargo ports, Port of San Juan, Port of Mayaguez, and Rafael Cordero Santiago Port of Americas. The three ports will be connected through the greater cargo distribution system and modeled at the mesoscopic level to encompass the integration of various modes, cargo, and ports of origin. Only through this level of incorporation can a holistic analysis of the elasticity of cargo connectivity resulting from a systematic disruption be achieved.

VISSIM Model showing movement off one mode of transportation and onto another.

Federal interstates within Puerto Rico.[10]
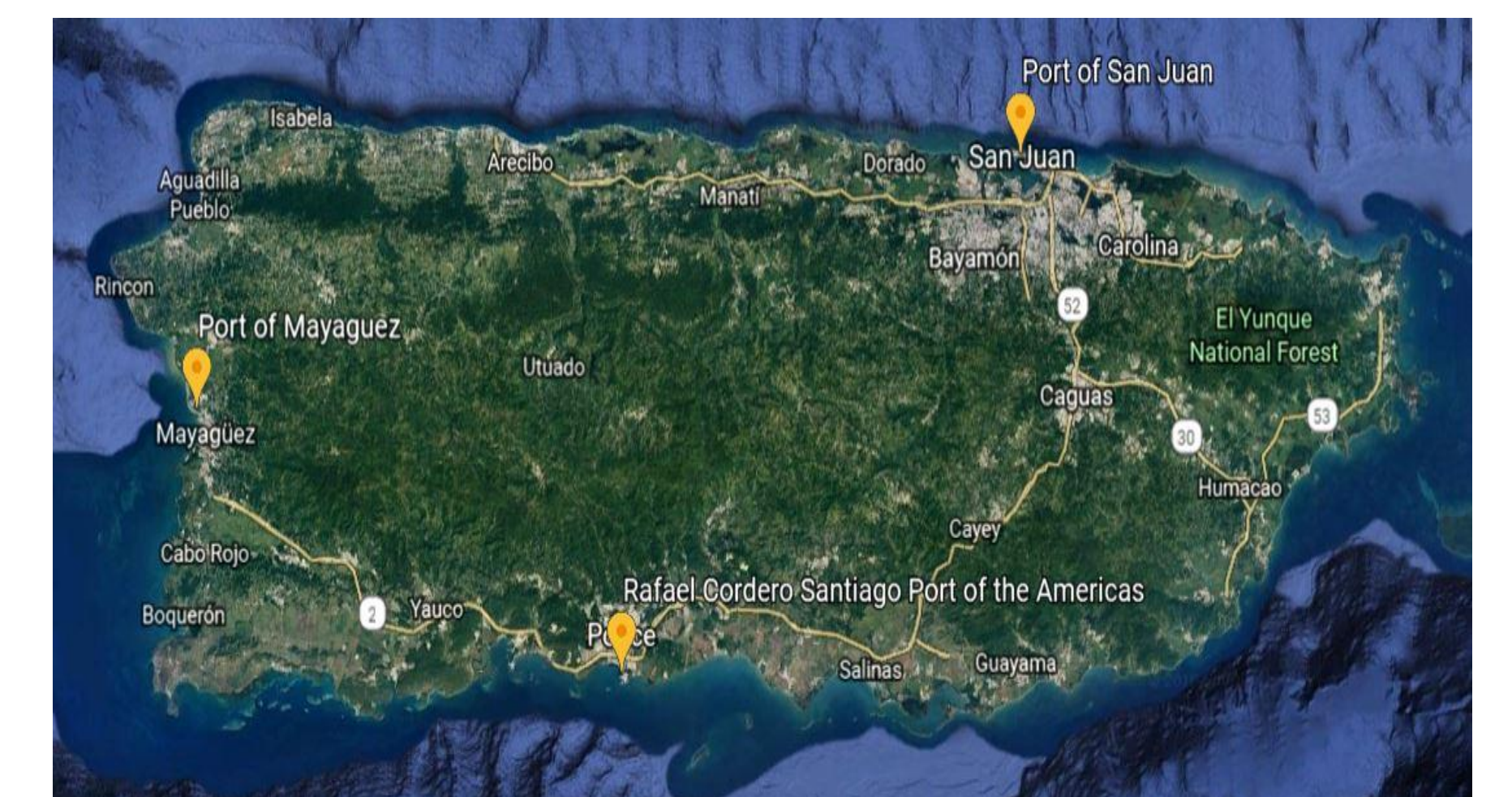
The three major ports within Puerto Rico that handle cargo, ferries, and cruise ships. (Google Earth, 2018.)

IMPLICATIONS

This research will have major impacts on society. By performing this research potential benefits can be achieved in public safety literacy, as well as the improvement of the well-being of individuals in a society. By enhancing emergency preparation and response times—i.e. allowing for the safe passage onto and off of the island and shipment of food, water, and preparedness and recovery supplies across the network in the days leading up to and following a major disaster this. It will help increase partnerships between academia, industry, and others by contributing research on a topic as important as resilient infrastructure from an engineering and academic standpoint. It will help to aid in new resilient infrastructure design and construction throughout the country and the world. It will also help to aid national security by providing data for the need for resilient infrastructure that can be applied to both natural and manmade disasters.

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