Puerto Rico contains three major seaports. They are San Juan Port, the Port of Ponce, and the Port of Mayaguez. In 2017, these ports were disrupted by the wind and waves Hurricane Maria brought to the coast of Puerto Rico. Hurricane Maria devastated the island and its 3.4 million residents. This storm registered as a category 4 hurricane that brought 155 mph winds and more than 7 feet of rain in some areas. Flooding displaced hundreds of thousands of people and left the entire island without power. Hurricane Maria was said to be the most devastating storm to hit Puerto Rico in 80 years. The ports along the coasts of the island suffered severe damage from the rising sea-levels and strong winds making landfall over them.

The contribution of this research is to empirically show how port clusters rely upon each other during disruptive events to increase the overall resiliency of water bourn commerce. The disruptions caused by Hurricane Maria in Puerto Rico, had both short-term and long-term impacts to the affected region. In the short-term, Puerto Rico experienced an inability for freight vessel to access any of the three port on the island territory, delaying millions of dollars worth of goods. Long-term, the economic impact and the recovery process of this region will likely be affected by the devastating storm.

The performance of maritime transportation systems struggle to remain reliable and resiliency during times of disruption. Major disruptions at a port may result from external threats such as storms, terror attacks, and oil or hazardous material spills as well as multiple catastrophic events. The extent of the disruption and damage to a port, and the duration of the disruption depend on the severity of the threat, the degree to which the port is vulnerable to it, and the decisions that are made in responding to the disruption. Resiliency of a port is defined in terms of the severity of the threat and the ability of the port to recover from such severe distress after the disruptive event.

For this study, vessel location information from onboard AIS transceivers will be used to generate average vessel dwell time within the port area of interest and net vessel transits into and out of the port areas of interest. Dwell time is the continuous length of time a vessel spends within the port area or associated regions such as offshore anchorages [1]. This indicates the capability of the port to efficiently handle cargo flows at the terminals and beyond [5]. During a disruptive event, there is a decrease in port performance. Vessels are processed at a slower rate, causing an increase in overall dwell time in the area surrounding the port. The ability of ports to recover from such a disruptive event determines their level of resiliency.

Table 1: Existing research data collected using AIS technology.

<table>
<thead>
<tr>
<th>Port Cluster</th>
<th>Port Name</th>
<th>Cargos</th>
<th>Time-Dependent Resiliency Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Coast</td>
<td>Boston</td>
<td>Oil, Chemical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tobacco, Forest Products</td>
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<td></td>
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<td>Consumer Goods</td>
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<td>Industrial Goods</td>
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<td>Automotive</td>
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<td>Maritime</td>
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<td>Professional Services</td>
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<td></td>
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<td>Medical</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: (a) Arrival times, (b) Dwell times for Long Beach displayed as a probability distribution function.

TIME-DEPENDENT RESILIENCY ANALYSIS

The time-dependent resiliency analysis plots will allow for systematic, objective measures of measuring the resiliency of ports in a cluster. In an increasing service system, network output is positively correlated with node service. These plots will analyze the port’s performance before, during, and after a disruptive event to determine their resiliency. A generic time dependent resiliency plot is shown in Figure 1 (a) for an increasing service system and Figure 2 (b) for a decreasing service system.

Figure 2: (a) Increasing Service System, (b) Decreasing Service System [7].

Mathematically, the resiliency of a system S at time t can be expressed as:

\[ R_S(t) = \frac{P_S(t) - P_S(0)}{P_S(0)} \]

where:
- \( R_S(t) \) is the resiliency of system S at time t,
- \( P_S(t) \) is the performance of the system at time t, corresponding to the time of maximum service loss,
- \( P_S(0) \) is the performance of the system at t=0, corresponding to the original state.

CRITERIA FOR RESILIENCE ANALYSIS

The ability of transportation systems to function when altered by a disruptive event, determines their level of resiliency. A generic time dependent resiliency plot is shown in Figure 1 (a) for an increasing service system and Figure 2 (b) for a decreasing service system [7].

TIME-DEPENDENT RESILIENCY ANALYSIS

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REFERENCES


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