Rebuilding Surface, Maritime, and Air Transportation in Puerto Rico After Hurricanes Irma and Maria

Supporting Documentation for the Puerto Rico Recovery Plan

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On August 8, 2018, the government of Puerto Rico submitted to the U.S. Congress its economic and disaster recovery plan, as required by the Bipartisan Budget Act of 2018. Under contract with the Federal Emergency Management Agency (FEMA), the Homeland Security Operational Analysis Center (HSOAC) provided substantial support in developing the plan by soliciting and integrating inputs from a wide variety of stakeholders, contributing analysis where needed, and supported drafting the plan. The plan included an overview of damage and needs, courses of action to meet those needs, estimated costs of the courses of action, and potential funding mechanisms for those costs.

To support federal agencies evaluating and funding recovery actions, HSOAC is releasing this detailed volume for the transportation sector. The purpose of this document is to provide decisionmakers greater detail on the conditions in Puerto Rico prior to the 2017 hurricane season, damage from Hurricanes Irma and Maria, courses of action that were identified to help the sector (and, more broadly, Puerto Rico) recover in a resilient manner, potential funding mechanisms, and considerations for implementers as they move forward.

This document will likely also be of interest to other stakeholders funding or implementing recovery activities, including government of Puerto Rico and local agencies, nongovernmental organizations, and the private sector. Furthermore, this body of material contributes to the larger literature about disaster recovery and resilience, and may be of interest to other communities planning for or recovering from similar disasters.

This research was sponsored by the Federal Emergency Management Agency and conducted within the Strategy, Policy, and Operations Program of the Homeland Security Operational Analysis Center, a federally funded research and development center (FFRDC). More information about HSOAC’s contribution to planning for recovery in Puerto Rico, along with links to other reports being published as part of this series, can be found at www.rand.org/hsoac/puerto-rico-recovery.

About the Homeland Security Operational Analysis Center

The Homeland Security Act of 2002 (Section 305 of Public Law 107-296, as codified at 6 U.S.C. § 185), authorizes the Secretary of Homeland Security, acting through the Under Secretary for Science and Technology, to establish one or more FFRDCs to provide independent analysis of homeland security issues. The RAND Corporation operates HSOAC as an FFRDC for the U.S. Department of Homeland Security (DHS) under contract HSHQDC-16-D-00007.

The HSOAC FFRDC provides the government with independent and objective analyses and advice in core areas important to the department in support of policy development,
decisionmaking, alternative approaches, and new ideas on issues of significance. The HSOAC FFRDC also works with and supports other federal, state, local, tribal, and public- and private-sector organizations that make up the homeland security enterprise. The HSOAC FFRDC’s research is undertaken by mutual consent with DHS and is organized as a set of discrete tasks. This report presents the results of research and analysis conducted under contract 70FBR218F00000032, “Puerto Rico Economic and Disaster Recovery Plan: Integration and Analytic Support.”

The results presented in this report do not necessarily reflect official DHS opinion or policy. For more information on HSOAC, see www.rand.org/hsoac. For more information on this publication, visit www.rand.org/t/RR2607.
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Summary

This report provides an in-depth review of the transportation sector in Puerto Rico before the September 2017 hurricanes, along with a review of the damage suffered, critical needs, and courses of action (COAs) that were selected by the government of Puerto Rico. This is one in a series of reports produced by the sector-specific Homeland Security Operational Analysis Center teams—teams that also assisted in the development of the long-term recovery plan Transformation and Innovation in the Wake of Devastation: An Economic and Disaster Recovery Plan for Puerto Rico, hereafter referred to as the Recovery Plan. This report covers all modes of transportation: surface (generally divided into roads, bridges, and surface public transportation systems, including bus and rail lines); maritime (seaports and passenger ferries); and air.

Damage and Needs Assessment

In the first phase we gathered information to write a damage and needs assessment report. This summarizes both the prestorm conditions—to the extent that information was available, we considered both the physical condition as well as usage patterns—as well as the damage caused by Hurricanes Irma and Maria. For this phase we reviewed published reports about transportation in Puerto Rico; conducted interviews with Puerto Rican officials and experts, as well as transportation subject-matter experts; and obtained and reviewed unpublished data. In some cases we conducted our own analysis or created our own graphics based on these data. With regard to surface transportation, most roads and bridges were generally in “fair” condition (as objectively measured on good–fair–poor scales used by the Federal Highway Administration). Congestion was relatively high in urban areas, and road safety (as measured in terms of fatalities per mile driven) was the worst in the nation. Public transportation was considered inadequate, with low rates of service provision and many areas lacking any options for nondrivers, and ridership has been on a gradual decline since 2000 despite the opening of a rail system in San Juan in 2005.

With regard to maritime transportation, the island is highly dependent on this sector, which is dominated by the Port of San Juan. The port handles high shares of inbound commodities (of particular note, all liquid fuels are imported), and its overall share of both inbound and outbound

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1 Governor of Puerto Rico, Transformation and Innovation in the Wake of Devastation: An Economic and Disaster Recovery Plan for Puerto Rico, San Juan, P.R.: Central Office of Recovery, Reconstruction, and Resiliency, August 8, 2018. More information about HSOAC’s contribution to planning for recovery in Puerto Rico, along with links to other reports being published as part of this series, can be found at www.rand.org/hsoac/puerto-rico-recovery.
cargo has been increasing since 2000. In addition, almost all cargo to and from the continental United States goes via San Juan (this amounts to approximately one-third of all inbound and 40 percent of all outbound cargo). Both inbound and outbound cargo peaked in 2003, and volumes have declined by roughly one-third since then. While the number of cruise ship calls in the Port of San Juan has declined since 2000, the number of passengers is about the same. Ferries serve the outlying islands of Culebra and Vieques several times daily, with ridership of fewer than 7,000 people per day, and some ferry terminals were in poor condition before the storms.

Air transportation was similarly dominated by Luis Muñoz Marín International Airport (SJU) in San Juan, with 90 percent of all passenger movements. However, the number of flights has been declining since it peaked in 2000. This airport was privatized in 2013 in response to increasing levels of debt and the need for major upgrades.

The estimated dollar value of damage incurred in each sector is provided in Table S.1. For some modes, two figures are provided: the amount needed to bring the infrastructure to a state of good repair, and the additional amount required to make enhancements to increase resilience. Combined, these two figures are approximately $3 billion. These estimates include damage to road surfaces and bridges; bus terminals and rail stations; piers, wharves, and buildings at seaports; ferry terminals and vessels; and airport runways and buildings. The repairs that are recommended range from minor fixes to major overhauls, and in some cases demolition and rebuilding. A number of separate pieces of port infrastructure have been assessed as “critical,” an official designation meaning that the structure is unsound and repairs are urgent.

Table S.1. Summary of Available Damage Estimates for Transportation Infrastructure as of June 2018

<table>
<thead>
<tr>
<th>Transportation Mode</th>
<th>Estimated Dollar Value of Damage—Repair Only</th>
<th>Additional Resilience Measures</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads and bridges</td>
<td>$646.7 million</td>
<td>N/A</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>Analysis by McKinsey for PRHTA Revised Fiscal Plan, June 2018</td>
</tr>
<tr>
<td></td>
<td>$14.5 million</td>
<td>N/A</td>
<td>Metropistas/Moody’s</td>
<td>Highways PR-5 and PR-22</td>
</tr>
<tr>
<td>Public transportation (surface)</td>
<td>$105.8 million</td>
<td>$150.7 million</td>
<td>Hill International</td>
<td>Tren Urbano</td>
</tr>
<tr>
<td></td>
<td>$14.6 million</td>
<td>$1.8 million</td>
<td>Hill International</td>
<td>Metropolitan Bus Authority</td>
</tr>
<tr>
<td></td>
<td>$36 million</td>
<td>$1.5 million</td>
<td>Hill International</td>
<td>Municipalities</td>
</tr>
<tr>
<td>Ports</td>
<td>$909.7 million</td>
<td>$895.8 million</td>
<td>MARAD and PRPA contractor reports</td>
<td></td>
</tr>
<tr>
<td>Ferries</td>
<td>$38.4 million</td>
<td>$102.5 million</td>
<td>Hill International</td>
<td>Maritime Transportation Authority</td>
</tr>
<tr>
<td>Airports</td>
<td>$108 million</td>
<td>N/A</td>
<td>Gvelop</td>
<td>Based on full reports, except for Luis Muñoz Marín International Airport</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1.874 billion</td>
<td>$1.150 billion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to identifying physical damage, we also analyzed the impact of the hurricanes on the usage of various modes of transportation. As of spring 2018, a few roadway sections and bridges remained closed, but all rail and bus service, ports, ferry service, and airports were operating. However, cargo shipping, passenger arrivals on cruise ships, and airline passenger movements fell dramatically following the storms. By March 2018, the latest period for which we were able to analyze data, cruise ship traffic had rebounded to the prehurricane levels typical for that period of the year. Cargo traffic was relatively unaffected; if anything, shipping seems to have increased, likely due to the need for recovery supplies. Air passenger traffic was estimated to be down from prestorm levels by 40 percent for arrivals and 24 percent for departures, while air cargo was less affected.

Finally, our assessment of needs also included the ongoing challenges for recovery. These include the challenges of geography and topography to create a more resilient road network; the need for better information on existing conditions; and the need to address congestion, safety, and options for those who do not drive. For public transportation they include staving off decline and ensuring service delivery. The port system needs sufficient redundant capacity to ensure that deliveries of critical imports continue during natural disasters or other severe interruptions in service. The airport system needs to be more physically resilient. All modes experienced financial shortfalls of varying degrees, suggesting that it is important to balance the need for resilience improvements and possible increases in capacity and redundancy with limited resources and the need for ongoing maintenance.

Courses of Action

In the second phase we developed a portfolio of COAs to address these ongoing needs. COAs are broadly defined as policies or projects that contribute to recovery or economic development. Some were new to Puerto Rico, while others reflect long-standing plans. Developing these COAs was an iterative process involving internal team discussions and revisions of COAs based on stakeholder feedback. Our general guidance for developing COAs included the principles that the COAs should

- be at a usable level of specificity (e.g., neither too broad nor too narrow)
- have been demonstrated to be effective, based on implementation in other contexts
- incorporate all needs for repairs to storm damage
- balance innovation with basic needs
- reflect best practices, as gleaned from examples in the continental United States and around the world
- address both recovery and economic development
- include both policies as well as specific projects
- collectively be manageable in number (between 20 and 30)
- represent all modes of transportation, as well as both passenger and goods movement
- address Puerto Rico’s specific needs, as identified in the first phase of our research.
Summary of Courses of Action

The Recovery Plan includes 22 COAs for transportation. Collectively they address all modes of transportation and four broad areas: repair and maintenance, upgrades, new capacity, and plans/policies/management. They are summarized in the Recovery Plan as follows:

Upgrade Ports and Consolidate Ownership to Improve Emergency Response and Attract New Maritime Business

Actions here include having port authorities, in collaboration with private operators, repair damage to ports and ferry terminals so they are at their full prehurricane capacity (TXN 12) and make upgrades that enhance their resilience to storms and sea level rise (TXN 22). To ensure that backup capacity exists if the Port of San Juan is damaged, the PRPA and other port operators can further develop an existing seaport (e.g., Ponce) to provide redundant capacity through the use of public-private partnerships (TXN 10). Reassessing the Marine Transportation System Recovery Plan can help the ports take advantage of lessons learned during the hurricane response, such as pre-positioning reserve capacities and assets to better respond to an emergency, establishing an integrated operations center, developing a communications protocol for first responders during a disaster, and implementing prehurricane protection measures in an integrated fashion to protect critical resources (TXN 13).

To better manage the marine transportation system as a whole and to make ports more attractive to maritime businesses and investors, input from industry experts indicates the need for consolidating ownership and oversight of Puerto Rico’s nine main ports (TXN 15). In addition to being a multipurpose port, it is recommended that the Port of Ponce be leveraged as a future regional transshipment hub for cargo traveling between North and South America, through the Panama Canal en route to Europe, and regional traffic within the Caribbean basin. Shippers could be incentivized to use it through reduced taxes or a government subsidy (TXN 14).

Prioritize Repairs to Roads and Bridges, and Extend Three Key Highways

Recovery actions here include the PRHTA repairing damaged roads and bridges and restoring them to prehurricane functionality to ensure the mobility of people, goods, and service providers. Within four years, this initiative would replace missing road signs and inoperable traffic signals and repair or replace collapsed or weakened bridges (TXN 16). The PRHTA can also harden, reengineer, or relocate infrastructure in high-risk areas to make it more resilient in future disasters, with a focus on the most cost-effective projects (TXN 2).

2 While all COAs are numbered, the numbers correspond to how the COAs are identified in the Recovery Plan, and are not in a prioritized order. TXN is the Recovery Plan designation for the transportation sector; each sector was assigned a three-letter code.
Under a new “fix it first” approach, the PRHTA can prioritize road maintenance and repair projects over new or expanded infrastructure. This approach improves roadway conditions and makes safety or operational improvements, and it prioritizes projects based on their cost-effectiveness (TXN 5). Projects to extend the highways PR-5 and PR-22 and to complete PR-10, potentially through the use of public-private partnerships, are included as surface transportation projects to improve mobility, safety, access, resilience, and emergency response and to complete Puerto Rico’s strategic highway network (TXN 19, TXN 20, TXN 21).

To better manage transportation infrastructure, public agencies can develop infrastructure asset management programs to inventory their assets and track their condition to improve maintenance, repair, and rehabilitation (TXN 11). In support of this effort, the PRHTA has submitted an initial asset management plan to the Federal Highway Administration that focuses on improved infrastructure conditions and cost-effective asset management. Related to this effort, the plan includes an action for the PRHTA to review its standards on road and bridge design. This will involve updates to include more innovative standards on roadway marking, lighting, drainage, and signs and signals (including using solar energy to power them) and better enforcement of both new and existing standards (TXN 1).

In addition, the PRHTA can develop an intelligent transportation system so that transportation operations across Puerto Rico can provide real-time traveler information, divert traffic away from crashes, clear crashes more quickly, and reduce the possibility of secondary crashes after an initial incident (TXN 9).

Develop New Mobility Options to Supplement Improvements to Bus Service

This includes having the Puerto Rico Metropolitan Bus Authority make bus service more reliable through transit signal priority (which gives buses additional time to cross a signalized intersection) and dedicated bus lanes, as well as bus stops that provide real-time arrival information and use smart card fare media (TXN 8). Developing additional options—such as ride hailing, ride sharing, expanded público (jitney) service, intercity bus service, bike or scooter sharing, and peer-to-peer car sharing—will address the dearth of other mobility services, particularly outside of San Juan (TXN 7).

In addition, the PRHTA proposes two new high-capacity transit services—likely bus rapid transit—to give travelers another way to reach SJU (TXN 17), which is currently served by just three bus routes, and to give the 130,000 residents of Caguas a public transit option to reach nearby San Juan (TXN 18).

Upgrade San Juan’s and Aguadilla’s Airports to Boost Resilience and Porta del Sol Tourism

To ensure that SJU can operate at full capacity both during normal operations and in an emergency, the PRPA and airport operator Aerostar Airport Holdings can repair remaining damage to the facilities (TXN 4), update Airport Emergency Plans to take advantage of lessons
learned from the hurricanes, and further develop a coordinated disaster recovery plan for the various airports across Puerto Rico (TXN 6).

In addition, the PRPA proposes to expand and upgrade Rafael Hernández International Airport in Aguadilla, including upgrading the runway, taxiways, and terminals. These actions would increase Puerto Rico’s overall capacity for air traffic and boost tourism in Porta del Sol, a region with beautiful beaches that are currently difficult to reach (TXN 3).

**Summary of Costs**

For each COA we developed a rough cost estimate based on damage estimates that included repair costs provided by contractors hired by the Federal Emergency Management Agency or other government entities (for those COAs focused on repairs and upgrades), experience from other locations where the COA is in use, or estimates developed by the government of Puerto Rico (for those COAs focused on new capacity). Because of the uncertainty, and in some cases the fact that the COAs could be implemented in multiple ways, we developed a range of costs for some COAs, which included both up-front costs and recurring costs over a period of 11 years (the time frame of the Recovery Plan). Estimated costs for each COA are provided in Table S.2. All cost estimates are very high-level estimates.
## Table S.2. Transportation Courses of Actions and Estimated Costs

<table>
<thead>
<tr>
<th>COA Number</th>
<th>COA Name</th>
<th>Potential Up-Front Costs</th>
<th>Potential Recurring Costs</th>
<th>Potential Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXN 1</td>
<td>Refine and Enforce Design Standards for Roads and Bridges</td>
<td>$2 million– $100 million</td>
<td>$3 million– $1 million</td>
<td>$6 million– $100 million</td>
</tr>
<tr>
<td>TXN 2</td>
<td>Harden Vulnerable Transportation Infrastructure</td>
<td>$1.3 million– $380 million</td>
<td>$1.3 million– $380 million</td>
<td>$380 million</td>
</tr>
<tr>
<td>TXN 3</td>
<td>Redevelop Rafael Hernández Airport</td>
<td>$400 million– $500 million</td>
<td>$0</td>
<td>$400 million– $500 million</td>
</tr>
<tr>
<td>TXN 4</td>
<td>Repair Airport Damage</td>
<td>$250 million– $500 million</td>
<td>$12 million</td>
<td>$270 million</td>
</tr>
<tr>
<td>TXN 5</td>
<td>Road Maintenance and Repair Program</td>
<td>$100 million– $5.5 billion</td>
<td>$900 million</td>
<td>$1.0 billion– $6.4 billion</td>
</tr>
<tr>
<td>TXN 6</td>
<td>Update Airport Emergency Plans</td>
<td>$4 million– $1 million</td>
<td>$5 million</td>
<td></td>
</tr>
<tr>
<td>TXN 7</td>
<td>Incentivize a Variety of Mobility Options</td>
<td>$450,000– $17 million</td>
<td>$4.9 million– $190 million</td>
<td></td>
</tr>
<tr>
<td>TXN 8</td>
<td>Improve Bus Service</td>
<td>$200,000– $750 million</td>
<td>$8 million– $730 million</td>
<td></td>
</tr>
<tr>
<td>TXN 9</td>
<td>Develop an Intelligent Transportation System</td>
<td>$30 million– $48 million</td>
<td>$78 million</td>
<td></td>
</tr>
<tr>
<td>TXN 10</td>
<td>Develop Redundant Seaport Capacity</td>
<td>$87 million– $160 million</td>
<td>$14 million– $23 million</td>
<td>$100 million– $180 million</td>
</tr>
<tr>
<td>TXN 11</td>
<td>Support Infrastructure Asset Management</td>
<td>$5 million– $1 million</td>
<td>$6 million</td>
<td></td>
</tr>
<tr>
<td>TXN 12</td>
<td>Repair Damage to Ports and Ferry Terminals</td>
<td>$940 million– $650 million</td>
<td>$46 million– $730 million</td>
<td></td>
</tr>
<tr>
<td>TXN 13</td>
<td>Reassess the Marine Transportation System Recovery Plan</td>
<td>$100,000– $300,000</td>
<td>$200,000– $500,000</td>
<td></td>
</tr>
<tr>
<td>TXN 14</td>
<td>Long-Term Planning to Develop Port of Ponce as a Regional Transshipment Hub</td>
<td>$50 million– $300 million</td>
<td>$50 million– $200 million</td>
<td>$100 million– $500 million</td>
</tr>
<tr>
<td>TXN 15</td>
<td>Consolidate Port Ownership</td>
<td>$0</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>TXN 16</td>
<td>Repair Damage to Surface Transportation Network</td>
<td>$800 million– $16 million</td>
<td>$820 million</td>
<td></td>
</tr>
<tr>
<td>TXN 17</td>
<td>Provide High-Capacity Transit Service to San Juan Airport</td>
<td>$400 million– $170 million</td>
<td>$570 million</td>
<td></td>
</tr>
<tr>
<td>TXN 18</td>
<td>Provide High-Capacity Transit Service Between San Juan and Caguas</td>
<td>$200 million– $170 million</td>
<td>$370 million</td>
<td></td>
</tr>
<tr>
<td>TXN 19</td>
<td>Extend PR-5</td>
<td>$220 million– $0</td>
<td>$220 million</td>
<td></td>
</tr>
<tr>
<td>TXN 20</td>
<td>Extend PR-22</td>
<td>$1 billion– $0</td>
<td>$1 billion</td>
<td></td>
</tr>
<tr>
<td>TXN 21</td>
<td>Complete PR-10</td>
<td>$370 million– $510,000</td>
<td>$370 million</td>
<td></td>
</tr>
<tr>
<td>TXN 22</td>
<td>Increase Port Facility Resilience</td>
<td>$360 million– $540 million</td>
<td>$0</td>
<td>$360 million– $540 million</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$3.9 billion– $13.3 billion</td>
<td>$1.1 billion– $2.7 billion</td>
<td>$5 billion– $16 billion</td>
</tr>
</tbody>
</table>

**NOTES:** Some figures are rounded to the nearest $10 million. Figures in this table match the estimates provided in the *Recovery Plan*, but in the course of writing this sector-specific report, some estimates have changed. The total for TXN 4 differs from the detailed estimate in Table 4.4 (summarized in Tables S.1 and 1.2) because the team changed its estimate of the total cost to repair airport damage after the *Recovery Plan* was submitted; see the explanation in Chapter 4, in the Hurricane Damage section, Facility Damage subsection. The estimate for TXN 12 changed based on more recently updated information, but by a much smaller amount. TXN 7 and TXN 8 differ due to errors.
Acknowledgments

This work would not have been possible without the assistance of many people. First, we would like to thank the Transportation Sector Solutions Team, led by Jose “Joe” Girot of the Federal Emergency Management Agency, and his very able staff at the Joint Recovery Office in San Juan: Chris Baggot, Jon Hain, Travis Johnson, and Daysha Rivera Ruiz. Without them we would not have had access to the data, advice, connections, and expertise to carry out our analysis.

Others who provided assistance at the Joint Recovery Office include Dan Genoa, Mike Lacey, and Paolo Pascetta of the Department of Homeland Security Office of Infrastructure Protection; Sarah Radcliff, Jim Robinson, and Chris Rotondo, who were part of the U.S. Department of Transportation team for the transportation Emergency Support Function; and Johann Sasso of the U.S. Army Corps of Engineers, who served as the infrastructure Recovery Support Function lead. All of them increased our understanding of conditions in Puerto Rico, both pre- and poststorm.

At the Department of Transportation, we also thank Michael Avery of the Federal Highway Administration, Travis Black and Scott Davies of the Maritime Administration, Robert Buckley and Jorismar Torres of the Federal Transit Administration, and Michael Callahan of the Office of Intelligence, Security, and Emergency Response. All of them provided helpful insights into transportation conditions and Department of Transportation programs.

Katherine Chambers, research physical scientist with the U.S. Army Corps of Engineers, Headquarters, Engineer Research and Development Center, Coastal and Hydraulics Laboratory, provided a valuable analysis of Automatic Identification System data, which we incorporated into this report.

We also had invaluable support from several agencies of the government of Puerto Rico. Carlos M. Contreras, Secretary of the Department of Transportation and Public Works, and Anthony Maceira, Executive Director of the Puerto Rico Ports Authority, provided valuable insights into our work midstream, informing the transportation elements of the Recovery Plan. Mayda Maitee Hernández of the Central Office of Recovery, Reconstruction, and Resiliency provided helpful recommendations and served as our main liaison with the government of Puerto Rico; she also introduced us to Migdalia Carrión Alers of the Puerto Rico Highway and Transportation Authority, who gave us insights into the planning process on the island.

At the RAND Corporation, early drafts of our work were very ably reviewed by Thomas Light of RAND and Thomas Wall of Argonne National Laboratory, and Jeremy Eckhause of RAND kept our quality assurance process on track. Jaime Hastings and Michelle Ziegler filled in on several occasions as our forward team representatives in the Joint Recovery Office. We received much-needed assistance with preparing this report from Sarika Bharil, Quiana Fulton,
and Rosa Maria Torres. Finally, we thank the rest of the 150-person RAND research team, especially Lara Schmidt, the program director; Cynthia Cook, the project director; and Justin Hodiak, deputy project director, for their patience and guidance.
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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</thead>
<tbody>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>AEP</td>
<td>Airport Emergency Plan</td>
</tr>
<tr>
<td>AIS</td>
<td>Automatic Identification System</td>
</tr>
<tr>
<td>AMA</td>
<td>Autoridad Metropolitana de Autobuses de Puerto Rico [Puerto Rico Metropolitan Bus Authority]</td>
</tr>
<tr>
<td>ASUR</td>
<td>Grupo Aeroportuario del Sureste, S.A.B. de C.V. [Southeast Airport Group]</td>
</tr>
<tr>
<td>ATADS</td>
<td>Air Traffic Activity Data System</td>
</tr>
<tr>
<td>ATM</td>
<td>Autoridad de Transporte Maritimo [Maritime Transport Authority, Puerto Rico]</td>
</tr>
<tr>
<td>BRT</td>
<td>bus rapid transit</td>
</tr>
<tr>
<td>BTS</td>
<td>Bureau of Transportation Statistics</td>
</tr>
<tr>
<td>BUILD</td>
<td>Better Utilizing Investments to Leverage Development</td>
</tr>
<tr>
<td>CCTV</td>
<td>closed-circuit television</td>
</tr>
<tr>
<td>CDBG-DR</td>
<td>Community Development Block Grant—Disaster Recovery</td>
</tr>
<tr>
<td>COA</td>
<td>course of action</td>
</tr>
<tr>
<td>Comm/IT</td>
<td>Communications / Information Technology (sector)</td>
</tr>
<tr>
<td>COR3</td>
<td>Central Office of Recovery, Reconstruction, and Resiliency</td>
</tr>
<tr>
<td>CPCB</td>
<td>Community Planning and Capacity Building (sector)</td>
</tr>
<tr>
<td>DDIR</td>
<td>Detailed Damage Inspection Report</td>
</tr>
<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
</tr>
<tr>
<td>DOT</td>
<td>Department of Transportation</td>
</tr>
<tr>
<td>DTOP</td>
<td>Departamento de Transportación y Obras Públicas [Department of Transportation and Public Works, Puerto Rico]</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>FFRDC</td>
<td>federally funded research and development center</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
</tr>
<tr>
<td>GAO</td>
<td>U.S. Government Accountability Office</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>HPMS</td>
<td>Highway Performance Monitoring System</td>
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<td>HSIP</td>
<td>Highway Safety Improvement Program</td>
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<tr>
<td>HSOAC</td>
<td>Homeland Security Operational Analysis Center</td>
</tr>
<tr>
<td>IRI</td>
<td>International Roughness Index</td>
</tr>
<tr>
<td>IT</td>
<td>information technology</td>
</tr>
<tr>
<td>ITS</td>
<td>intelligent transportation system</td>
</tr>
<tr>
<td>LNG</td>
<td>liquefied natural gas</td>
</tr>
<tr>
<td>LRT</td>
<td>light rail transit</td>
</tr>
<tr>
<td>MARAD</td>
<td>Maritime Administration</td>
</tr>
<tr>
<td>MNW</td>
<td>Matrix New World Engineering</td>
</tr>
<tr>
<td>MOP</td>
<td>municipally owned property</td>
</tr>
<tr>
<td>MPO</td>
<td>metropolitan planning organization</td>
</tr>
<tr>
<td>MTS</td>
<td>marine transportation system</td>
</tr>
<tr>
<td>NCR</td>
<td>Natural and Cultural Resources (sector)</td>
</tr>
<tr>
<td>NHPP</td>
<td>National Highway Performance Program</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>operations and maintenance</td>
</tr>
<tr>
<td>P3</td>
<td>public-private partnership</td>
</tr>
<tr>
<td>PREMA</td>
<td>Puerto Rico Emergency Management Agency</td>
</tr>
<tr>
<td>PREPA</td>
<td>Puerto Rico Electric Power Authority</td>
</tr>
<tr>
<td>PRHTA</td>
<td>Puerto Rico Highway and Transportation Authority</td>
</tr>
<tr>
<td>PRIDCO</td>
<td>Puerto Rico Industrial Development Company</td>
</tr>
<tr>
<td>PRP3A</td>
<td>Puerto Rico Public-Private Partnerships Authority</td>
</tr>
<tr>
<td>PRPA</td>
<td>Puerto Rico Ports Authority</td>
</tr>
<tr>
<td>RIITS</td>
<td>Regional Integration of Intelligent Transportation Systems, Los Angeles County, California</td>
</tr>
<tr>
<td>SHOPP</td>
<td>State Highway Operation and Protection Program</td>
</tr>
<tr>
<td>SJU</td>
<td>Luis Muñoz Marín International Airport (San Juan, Puerto Rico)</td>
</tr>
<tr>
<td>STBGP</td>
<td>Surface Transportation Block Grant Program</td>
</tr>
<tr>
<td>TEU</td>
<td>twenty-foot equivalent unit (of cargo capacity)</td>
</tr>
<tr>
<td>USACE</td>
<td>U.S. Army Corps of Engineers</td>
</tr>
<tr>
<td>USCG</td>
<td>U.S. Coast Guard</td>
</tr>
<tr>
<td>USDOT</td>
<td>U.S. Department of Transportation</td>
</tr>
</tbody>
</table>
1. Background, Methods, and Data

This report is one of a series of reports that provide supporting analysis to the Puerto Rico long-range recovery plan, *Transformation and Innovation in the Wake of Devastation: An Economic and Disaster Recovery Plan for Puerto Rico*. This report provides more in-depth background, giving greater context regarding transportation in Puerto Rico, a discussion of the data sources and types of analysis conducted with respect to prestorm conditions, hurricane damage, and a summary of the dollar value of damage to the transportation sector. The information was current as of the time this report was originally drafted, in the spring of 2018.¹

Overview of Transportation in Puerto Rico

Reliable transportation is crucial to any economy. The Department of Homeland Security (DHS) considers transportation to be lifeline infrastructure, without which normal life or disaster recovery is impossible. Transportation includes both passenger and freight movement, by ground (surface transportation), water (maritime transportation), and air. All of these modes were severely affected by Hurricanes Irma and Maria, with major dislocations to daily life and the ability to move relief supplies around the island.

While transportation is essential to economic development and recovery, Puerto Rico’s transportation context differs from that of the continental United States in three important ways.

First, as an island, the port system is extremely important, and the Port of San Juan has been called the island’s most important piece of infrastructure given the high reliance on imports (Puerto Rico imports approximately 85 percent of its food, and all of its liquid fuel). The Port of San Juan handles 79 percent of all shipments for the entire island.² Without a robust port system, economic activity would be severely hampered.

Second, all tourists arrive by either air or sea, making the Port of San Juan and Luis Muñoz Marín International Airport (SJU) very important to the maintenance and growth in tourism. This in turn supports the initiative in the *Recovery Plan* to expand the visitor economy.

Finally, while freight rail and pipelines carry a substantial fraction of goods and fuels in the continental United States, all freight within Puerto Rico moves via truck. These movements

¹ More information about HSOAC’s contribution to planning for recovery in Puerto Rico, along with links to other reports being published as part of this series, can be found at www.rand.org/hsoac/puerto-rico-recovery.

primarily take place on the strategic highway network, which generally circumnavigates the island, or on the streets of the San Juan metropolitan area. During a serious disruption, goods can be moved via alternate routes, but not via alternate modes.

One other characteristic is noteworthy: Puerto Rico has been an early adopter of public-private partnerships (P3s) to build and operate major transportation infrastructure, more so than most U.S. states. The Teodoro Moscoso Bridge in San Juan, completed in 1994, is considered the first P3 of the modern era. Other major P3s from the 2010s include highways PR-5 and PR-22, as well as SJU. These assets continue to be owned by the government of Puerto Rico but are operated by private entities under long-term concession agreements.

**Damage Assessment Methodology and Data**

This section provides information on available data (for both pre- and poststorm conditions). These data provide the basis for assessing the extent of damage caused by the storms and placing it in the context of existing conditions. The purpose is to provide a baseline to help determine what is needed to recover to levels exceeding prestorm conditions, since prestorm conditions were not necessarily adequate for travel demand, economic development, and resilience to natural disasters. In this report, damage assessments are presented through March 19, 2018, six months after Hurricane Maria made landfall, unless otherwise noted.

**Process**

Since extensive damage assessments had been conducted by the Federal Emergency Management Agency (FEMA) and other agencies in the transportation sector, the Homeland Security Operational Analysis Center (HSOAC) did not conduct any independent damage assessments. The discussion below synthesizes the various assessments that we have been provided through FEMA, the Federal Highway Administration (FHWA), and the Puerto Rico Department of Transportation and Public Works (DTOP, for Departamento de Transportación y Obras Públicas). We have reviewed these reports to develop a sense of their thoroughness, and have cross-checked reports against each other for consistency. We have not conducted independent site visits to all the sites mentioned in this report. However, we have had personal communication with multiple staff members at the Puerto Rico Highway and Transportation Authority (PRHTA) and made site visits to the ports at Mayagüez and Ponce.³

³ Given the pace of the project, many of these communications were informal visits or telephone calls, and although we clearly identified ourselves and the project, we did not consistently ask people for permission to quote them. Therefore, where we cite personal communications with agency staff, we include only the agency name, not names of specific individuals. A full list of all agencies with which we have had contact is available in documentation that can be found in Appendix B.
We also examined hurricane impacts by studying data from the Puerto Rico Ports Authority (PRPA) on the utilization of different airport and port facilities. These data include measures of the number of passengers arriving at and departing from different airports, the number of tons of cargo departing from different airports, and similar information available for certain ports. We also compared data provided by the U.S. Army Corps of Engineers (USACE) on vessel movements by type and port, pre- and poststorm. By comparing prestorm averages with poststorm trends, we can analyze the impact of the hurricanes.4

**Data Sources**

With some exceptions, most of the data that we used to assess prestorm conditions were publicly available via online sources, which are cited in the relevant chapters. Damage assessment data were mostly provided directly to the HSOAC team by one of the following agencies: FEMA, the Federal Transit Administration (FTA); DTOP, which is responsible for all surface transportation as well as passenger ferry service; the PRPA, which oversees most seaports and airports; and MARAD.5 Most of these data are not available publicly.

With regard to surface transportation, DTOP Emergency Operations Center provided monthly updates in 2018 on Hurricane Maria damage. This report details DTOP debris removal process, as well as the then-current operability and restoration processes of Puerto Rico’s highways and public transportation systems. DTOP also provided a dashboard for information regarding the operability of roadways, bridges, public transportation, and public services across the island.6 The most recent one, as of the time of this writing, was dated March 9, 2018; updates were provided on the ninth day of every month.

The FHWA provided Detailed Damage Inspection Report (DDIR) data from Puerto Rico following the hurricane. These data include where and when inspections were carried out, as well as descriptions and cost estimates of the damage. At the time of this writing, some road and bridge inspections, conducted by engineers engaged by DTOP or FEMA, were still underway.

The FTA provided damage assessment data for Puerto Rico’s transit systems. These data include estimated repair costs, the results of the assessments measuring impacts across multiple domains, and the location of the facilities that were assessed. These data encompass the facilities

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4 It is important to note that some of the reductions in utilization observed could be due to storm damage reducing the supply of infrastructure (i.e., a damaged airport cannot receive passengers), but some of that reduction could also be because of reduced demand (people not wanting to travel to Puerto Rico after a severe hurricane). Comparing our findings from this analysis with the damage assessments can help to uncover which explanation is driving outcomes.

5 Specific information on transportation governance by mode is available in Chapters 2, 3, and 4.

6 This one-page dashboard summarizes the status of a number of different types of infrastructure and services under DTOP’s purview, including closed roadways and bridges; the operating status of rail stations, buses, and ferries; and the operating hours of Department of Motor Vehicle offices.
of multiple organizations: the Metropolitan Bus Authority (AMA, for Autoridad Metropolitana de Autobuses de Puerto Rico), the PRHTA, the Puerto Rico Maritime Transport Authority (ATM, for Autoridad de Transporte Maritimo), and the municipal-level transportation authorities.

The PRPA engaged its own contractors to assess damage at the seaports it owns; four such assessments were shared with the HSOAC team. The U.S. Department of Transportation Maritime Administration (MARAD) was also given a mission assignment by FEMA to conduct structural assessments of all ports, to include both aboveground and underwater assessments, as PRPA assessments did not include the latter. This includes 23 separate assessments, as some ports had multiple assessments for different piers.

For airports, the PRPA also engaged its own contractors, and nine such assessments were provided to the HSOAC team in February 2018. The PRPA also provided two summaries of airport damage, one in June and a second in August. These three sets of figures are different, and we were unable to ascertain the reasons for the discrepancies. The PRPA summaries included a total damage estimate for SJU, but no detailed assessment was available.

Utilization data on ports and airports come from the PRPA, which provides monthly data on the number of airline passengers arriving at and departing from different airports, the number of cargo tons arriving at and departing from different airports, the number of cruise ship passengers and cruise ship arriving at the Port of San Juan, and the number of cargo tons processed by the Port of San Juan. Automatic Identification System (AIS) data were collected and summarized by USACE.

Table 1.1 summarizes these data sources.

Data Analysis

We have analyzed larger data sets and developed tables, maps, and other graphics to illustrate notable trends in the data or spatial patterns. We have also used monthly data on passenger and freight volumes at airports and seaports to develop a regression analysis of the impact of Hurricane Maria on these volumes.

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7 Mission assignments are formal requests from FEMA to other government agencies to carry out work related to recovery.

8 PRPA, Strategic Plan for Recovery, Reconstruction, and Resiliency, Preliminary Draft, Appendix B.1, PRPA Damage Inventory. Undated; provided to HSOAC in June 2018.

9 PRPA, PRPA Facilities Description (fact sheet), August 14, 2018. Provided to HSOAC in August 2018.

10 See Chapter 4, Facility Damage, for a more detailed description of these varying estimates.
### Table 1.1. Summary of Data Sources and Information Gaps for Transportation

<table>
<thead>
<tr>
<th>Source</th>
<th>Date Range</th>
<th>Prestorm</th>
<th>Poststorm</th>
<th>Recovery</th>
<th>Data Acquisition Status</th>
<th>Evaluation Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway segment length, location, condition and</td>
<td>DTOP</td>
<td>2016</td>
<td>Y</td>
<td></td>
<td>Provided to HSOAC team</td>
<td>Useful for DTOP roads; does not cover all roads.</td>
</tr>
<tr>
<td>information about traffic volumes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway ownership and functional classification</td>
<td>FHWA, Highway</td>
<td>2014</td>
<td>Y</td>
<td></td>
<td>Publicly available</td>
<td>Centerline miles on roads owned by DTOP and municipalities, divided by rural/urban and functional classification.</td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Monitoring System</td>
<td></td>
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<tr>
<td></td>
<td>(HPMS)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTOP Status Dashboard</td>
<td>DTOP</td>
<td>Current as of March 9, 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Concise one-page summary of operational status for roads, bridges, and San Juan public transportation systems.</td>
</tr>
<tr>
<td>Executive summary</td>
<td>DTOP</td>
<td>Current as of January 18, 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>More details on operational status for roads, bridges, and San Juan public transportation systems; has not been updated since January 18, 2018.</td>
</tr>
<tr>
<td>Tracking table</td>
<td>FHWA</td>
<td>Current as of March 20, 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Describes detailed damage inspection reports on roads and bridges, the majority of which have been &quot;signed&quot; by FHWA engineers. Includes cost estimates for individual reports and some summary statistics. Costs are broken down into emergency and permanent repairs.</td>
</tr>
<tr>
<td>PRHTA Revised Fiscal Plan (cost of road and bridge</td>
<td>McKinsey</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Publicly available; additional information provided to HSOAC team</td>
<td>The most recently certified Revised Fiscal Plan for the PRHTA is dated June 29, 2018. McKinsey, the consulting firm that drafted this plan, provided us an update to this information.</td>
</tr>
<tr>
<td>Source</td>
<td>Date Range</td>
<td>Prestorm</td>
<td>Poststorm</td>
<td>Recovery</td>
<td>Data Acquisition Status</td>
<td>Evaluation Notes</td>
</tr>
<tr>
<td>--------</td>
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<td>------------------</td>
</tr>
<tr>
<td>Report on damage to PR-5, PR-22, and the Teodoro Moscoso Bridge</td>
<td>Not available</td>
<td>Unknown</td>
<td>Y</td>
<td></td>
<td>Not provided to HSOAC team</td>
<td>While we assume that the Spanish firm Abertis’s Autopistas and Metropistas have undertaken an assessment of the damage suffered because of Hurricane Maria, FEMA has confirmed that it does not have access to these reports.</td>
</tr>
<tr>
<td>Transit ridership</td>
<td>FTA, National Transit Database</td>
<td>2000–2016</td>
<td>Y</td>
<td></td>
<td>Publicly available</td>
<td>Number of weekday boardings, by transit service.</td>
</tr>
<tr>
<td>Puerto Rico Hurricane Maria Transit Infrastructure and Vehicle Damage Assessment Report</td>
<td>Hill International</td>
<td>Current as of May 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Gives information on the damage done to public transportation services around the island, as well as smaller regional services. Includes repair cost estimates.</td>
</tr>
<tr>
<td>Maritime Transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruise ship passengers, vessel calls, and cargo movement (tons and 20-foot equivalent units [TEUs])</td>
<td>PRPA</td>
<td>July 2013–March 2018 (monthly)</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Port of San Juan only.</td>
</tr>
<tr>
<td>Port cargo volumes and movements</td>
<td>U.S. Army Corps of Engineers (USACE)</td>
<td>2000–2016</td>
<td>Y</td>
<td></td>
<td>Publicly available</td>
<td>Short tons of cargo in- and outbound for six ports; cargo by type; basic origin/destination (continental United States versus international).</td>
</tr>
<tr>
<td>Consultant damage assessment reports on three small ports</td>
<td>Gvelop</td>
<td>Current as of November 2017</td>
<td>Y</td>
<td></td>
<td>Provided to HSOAC team</td>
<td>Covers three ports; good narrative summary of aboveground damage (underwater assessment not conducted).</td>
</tr>
<tr>
<td>Consultant damage assessment report on the Port of San Juan</td>
<td>Iglesias-Vazquez and Associates</td>
<td>Current as of November 2017</td>
<td>Y</td>
<td></td>
<td>Provided to HSOAC team</td>
<td>Covers multiple piers at the Port of San Juan; good narrative summary of aboveground damage (underwater assessment not conducted).</td>
</tr>
<tr>
<td>Source</td>
<td>Date Range</td>
<td>Prestorm</td>
<td>Poststorm</td>
<td>Recovery</td>
<td>Data Acquisition Status</td>
<td>Evaluation Notes</td>
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<td>-------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Port/pier structural assessments</td>
<td>MARAD contractors</td>
<td>Current as of May 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>MARAD commissioned 23 assessments, including underwater assessments; provides condition of various structures and overall condition, as well as estimated dollar value of damage.</td>
</tr>
<tr>
<td>Vessel movements by vessel type and dwell time at ports</td>
<td>USACE</td>
<td>January 2015–June 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>HSOAC commissioned analysis of Automatic Identification System (AIS) data.</td>
</tr>
<tr>
<td>Cargo and passenger volumes by airport</td>
<td>PRPA</td>
<td>July 2013–March 2018 (monthly)</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Passenger, cargo, and flights for all airports except SJU (passenger only).</td>
</tr>
<tr>
<td>Airport utilization data</td>
<td>PRPA</td>
<td>June 2013–March 2018 (monthly)</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>Monthly passenger counts and cargo tonnage arriving at different airports in Puerto Rico.</td>
</tr>
<tr>
<td>Air Traffic Activity Data System (ATADS)</td>
<td>Federal Aviation Administration (FAA)</td>
<td>1989– ; preceding month (updated regularly)</td>
<td>Y</td>
<td>Y</td>
<td>Publicly available</td>
<td>Daily counts of arrivals and departures at SJU and Rafael Hernández International Airport (only) broken down by type of traffic (military, cargo, etc.). No data for the period during and immediately after hurricane landfall.</td>
</tr>
<tr>
<td>Consultant damage assessment reports on PRPA-operated airports</td>
<td>Gvelop</td>
<td>Current as of September/October 2017</td>
<td>Y</td>
<td></td>
<td>Provided to HSOAC team</td>
<td>Good narrative summary of damage; if subsequent, more detailed, assessments were conducted, they were not provided.</td>
</tr>
<tr>
<td>Report on damage at SJU</td>
<td>Not available</td>
<td>Unknown</td>
<td>Y</td>
<td></td>
<td>Not provided to HSOAC team</td>
<td>While we assume that Aerostar has undertaken an assessment of the damage suffered because of Hurricane Maria, to the best of our knowledge they have not provided it to FEMA.</td>
</tr>
<tr>
<td>Summaries of airport damage</td>
<td>PRPA</td>
<td>Summer 2018</td>
<td>Y</td>
<td>Y</td>
<td>Provided to HSOAC team</td>
<td>PRPA provided two damage inventories with very brief descriptions of damage and an estimated dollar value.</td>
</tr>
</tbody>
</table>

NOTE: Blank cells indicate that data are not available for these time periods.
Identifying Data Gaps

At the time of this writing, damage assessments were not made available to the HSOAC team for the main airport, SJU, and two major highway segments that are privately operated. The fact that the dollar amount of airport damage changed from the fall of 2017 to June 2018 and August 2018 suggests that assessments were updated, but we were unable to acquire the updated reports. Road and bridge assessments continue to change as additional inspections are completed; for this report, we have used sources current as of March 19, 2018.

We do not have complete data on TEUs moved by port to give an indication of containerized shipping before the storms. While these are available through the Bureau of Transportation Statistics (BTS) and the PRPA for the Port of San Juan, they do not include other ports. MARAD data on TEUs for the ports of Mayagüez, Ponce, and San Juan do not include Jones Act trade with continental U.S. ports, which excludes a large portion of inbound and outbound shipments, so it would present an incomplete picture of shipping to and from the island.

Assumptions and Uncertainties

We assume that the data sources and reports that we have reviewed to develop this report are accurate and do not omit any pertinent information.

Damage Caused by Hurricanes Irma and Maria

Summary of Key Impacts

Transportation damage was extensive. With regard to surface transportation, the main immediate effect was debris blocking roads, but over 6,000 incidents were reported to DTOP, including landslides and collapsed or seriously weakened bridges. Much roadway signage was destroyed, and many traffic signals were damaged physically or rendered nonoperational. Bus service in San Juan was suspended for several weeks, and rail service for three months.

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13 Much freight is moved between ships, ports, and rail in containers, and one TEU is a standard size that allows containers to be moved easily between modes. As such, the volume of shipping is often measured in TEUs. See World Shipping Council, “Containers,” webpage, undated.

14 BTS data includes only the country’s largest ports (see BTS, Port Performance Freight Statistics: Annual Report to Congress, 2017, Washington, D.C.: Bureau of Transportation Statistics, 2018c), and the second and third largest ports (Ponce and Mayagüez) are not administered by the PRPA.

15 The Jones Act is discussed in Chapter 3.

16 The document we obtained—DTOP, Emergency Operations Center, Hurricane Maria 2017, Executive Summary, January 18, 2018—did not contain the appendixes that should provide a more specific count of incidents by category. We requested a copy but did not receive one.
In the maritime sector, ferry service between the Puerto Rican mainland and the islands of Culebra and Vieques was suspended for several days. Ports sustained varying amounts of landside structural damage. Waterside operations were resumed within 72 hours for the majority of ports and, in most cases, as soon as channels were deemed safe for vessel traffic.

Air travel was severely interrupted for several days. In addition, access to the radar tower for SJU, located in El Yunque National Forest, was limited due to road damage sustained in the storms. However, all airports are currently operational.

While estimates are not available, the extent of damage to the roadway network affected people’s ability to reach emergency assistance, medical care, jobs, schools, and friends and relatives. Given the mountainous interior, some communities were severely impacted, as many small towns have only one or two roads that reach them. Disruptions at the Port of San Juan—both to waterside and landside operations—meant that emergency supplies were slow to reach people in need.

Table 1.2 summarizes the extent of the dollar value of damage that we have obtained from the sources cited in Table 1.1. We believe the estimates based on inspections are largely complete and the best available, although we have not been able to verify them independently. The cost of repairs based on inspections totals $1.8 billion, while mitigation measures would cost an additional $1.1 billion.

<table>
<thead>
<tr>
<th>Transportation Mode</th>
<th>Estimated Dollar Value of Damage—Repair Only</th>
<th>Additional Resilience Measures</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads and bridges</td>
<td>$646.7 million</td>
<td>N/A</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>Analysis by McKinsey for the PRHTA Revised Fiscal Plan, June 2018</td>
</tr>
<tr>
<td></td>
<td>$14.5 million</td>
<td>N/A</td>
<td>Metropistas/Moody’s</td>
<td>Highways PR-5 and PR-22</td>
</tr>
<tr>
<td>Public transportation (surface)</td>
<td>$105.8 million</td>
<td>$150.7 million</td>
<td>Hill International</td>
<td>Tren Urbano</td>
</tr>
<tr>
<td></td>
<td>$14.6 million</td>
<td>$1.8 million</td>
<td>Hill International</td>
<td>MBA</td>
</tr>
<tr>
<td></td>
<td>$36 million</td>
<td>$1.5 million</td>
<td>Hill International</td>
<td>Municipalities</td>
</tr>
<tr>
<td>Ports</td>
<td>$909.7 million</td>
<td>$895.8 million</td>
<td>MARAD and PRPA contractor reports</td>
<td></td>
</tr>
<tr>
<td>Ferries</td>
<td>$38.4 million</td>
<td>$102.5 million</td>
<td>Hill International</td>
<td>Maritime Transportation Authority</td>
</tr>
<tr>
<td>Airports</td>
<td>$108 million</td>
<td>N/A</td>
<td>Gvelop</td>
<td>Based on full reports, except for Luis Muñoz Marin International Airport</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1.874 billion</strong></td>
<td><strong>$1.150 billion</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: N/A means not applicable; no “repair with mitigation” costs were provided. Estimates do not include damage associated with business losses caused by storm action.
The Organization of This Report

This report is organized in six chapters. Following the basic background and descriptions given in the present chapter, Chapters 2, 3, and 4 provide the full background and damage assessments for the three types of transportation: surface, consisting of roads, bridges, and surface public transportation (Chapter 2); maritime, including seaports and ferries (Chapter 3); and air (Chapter 4). These chapters generally follow a parallel structure, describing the assets and key stakeholders, discussing prestorm physical conditions and usage trends, and providing detail on the types of damage sustained to each mode of transportation.

Chapter 5 discusses recovery needs across the various modes of transportation and how these intersect with prestorm needs. Chapter 6 describes our approach to developing courses of action (COAs) and portfolios (combinations of COAs), and summarizes them. Chapter 7 presents our conclusions. Information about all COAs, including descriptions; potential benefits, spillover impacts, and costs; and possible funding mechanisms and pitfalls are presented in Appendix A, and Appendix B lists the organizations with which we consulted in developing this report.
2. Damage Assessment: Surface Transportation

Roads and Bridges

This section describes the extent of roads and bridges in Puerto Rico and their prestorm conditions. Public transportation is covered in the following section.

Key Assets and Governance

With more than 16,500 mi of roads within its 5,300 mi², Puerto Rico has one of the densest roadway networks in the United States.¹ Roads are commonly characterized in four ways: by location (rural or urban), by the entity responsible for managing them, by their inclusion in the federal aid network, and by their functional class (e.g., interstate, local road).² Table 2.1 shows Puerto Rico’s roads using these four designations. There are also a small number of miles owned by federal agencies on public lands; these are not shown in Table 2.1. The HPMS data for Puerto Rico do not include any private roads, and data on the extent of private roadways in Puerto Rico were not available.³

Within Puerto Rico’s road network are 2,222 bridges and two tunnels, and the island has approximately 1,100 gas stations.⁴

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¹ These figures are for centerline miles of road (i.e., one mile of roadway is considered one centerline mile, regardless of the number of lanes). The roadway network’s density is like that of Connecticut, Massachusetts, and Rhode Island, based on data on road mileage (FHWA, 2015) and the U.S. Census (2018).

² The FHWA classifies urban areas (as defined by the U.S. Census Bureau) with a population of 5,000 or above as urban and areas with a population of less than 5,000 as rural. Federal-aid roads are eligible to receive funding from the FHWA; other roads must be funded from local or state sources. See FHWA, *Highway Functional Classification Concepts, Criteria and Procedures*, Washington, D.C.: FHWA, Publication FHWA-PL-13-026, 2013.

³ According to the *HPMS Field Manual*, “All roads open to public travel are reported in HPMS regardless of ownership, including Federal, State, county, city, and privately owned roads such as toll facilities” (FHWA, Office of Highway Policy Information, *Highway Performance Monitoring System Field Manual*, Washington, D.C.: FHWA, December 2016, Chapter 1, Section 1.2). However, FHWA’s 2014 guidance (FHWA, *All Road Network of Linear Referenced Data Reference Manual*, September 2014) states that state DOTs have not been required to track private roadway data. HPMS data for Puerto Rico do not include any roadway miles listed as “Other Jurisdictions” (FHWA, 2015). Data obtained by the HSOAC team from DTOP contain only data on DTOP-owned roads, and our contact at the DTOP indicated that municipalities do not track roadway miles in their jurisdictions.

Table 2.1. Rural and Urban Roads in Centerline Miles by Ownership and Functional Class, 2014

<table>
<thead>
<tr>
<th></th>
<th>Rural Miles: 3,085</th>
<th>Urban Miles: 13,460</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By Ownership:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,025</td>
<td>3,550</td>
</tr>
<tr>
<td>DTOP</td>
<td>2,060</td>
<td>9,910</td>
</tr>
<tr>
<td>Municipalities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal-aid roads</td>
<td>540</td>
<td>2,710</td>
</tr>
<tr>
<td>Non-federal-aid roads</td>
<td>485</td>
<td>840</td>
</tr>
<tr>
<td><strong>By Functional Class:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstates</td>
<td>30</td>
<td>235</td>
</tr>
<tr>
<td>Other freeways and expressways</td>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>Other principal arterial roads</td>
<td>50</td>
<td>380</td>
</tr>
<tr>
<td>Minor arterial roads</td>
<td>230</td>
<td>945</td>
</tr>
<tr>
<td>Major collector roads</td>
<td>230</td>
<td>1,080</td>
</tr>
<tr>
<td>Minor collector roads</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Local roads</td>
<td>240</td>
<td>840</td>
</tr>
<tr>
<td></td>
<td>2,060</td>
<td>9,690</td>
</tr>
</tbody>
</table>

**NOTES:** Numbers are rounded to the nearest 5, and cells under 5 are shown as 0. DTOP is the equivalent of a state department of transportation; Puerto Rico’s only local government entities are municipalities, which serve both city and county functions.

The strategic highway network, as identified in the *Puerto Rico 2040 Islandwide Long Range Transportation Plan*, is shown in Figure 2.1.5

Of the 16,500 mi of roads, approximately two-thirds of the network is owned by the 78 municipalities (see Table 2.1). Municipalities are generally responsible for maintenance, but not for design and construction of new roads (or major repairs to existing roads). DTOP owns the remaining one-third of the network. It also assists municipalities that require major rehabilitation and construction. Within DTOP, the agency responsible for road maintenance is the PRHTA.

The FHWA provides funding for major improvements on the approximately 3,500 mi of road that are considered part of the federal-aid network, which includes the National Highway System. The FHWA’s Office of Federal Lands Highway, Eastern Federal Lands Highway Division, is responsible for design and construction of roughly 30 mi of roads on land owned by other federal agencies. These roads are in El Yunque National Forest, which is run by the U.S. Forest Service, and in several wildlife refuges, run by the U.S. Fish and Wildlife Service.

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5 DTOP, 2013b, p. 5-3. This defines the strategic highway network as “the core roadway network linking all regions of the island. It has a coastal ring road looping around the island and cross-island corridors.” This differs from the U.S. Army’s definition of a Strategic Highway Network, which are highways that link military installations; see U.S. Army, Transportation Engineering Agency, “Highways for National Defense (HND),” webpage, undated.
All U.S. metropolitan regions are required to develop and periodically update long-range transportation plans, generally for a 20- to 30-year planning horizon. This type of long-range planning is done by the Puerto Rico Metropolitan Planning Organization (MPO). Unlike MPOs in the continental United States, the Puerto Rico MPO covers the whole island, not individual metropolitan regions. The island is divided into several regions: San Juan (which includes 38 municipalities), Aguadilla (11 municipalities), and five “nonmetropolitan” transportation planning regions (North, Southwest, South, Southeast, and East), as shown in Figure 2.2. However, the MPO produces four distinct long-range plans: one for San Juan, one for Aguadilla, one for the five combined transportation planning regions, and one island-wide plan. The MPO is staffed with employees of DTOP and the PRHTA. Since the MPO and the PRHTA are essentially the same organization, it complies with federal regulations that require a statewide plan, as well as regulations that require plans for individual metropolitan areas. Given the importance of the nonmetropolitan regions to the island’s interconnectivity, the MPO chooses to prepare a plan for these five regions as well.

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6 DTOP, 2013b.
7 PRHTA, staff and planning contractor, telephone communication with Liisa Ecola and Kenneth Kuhn, May 3, 2018d. The regulations cited are Code of Federal Regulations, Title 23, Highways, Section 450, Planning Assistance and Standards, Subpart B, Statewide and Nonmetropolitan Transportation Planning and Programming; and Code of Federal Regulations, Title 23, Highways, Section 450.310 (d)(4)(ii), Metropolitan Planning Organization Designation and Redesignation.
At the time this report was written, the most recent long-range plan, the *Puerto Rico 2040 Islandwide Long Range Transportation Plan*, had been released in 2013 (referred to hereafter as the *Islandwide Long Range Transportation Plan*). The 2045 plan was released in December 2018.\(^8\)

Two toll roads (PR-5 and PR-22) and one bridge (Teodoro Moscoso) are privately operated, both by organizations (Metropistas and Autopistas, respectively) that are part of the Spanish firm Abertis.\(^9\) The P3 agreement for the operation of the two existing toll roads was signed in 2011 and lasts for 50 years.\(^10\) The P3 agreement for the bridge was signed in 1991. Autopistas designed and built the bridge, and currently has a concession agreement to collect tolls and maintain the bridge through 2044.\(^11\) In both cases the deals were negotiated with the assistance of the Puerto Rico Public-Private Partnerships Authority, and the agreements are between the PRHTA and the private operator.

The agencies responsible for roads and bridges are provided in Table 2.2.

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9 The full legal names are Autopistas Metropolitanas de Puerto Rico, LLC (known as Metropistas) and Autopistas Puerto Rico; hereafter referred to as Metropistas and Autopistas. Abertis, undated, and Abertis, 2016.


Table 2.2. Agencies Responsible for Roads and Bridges

<table>
<thead>
<tr>
<th>Agency</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>Maintain local roads and bridges</td>
</tr>
<tr>
<td>DTOP/PRHTA</td>
<td>Maintain federal aid roads and bridges; design, rehabilitate, and build new roads and bridges</td>
</tr>
<tr>
<td>FHWA</td>
<td>Funds roads on the federal-aid highway system; designs and builds roads on federal lands</td>
</tr>
<tr>
<td>MPO</td>
<td>Develops long-range transportation plans</td>
</tr>
<tr>
<td>Public-Private Partnerships Authority</td>
<td>Issues requests for proposals and negotiates for P3 arrangements</td>
</tr>
<tr>
<td>Abertis (parent company of Autopistas and Metropistas)</td>
<td>Operates PR-5, PR-22, and the Teodoro Moscoso Bridge</td>
</tr>
</tbody>
</table>

**Prestorm Conditions and Challenges**

The following sections describe the conditions and use of roads and bridges before Hurricanes Irma and Maria.

**Structure and Serviceability**

Major roads in Puerto Rico were, overall, in fair condition before Hurricane Maria hit (on a scale of good–fair–poor). Data provided by DTOP, taken from the organization’s HPMS submittal to the FHWA, describes the extent and severity of four types of distress on sections of federal-aid highways, including:

- roughness as measured by the International Roughness Index (IRI)
- the percentage and length of cracking
- the depth of ruts in vehicle wheel paths
- faulting (a difference in elevation between adjacent sections of road surface separated by a crack or joint).\(^\text{12}\)

The FHWA’s *HPMS Field Manual* provides methods for using these four indicators to categorize pavement as being in good, fair, or poor condition, either in terms of distress on a specific segment or overall, as shown in Table 2.3.

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\(^{12}\) The HPMS is a national system to which all states and Puerto Rico submit data in a specified format. This data set with information on road segment condition includes only data from the 4,357 km (2,707 mi) of road in Puerto Rico eligible for federal aid.
Table 2.3. Definitions of Good, Fair, and Poor Condition for Four Types of Pavement Distress

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRI Rating</td>
<td>95 or less</td>
<td>Between 95 and 170</td>
<td>170 or higher</td>
</tr>
<tr>
<td>Cracking</td>
<td>Continually reinforced concrete pavement</td>
<td>Between 5–10% of surface area</td>
<td>10% or more of surface area</td>
</tr>
<tr>
<td></td>
<td>5% or less of surface area</td>
<td>Between 5–15% of surface area</td>
<td>15% or more of surface area</td>
</tr>
<tr>
<td></td>
<td>Asphalt</td>
<td>Between 5–20% of surface area</td>
<td>20% or more of surface area</td>
</tr>
<tr>
<td>Ruts</td>
<td>0.2 inches deep or less</td>
<td>Between 0.2 and 0.4 inches deep</td>
<td>0.4 inches deep or more</td>
</tr>
<tr>
<td>Faulting</td>
<td>0.1 inches or less</td>
<td>Between 0.1 and 0.15 inches</td>
<td>0.15 inches or more</td>
</tr>
</tbody>
</table>


The overall or composite categorization is based on counts of the number of times a section of road is classified as being in poor condition when looking at individual distresses. It implicitly assumes that all distresses are equally important, although IRI alone has been shown to account for the majority of the variation in the overall condition ratings of road sections and is alone used by the World Bank to estimate user costs as a function of road condition.\textsuperscript{13}

While more roads were rated fair, before the storms there were sections of roads in both good and poor conditions in different areas of Puerto Rico. Figure 2.3 shows the geographic locations of the sections of road that are in good (green), fair (black), and poor (red) condition. This map is based on the ratings that combine data on different distresses, which is why the majority of the road sections displayed are rated as fair (black).

Figure 2.3. Map of Pavement Conditions on Federal-Aid Roads in Puerto Rico

SOURCE: Unpublished GIS data on road conditions provided by DTOP staff to HSOAC

Figure 2.4 shows pie charts of the pavement conditions, in terms of miles of roadway aggregated by condition for 2,707 mi of roads on the federal-aid network, broken down by pavement type (asphalt versus concrete), and for overall conditions and conditions based on IRI alone. Roughness as measured by IRI is arguably the single most important measure of the serviceability of a road, for the reasons noted earlier. However, the composite condition index is the measure preferred by the FHWA and does incorporate additional distress-specific results that may relate to the structural condition of roads. This is why results obtained when focusing on IRI alone and when focusing on the composite condition index are both shown. The results when focusing on IRI alone, in terms of the distributions of the conditions of road sections, are noticeably different from the results when using a composite condition index. This is again due to the fact that the composite condition index ratings are based on simple counts of how often road sections are categorized as being in good, fair, or poor condition, implicitly assuming that all of the distress-specific classifications are equally important.

The pavement on most of the road network can be characterized as in fair condition, when using the composite condition index, as Figure 2.3 indicates. The picture is slightly worse for concrete roads than asphalt roads. Concrete roads generally serve more and heavier traffic; often roads that will not be used by heavy trucks are paved in asphalt because asphalt roads are generally cheaper to construct and the increased durability of concrete roads is less important when truck traffic is not present.

14 This matches the total for urban federal-aid roads maintained by DTOP.
The picture is substantially worse when looking exclusively at roughness as opposed to the composite condition rating. In fact, most road sections are classified as being in fair condition because they are in poor condition only with respect to roughness among the four types of distress measured. Roughness describes the vertical profile of the road surface from an overall level that relates to ride quality. Roughness is the single variable that is most strongly linked to the perception of drivers and vehicle passengers of the condition of a road. Rough roads lead to relatively high user costs, including lower traffic speeds, higher crash risks, additional fuel use and pollutant emissions, and reduced ride quality. The rough condition of Puerto Rican roads indicates that even before the storms, increased maintenance and repair activities were likely warranted despite the relatively better condition data observed when using a composite condition index. Regions with declining populations often struggle to keep their infrastructure networks in good condition using available revenues. That may have been an issue in Puerto Rico even before Hurricane Maria.

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15 This is as opposed to micro- and macrotexture, which focus on smaller-scale measurements that relate more to tire traction, road noise, and the like.

Puerto Rico’s bridges were last assessed by the FHWA in 2017. The FHWA maintains the National Bridge Inventory and categorizes bridges as being “structurally deficient” or not, as well as being in good, fair, or poor condition. A bridge is labeled structurally deficient if its deck, superstructure, substructure, or culvert is in poor or worse condition.\footnote{FHWA, “Bridges & Structures: Tables of Frequently Requested NBI Information,” webpage, updated April 10, 2018a.} These classifications, although general, represent a standard way to describe the conditions of bridges. Of the 2,325 bridges in Puerto Rico in the National Bridge Inventory, 13 percent (301) were classified as structurally deficient.\footnote{FHWA, “Bridges & Structures: Deficient Bridges by Highway System 2017,” webpage, updated December 31, 2017f.} In comparison, bridges identified as structurally deficient across the United States make up roughly 9 percent of all bridges.\footnote{FHWA, “Bridges & Structures: Deficient Bridges by Highway System 2017,” webpage, updated December 31, 2017f.} The fractions of Puerto Rico’s bridges that were classified as being in good, fair, and poor conditions in 2017 were 19, 69, and 12 percent, respectively.\footnote{FHWA, “Bridges & Structures: Bridge Condition by Highway System 2017,” webpage, updated December 31, 2017e.} The numbers are slightly better for National Highway System bridges: 20 percent are in good condition, and only 8 percent are in poor condition.\footnote{FHWA, “Bridges & Structures: Bridge Condition by Highway System 2017,” webpage, updated December 31, 2017e.} Figure 2.5 shows Puerto Rico bridge conditions.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{puerto_rico_bridge_conditions.png}
\caption{Puerto Rico Bridge Conditions, 2017}
\end{figure}

\textbf{SOURCE:} Counts by condition: FHWA, 2017a; Counts by deficient status: FHWA, 2017b.
Congestion and Safety

The Texas Transportation Institute conducted its most recent analysis of traffic congestion in Puerto Rico in 2014, and found that San Juan’s cost of congestion was about $1.6 billion, an increase from under $1.5 billion in 2000. Included in this estimate are both the cost of “wasted” fuel (i.e., the amount of additional fuel consumed because vehicles are stuck in traffic) and the lost productivity cost (the number of additional person-hours spent in traffic multiplied by an average dollar figure).22

Roughly 60 percent of vehicle miles traveled occur in San Juan, with the southern part of the island coming in second, at 10 percent. The highway network experiences congestion in its urban areas due to daily commuter traffic. According to the Puerto Rico 2040 Islandwide Long Range Transportation Plan, 36 percent of a representative selection of road segments on the island receive a level of service grade of A, B, or C based on the ratio of traffic volume to road capacity, while 26 percent of the road segments that were selected received the worst grade of F.23 Level of service grades are “worst in the municipalities comprising the central core of the San Juan region, including Bayamón, Guaynabo, San Juan, Carolina and Trujillo Alto.”24 The roads that received the worst grade may be in good condition structurally, but are likely to suffer from congestion during peak periods. In addition to increasing travel times for road users, such congestion could affect emergency services or efforts to distribute relief supplies after a disaster. There were additional congestion issues with some older, smaller roads in other cities.

Puerto Rico’s traffic safety record is mixed. On the positive side, fatalities have been declining: In 2016, the most recent year for which figures are available, there were 279 fatalities from vehicle crashes, a decrease from 310 in the previous year; most states experienced an increase in fatalities over this period. In 2015, the number of people who died in vehicle crashes per 100,000 population was 8.9, lower than the U.S. average of 10.9. However, the number of people who died in vehicle crashes per 100 million mi driven was 2.12, nearly double the U.S. average of 1.13 and higher than in any state (the next highest is South Carolina, at 1.89 fatalities per 100 million mi driven).25 While this rate has declined over the past 15 years, it has remained

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23 Levels of service A, B, and C are the best three of a six-letter scale (A–F) that is used to characterize congestion levels. Selected roadway segment ratings are available in DTOP, 2013b, Table 5-9.
24 DTOP, 2013b, p. 5-4.
higher than the average U.S. rate throughout that period (see Figure 2.6). This suggests that driving is more dangerous in Puerto Rico than anywhere else in the United States.\(^{26}\)

**Figure 2.6. Traffic Crash Deaths per 100 Million Miles Driven, 2000–2015**

![Graph showing traffic crash deaths per 100 million miles driven from 2000 to 2015 for Puerto Rico and the U.S. average.](image)


The low ratio of deaths per 100,000 miles driven reflects the fact that Puerto Rico has the least miles traveled per capita in the United States: 4,200 in 2014. The U.S. average for the same year is approximately 9,500 mi per capita.\(^{27}\)

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\(^{26}\) Because the absolute number of crashes in the United States is not available (there is no national database of all vehicle crashes, only a sample that is too small to make comparisons across states), it is impossible to say if this reflects a higher number of crashes per mile driven, that the crashes that occur are more serious, or whether the difference is due to postcrash survival rates that may be lower if crash victims do not have rapid access to appropriate levels of trauma care. The rate may also be influenced by inaccurate data on total vehicles miles traveled, which would skew the results. DTOP staff told us that vehicles miles traveled data provided by the FHWA may be incorrect, but even the most recent Strategic Highway Safety Plan Annual Report for 2016 puts the 2015 rate at 1.96. CSA Architects and Engineers, LLP, Puerto Rico Strategic Highway Safety Plan, Annual Report 2016, San Juan, P.R.: PRHTA, October 2016.

Public Transportation

This section describes the extent of surface public transportation systems in Puerto Rico (ferries are covered in Chapter 3). There is no long-distance rail service, either passenger or freight, on the island.  

Key Assets and Governance

Public transportation is fairly limited, with relatively little service provided outside the San Juan metropolitan area. There is one heavy rail system in San Juan, the Tren Urbano, which opened in 2005 and was the most recent heavy rail system to be built in the United States. The Tren Urbano consists of one line with 16 stations over approximately 10 mi of right-of-way. Ten stations are elevated, four are at grade, and two are underground. Five have park-and-ride stations.  

Two types of bus services operate in San Juan: fixed-route bus service along about two dozen routes in mixed right-of-way, with a total fleet of 118 vehicles, and express Metrobus service along three routes, one of which is a bus rapid transit line operating on a highway that connects to the Tren Urbano.  

According to FTA statistics for 2016, the Tren Urbano has 32 vehicles in maximum service, and Metrobus has 26, with a total available (including spares) of 128 (this total does not break out railcars and buses into service vehicles and spares).  

While there is a público (jitney) network that serves both major cities and some intercity trips, vehicles are privately owned and operated and do not operate on fixed schedules.

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28 Beginning in the 1890s, as sugarcane became the predominant crop, private rail lines were built to move crops to processing centers. This resulted in an extensive rail system that moved both goods and passengers and had lines around most of the island’s perimeter. Additionally, in the first half of the 1900s, San Juan had an extensive streetcar network (as did most U.S. cities at the time), but service ended after World War II. Gricel M. Surillo Luna, Moving Forward: Railways in Puerto Rico, dissertation, Graduate Center, City University of New York, 2017.

29 DTOP, 2013b.

30 Oficina del Gobernador, La Fortaleza, “Orientan Sobre Reorganización en Servicio de Transporte Colectivo” [“Guidance on Reorganizing Mass Transit Service”], webpage, July 15, 2015; this webpage describes the 2015 reorganization of the bus network, which eliminated about a dozen routes, and it thus supersedes bus information in the Islandwide Long-Range Transportation Plan from 2013. The FTA National Transit Database designates these buses as motor buses; distinguished from trolley buses that run on overhead catenary wires. The FTA does not collect information on the type of fuel used by the bus fleet (diesel, electric, etc.); see FTA, 2016 Service (spreadsheet), undated. The express routes are described in the announcement of the bus service reorganization; see, for example, Oficina del Gobernador, 2015; and Benjamin Colucci Rios, “Dynamic Toll Lane: A Success Story as Part of the Public Private Partnerships in the Commonwealth of Puerto Rico,” paper presented at the Second International Conference on Public-Private Partnerships, Austin, Tex., May 26–29, 2015.

According to the FTA’s National Transit Database, 1,884 público vehicles were in service before Hurricanes Irma and Maria hit the island.33

In San Juan, all public transportation is provided or overseen by government of Puerto Rico agencies; there are no local transit operators or transit authorities. Within DTOP, the Integrated Transport Authority is responsible for bus service. Within the Integrated Transport Authority, the AMA provides most bus service.34 Private operator First Transit (headquartered in Cincinnati, Ohio) operates the three San Juan Metrobus lines and some of the regular bus service, under contract with the PRHTA.35

Two private contractors, Alternate Concepts (headquartered in Boston) and Herzog Transit Services, Inc. (headquartered in St. Joseph, Missouri) have a joint venture to operate the Tren Urbano. Alternate Concepts was part of the team that designed and built the Tren Urbano, which opened in June 2005. The joint venture began in 2016.36 The public partner for the Tren Urbano is the PRHTA.37

In addition, 31 municipalities operate some type of bus service of demand responsive (paratransit) service, but these generally run on a small scale: the majority of these operators have fewer than ten vehicles in service.38 Taxis and one ride hailing service, Uber, operate in the largest cities, but information on the number of vehicles is not available. There are no scheduled intercity buses, either public or private. The 2040 Long Range Transportation Plan: Puerto Rico’s Five Transportation Planning Regions39 refers to regulation of públicos, which are regulated by the Public Service Commission. This document also mentions social service agencies providing some transportation services, but we have been unable to determine the extent of their activities. Agencies responsible for public transportation are provided in Table 2.4.

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32 Puerto Rico’s jitney services are comprised of privately operated vehicles (públicos) that generally serve standard routes, either within or between cities.
34 Oficina del Gobernador, 2015.
37 DTOP, “Historia” (“History”), webpage, undated.
Table 2.4. Agencies Responsible for Public Transportation—Surface

<table>
<thead>
<tr>
<th>Agency</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTOP</td>
<td>Government of Puerto Rico agency responsible for providing public transportation</td>
</tr>
<tr>
<td>Integrated Transit Authority</td>
<td>Agency within DTOP responsible for providing public transportation</td>
</tr>
<tr>
<td>AMA</td>
<td>Agency within DTOP that provides bus service</td>
</tr>
<tr>
<td>PRHTA</td>
<td>Agency within DTOP responsible for the Tren Urbano and Metrobus</td>
</tr>
<tr>
<td>Alternate Concepts</td>
<td>Private-sector joint venture partner that operates the Tren Urbano</td>
</tr>
<tr>
<td>Herzog Transit Services, Inc.</td>
<td>Private-sector joint venture partner that operates the Tren Urbano</td>
</tr>
<tr>
<td>First Transit</td>
<td>Private-sector provider of express and regular bus service</td>
</tr>
<tr>
<td>Municipalities</td>
<td>Provide local bus and demand-responsive service</td>
</tr>
</tbody>
</table>

Prestorm Conditions and Challenges

Public transportation is generally considered inadequate, and ridership has been declining. As the Islandwide Long Range Transportation Plan notes, “Fixed-route bus service in various communities is very limited, público fleets are aging, [and] the number of routes in actual service has decreased.”40 There is no public intercity transportation except for some público routes, so residents who do not drive face very limited transportation options. This is a major concern since “there are many Puerto Rico households without access to an automobile and many more with only one vehicle. These households are reliant on public transportation, walking, and rides from friends and service organizations.”41

Ridership on all modes of transit has been steadily declining over the past decade. Ridership on the Tren Urbano had grown from about 26,000 daily boardings in 2005 (the year it opened) to 32,000 in 2011. This increase seems to be linked to a fare reduction in 2010; fares returned to their previous level ($1.50 per ride, which remains the current fare) in 2014.42 The most recent FTA statistics, for 2016, show daily boardings of 28,562, with a steep drop from 37,706 in 2014. This could be due to the higher fare, general population decline, unemployment, or other factors. Ridership is far below the planning estimates of over 110,000 riders per day.43

Ridership on other modes, including buses and públicos, has been declining gradually since 2009, most precipitously on AMA bus service, which fell from over 100,000 average weekday boardings in 2003 to 16,000 in 2016. Bus service was reorganized in 2015, with about a dozen

40 DTOP, 2013a, p. 2-11.
41 DTOP, 2013b, p. 2-1.
routes eliminated; this may account for some of the decline.\textsuperscript{44} Ferry ridership ranges between 3,000 and 5,700 weekday boardings, with no general increase or decrease over this time period.\textsuperscript{45} Overall transit ridership on all modes is lower now than when the Tren Urbano opened. Figure 2.7 shows overall transit ridership.

\textbf{Figure 2.7. Transit Ridership in Puerto Rico, by Mode, 2002–2016}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure27.png}
\caption{Transit Ridership in Puerto Rico, by Mode, 2002–2016}
\end{figure}

SOURCES: 2002–2011: DTOP 2013b, Figure 5.11. 2012–2016: FTA, National Transit Database (various years). NOTE: Ferry information provided only from 2012 to 2016.

Among the country’s 15 heavy rail systems, Tren Urbano has the highest operating costs and costs per passenger, the second-lowest farebox recovery (the proportion of operating costs that is paid directly by riders through fares), and the second-lowest ridership (see Figure 2.8). Farebox recovery is 16 percent, while the average for all other U.S. heavy rail systems is 57 percent. FTA statistics do not suggest why operating costs are so much higher than for other systems.

\textsuperscript{44} Officina del Gobernador, 2015.

\textsuperscript{45} We did not obtain ferry ridership for the period of 2000–2011, as it was not provided in the \textit{Puerto Rico 2040 Islandwide Long Range Transportation Plan}. 
Figure 2.8. Comparison of U.S. Heavy Rail Systems’ Annual Ridership and Operating Cost for One Vehicle Hour, 2016

NOTE: The figure includes heavy rail systems in these metropolitan areas: Atlanta; Baltimore; Boston; Chicago; Cleveland; Los Angeles; Miami; Philadelphia; the borough of Staten Island in New York City; Washington, D.C.; and two systems that serve the New Jersey suburbs of New York City. Other New York City transit is not included, since ridership is so much higher that it would hide the distinctions between other systems. New York City transit hourly costs are $292 per hour.

Funding, Functional, and Operational Challenges

In surface transportation, a key challenge is the lack of funding available for system maintenance and improvement. According to the PRHTA Fiscal Plan 2017–2026, “PRHTA’s current fiscal situation reflects a $4.49 billion financial gap for the next 10 year[s] mostly impacted by the clawback provision which redirects 73 percent, or about $4.57 billion, of its operating revenues to the Central Government. Bondholders of the PRHTA are expected to cease receiving money for debt repayment by July 2017, when the reserve funds that have been used until now run out.”

The agency has experienced operating losses each year since 2012. These problems have been ongoing; according to a 2010 study,

the financial position of the PRHTA appears to be deteriorating further. Tax and fee income generated from its dedicated revenue sources have not kept pace with inflation due to inflation-based increases in costs and no commensurate increase

46 PRHTA, 2017, slide 5.
in revenues. Moreover, there have been significant expenses linked to Tren Urbano, putting pressure on the PRHTA budget.47

The Islandwide Long Range Transportation Plan notes that fully half of revenues are pledged to debt repayment. Also, many conventional sources of revenue for transportation agencies have not been raised in decades. The 16-cent-per-gallon gas tax in Puerto Rico has not been raised since 1976, the $15 license fee has not been raised since it was introduced in 1982, and the $3-per-barrel petroleum tax (on fuel used for energy production, rather than vehicles) has not been raised since 2005. “Toll leakage” (the underpayment of tolls) is considered a problem.48 The gas tax is lower than that of any state except Alaska.49

With regard to its capacity, the PRHTA Fiscal Plan 2017–2026 enumerates the following challenges:

- “more than $400 million in available federal funding is not deployed due to delayed processes for project advancement, project completion and provider payments50
- outdated and nonstandard documentation and requirements
- lack of communication and feedback integration between planning and construction departments
- increased project costs and overruns from original budgets
- misalignment of current capabilities with needed core competencies.”51

In 2016, the PRHTA signed a memorandum of understanding with the FHWA to address some of these issues.52 The PRHTA’s four main requirements under this memorandum are to revise its billing process to ensure prompt payment to contractors; validate its toll credit balance; engage a consultant to develop an organizational capacity development plan; and upgrade internal systems to expedite project delivery. According to the PRHTA Fiscal Plan 2017–2026, all four initiatives are underway.53

48 DTOP, 2013b.
49 American Petroleum Institute, “Motor Fuel Taxes: Gasoline Tax Reports,” webpage, 2017. These per-state rates include the federal tax of 18.3 cents per gallon.
50 Essentially this means that DTOP cannot spend all of the money it is eligible to receive from the FHWA.
51 PRHTA, 2017, slide 17.
52 Memorandum of Understanding Between the Commonwealth of Puerto Rico Highway and Transportation Authority, and the U.S. Department of Transportation, Federal Highway Administration, for Puerto Rico Highway Project and Program Delivery Improvement, signed February 2016.
Hurricane Damage

Roads and Bridges

In the face of an approaching storm, relatively little can be done to safeguard roads and bridges, which are outdoor and immobile. In the immediate aftermath of a storm, removing debris is a critical issue. As is noted in *Build Back Better Puerto Rico: Request for Federal Assistance for Disaster Recovery*, Maria generated over 6 million yd³ of debris, and at the lowest point, fewer than 400 mi of the 16,700 mi of roadways were passable. Most traffic signals were not operating after the storms, either due to physical destruction or the lack of power.\(^{54}\) Local police officers managed traffic during daylight hours or at peak times at certain intersections where traffic control devices were nonoperational. This continued for several months after the storms. Gasoline was scarce in the weeks after the hurricane, leading to long lines and the closure of some gas stations.\(^ {55}\) Relief supplies were difficult to move from the Port of San Juan due to debris in many roadways and a shortage of trucks, drivers, and fuel, creating serious bottlenecks in distribution.\(^ {56}\) FHWA made available $40 million in “quick release” emergency relief funds to help restore essential services.\(^ {57}\)

According to DTOP, as of January 18, 2018, 15 bridges and 21 major roadways remained closed for safety reasons. By March 9, nine bridges and 15 roadway segments were still closed, all on secondary or tertiary roads and mostly in smaller towns or rural areas.\(^ {58}\) Road damage is reported as kilometer posts, not segments, so the data do not show the length of segments affected.\(^ {59}\) Repairs on these and other roads were ongoing at the time this report was written.

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\(^{58}\) Secondary roads are considered collector roads, and tertiary roads are the equivalent of local roads. Information about which roads remained closed is from DTOP, Emergency Operations Center, “Status Dashboard,” fact sheet, updated March 9, 2018b. Information on road type is from DTOP, Emergency Operations Center, *Hurricane Maria 2017: Executive Summary*, San Juan, P.R.: DTOP, 2018a.

\(^{59}\) DTOP summaries report damage at a specific kilometer post along a road segment (e.g., kilometer post 2.2 along roadway PR-109). Without information about the distance to the nearest alternative route, it is impossible to say how many miles of road are affected. Note also that DTOP’s list does not include roads maintained by municipalities, about which no centralized information is available.
At the time of this writing, FEMA had a short list of critical projects for roads and bridges, including severe damage to the road (off PR-184) that serves a major weather radar installation; a retention pond draining under a major north–south road (PR-10) that could lead to collapse; a bridge weakened from debris in the water underneath that could result in collapse; and a small number of other roads that remained closed for safety reasons.

Damage produced by the storms includes landslides, damage to roadway surfaces, lack of streetlights and traffic signals, and structural damage to bridges. In terms of the dollar value of damage to roads and bridges, two estimates are available. FHWA has referenced 1,179 DDIRs describing the conditions of different sections of roadway and bridges in Puerto Rico as of March 20, 2018. The overwhelming majority of these DDIRs (965) were reported as “eligible and signed”—that is, approved by an FHWA engineer. Much of the damage is listed as being caused by “washout” or “landslide(s).” A smaller number of DDIRs (206) have been categorized as being “not eligible and signed” by a FHWA engineer. Much of this damage is described as preexisting.

Updated DDIR figures were used to develop the estimate of road repairs needed for the PRHTA Revised Fiscal Plan. This indicates that expected costs for emergency and permanent repairs to roads and bridges will total $646.7 million. Note that these figures do not include debris removal, which is a considerable cost.

While FEMA did not inspect PR-5 and PR-22, since they are privately operated, a Moody’s investor report indicated that repairs to those roads were estimated at $14.5 million.

Public Transportation

The Tren Urbano was shut down the day before landfall in anticipation of Hurricane Maria, with railcars securely stored, power generator fueled, and a total system electrical power shutdown. We have not located any information regarding prestorm preparations for buses

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60 PRHTA, Revised Fiscal Plan, 2018–2023, certified June 29, 2018. Note that this differs from the PRHTA Fiscal Plan 2017–2026, which pre-dated the storms and covered a longer period of time, as well as from the draft New Fiscal Plan for Puerto Rico, dated April 5, 2018, which is a government-wide fiscal plan and had not yet been certified at the time of this writing. Because of the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA), fiscal plans require certification by the Final Oversight and Management Board for Puerto Rico.

61 Financial Oversight and Management Board for Puerto Rico, 2018. This plan contains a figure of $653 million for storm damage, but subsequent communication with staff at the consulting firm McKinsey, which developed the figures, provided the $646.7 million figures. Email communication with McKinsey staff, June 2018.

62 According to FEMA procedures, debris removal is considered an emergency expense as opposed to permanent work, so figures for long-term repair do not include debris removal.


specific to Hurricane Maria. Both bus and train services were unavailable directly following the storm due to power loss and streets being blocked. FTA made $8.4 million available to help restore transit service immediately following the hurricane (funds that could be used for both surface and maritime transportation).\(^{65}\)

Service on the Tren Urbano was suspended until December 19, 2017, largely due to the lack of power at key substations and the difficulty of running tests to evaluate operations.\(^{66}\) Three stations suffered structural damage; they reopened following emergency repairs in January, April, and May 2018.\(^{67}\) A bus bridge was established to service those stations while repairs were carried out.\(^{68}\)

No bus service was provided immediately following the storm, but AMA service on 21 of 23 routes was restored by September 29, 2017.\(^{69}\) By March 2018, San Juan bus services were operating at similar service levels as before the storm. Reports of when other bus and paratransit services around the island were suspended and restarted are not available.

The damage to the surface transit systems was reported in the *Puerto Rico Hurricane Maria Transit Infrastructure and Vehicle Damage Assessment Report: Final Draft* and are summarized in Table 2.5.\(^{70}\) The assessments offer three different estimates for repair costs: repair to functionality, repair to code and standard, and repair with mitigation (meaning that additional “resiliency” upgrades were identified and added to the costs of repairing to code and standard). Repair to functionality is generally the least costly, while repair with mitigation is generally the most costly. However, it is often the case that the repair to code and standard estimate is equivalent to the repair with mitigation estimate, meaning that no additional upgrades were identified.

The total damage and resilience increases to the Tren Urbano system are estimated to cost $257 million. The operations and maintenance (O&M) facility and yard suffered some damage to components and roofing, with some water and mold damage to interiors; damage totals $7.5 million, with an additional $3.5 million in recommended upgrades. Among the 16 stations, repairs to code and standard ranged from $3.3 million to $7 million. Most stations did not suffer any structural damage, though it was common for there to be component and cladding damage along with water intrusion and mold. The railcars sustained very little damage, and there was no structural damage to the guideway and track. However, the report identifies $6 million in repairs

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\(^{65}\) Chirls, 2018.


\(^{67}\) “Reabre la estación Domenech del Tren Urbano” [“The Tren Urbano Domenech Station Reopens”], *El Nuevo Día*, May 21, 2018.

\(^{68}\) DTOP, Emergency Operations Center, 2018b.


\(^{70}\) Hill International, 2018. Although the report is dated May 9, 2018, most of the field assessments were completed in October and November 2017, and thus reflect conditions at that time. FTA officials provided this report to the HSOAC research team.
(as part of the $16.5 million in systems repairs shown in Table 2.5) to upgrade the guideway and track to code, although the only specific item mentioned in the report was that several sound attenuators/parapets need to be replaced.

The power systems are the largest repair cost for the Tren Urbano, with the estimated cost to repair being $11 million systemwide with $140 million for additional resilience. Damage to the power system included flooding and other water penetration at traction power substations, failures of breaker protection control devices (which are sufficiently old that replacement parts are no longer available from the manufacturer), damage to security fencing, loss of air-conditioning, and other station-specific damage. The additional resilience items include a turbine engine to maintain pumps to prevent flooding, and replacement of power system components at the most heavily damaged traction power substation.

The AMA’s facilities were impacted to a much lesser degree than the Tren Urbano. The total repair costs are estimated at $16 million, $8 million of which is required to repair the AMA O&M facility. This facility, located in San Juan, suffered damage to various structures, including broken windows, doors, roof vents, repair bus service areas, and roofing. In addition to structural damage, water damage left electrical systems and interior items damaged or unusable. Damage to bus terminals was quite varied, with some terminals suffering no damage at all, while others, like the Carolina Bus Terminal and Iturregui Bus Terminal, are left with $2 million and $1.7 million in repairs, respectively. Damage at Carolina was related largely to loss of roofing, flooding, and damage to fencing, while Iturregui’s damage was related to the roll-up door, security screen, radio tower cables, and ventilation louvers. The AMA’s radio tower Marsol facility sustained $3.4 million in damage with one tower knocked down, tension cables damaged, and further interior damage caused by water penetration.

Repair and resilience costs estimated for the municipalities’ transit systems total $37.5 million. The bus terminals in Aguadilla, Arecibo, Cayey, and Loiza were among the most costly repairs, with each terminal’s estimated repairs costing approximately $2.5 million. Structural, interior, and fencing damage, in addition to water intrusion, are common in these terminals. Damage to vehicles were generally much less costly than damage to structures—both bus and público terminals as well as bus shelters.
### Table 2.5. Damage Summary for Puerto Rico Surface Public Transportation Systems

<table>
<thead>
<tr>
<th>Facility</th>
<th>Major Areas of Damage</th>
<th>Estimated Repair Costs</th>
<th>Resilience Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Repair to Functionality</td>
<td>Repair to Code and Standard</td>
</tr>
<tr>
<td><strong>Tren Urbano O&amp;M facility</strong></td>
<td>Components, cladding, roofing, doors, and interior damage</td>
<td>$120,000</td>
<td>$7,557,823</td>
</tr>
<tr>
<td><strong>Tren Urbano stations</strong></td>
<td>Components, cladding, and various degrees of water penetration</td>
<td>$843,000</td>
<td>$70,544,641</td>
</tr>
<tr>
<td><strong>Tren Urbano systems (excluding power)</strong></td>
<td>Flooding and other water penetration at traction power substations, failures of breaker protection control devices, security fencing, loss of air-conditioning, and other station-specific damage</td>
<td>N/A</td>
<td>$16,459,972</td>
</tr>
<tr>
<td><strong>Tren Urbano Power</strong></td>
<td>Flooding and other water penetration at traction power substations, failures of breaker protection control devices, security fencing, loss of air-conditioning, and other station-specific damage</td>
<td>N/A</td>
<td>$11,087,475</td>
</tr>
<tr>
<td><strong>Tren Urbano railcars</strong></td>
<td>Minimal storm damage; no replacement vehicles needed</td>
<td>N/A</td>
<td>$186,558</td>
</tr>
<tr>
<td><strong>AMA buses</strong></td>
<td>Roof hatches were main component damaged, although buses were repaired within a week of the hurricane</td>
<td>$15,349</td>
<td>None</td>
</tr>
<tr>
<td><strong>AMA O&amp;M facility</strong></td>
<td>Structural and interior damage, including windows, doors, light fixtures, bus service areas, and administrative office interior</td>
<td>N/A</td>
<td>$8,332,516</td>
</tr>
<tr>
<td><strong>AMA bus terminals</strong></td>
<td>Varying levels of damage; shelter roofing, flooding, and fencing damage</td>
<td>N/A</td>
<td>$2,779,230</td>
</tr>
<tr>
<td><strong>AMA radio tower</strong></td>
<td>Tower knocked over, tension cable damaged, and water intrusion damage</td>
<td>N/A</td>
<td>$3,461,997</td>
</tr>
<tr>
<td><strong>Municipalities</strong></td>
<td>Varying levels of damage, including roofing and structural damage, flooding, and damaged windows/fencing</td>
<td>N/A</td>
<td>$35,990,462</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>$978,349</td>
<td>$156,416,024</td>
</tr>
</tbody>
</table>


NOTE: N/A indicates that there was no “repair to functionality” cost provided, only costs to “repair to code and standard.” Where identical costs were included in two or three categories, we assumed that this was the cost to repair to the lowest level, to avoid double-counting (e.g., the amount $15,349 was provided for AMA buses in all three categories: repair to functionality, repair to code and standard, and additional resilience measures; we have included this amount only in the repair to functionality column).
3. Damage Assessment: Maritime Transportation

Puerto Rico’s marine transportation system (MTS) dates to Spanish colonial times, when the island was established as a port (Puerto Rico means “rich port,” highlighting why it was an important colony for Spain). The Spanish established two main ports, in Ponce and San Juan; both began operations in 1804.¹

Key Assets and Governance

As an island, Puerto Rico relies on maritime shipping to maintain daily life, economic activity, and government services. Virtually anything that cannot fit in the belly of an airplane must be moved via maritime conveyance to and from Puerto Rico’s ports. Maritime shipping is critical to disaster preparedness, response, and recovery efforts. This section describes the extent of maritime transportation in Puerto Rico, including seaports and passenger ferries.

Seaports

Fifteen cities in Puerto Rico are supported by maritime trade or activities within seaports (see Figure 3.1). Nine of the ports on the island support the MTS. The largest port is the Port of San Juan, owned by the PRPA, a public corporation of the government of Puerto Rico. The port terminal property and docks are owned by the PRPA, but are leased by privately owned entities that are responsible for the security, safety, and supporting infrastructure within their properties. Two other major ports are municipally owned: the Port of Ponce (Rafael Cordero Santiago Port of the Americas), owned by the municipality of Ponce and run by the Ponce Port Authority; and the Port of Mayagüez, owned by the Mayagüez Port Commission and the Puerto Rico Industrial Company (PRIDCO). The PRPA also has authority over additional, smaller ports, including Arecibo, Fajardo, Guanica, Guayanilla, and Yabucoa.

In addition, the PRPA recently acquired, via a no-cost public benefit conveyance, the dock areas at the Port of Ceiba. This deepwater port was previously used by the U.S. Navy as Naval Station Roosevelt Roads and was being considered, at the time of this writing, as a site for a ferry terminal and a potential redevelopment project. The PRPA also has jurisdiction over the ports serving the small islands of Culebra and Vieques, which are 17 mi and 8 mi off the coast of Puerto Rico, respectively. The remainder of the ports that support maritime trade generally have single-purpose terminals or are based around tourism and local fishing industries.

General details of each of the seaports that substantively support maritime trade or the economy of Puerto Rico are discussed in the following paragraphs. Maps are provided for the four largest ports: San Juan, Ponce, Mayagüez, and Ceiba (Roosevelt Roads). The other ports are far smaller and generally do not have multiple piers or docks. Vessel tracks were provided by USACE.²

**San Juan:** The Port of San Juan is the largest port serving Puerto Rico, and it includes the only bay on Puerto Rico’s north coast. Port of San Juan facilities are located in the historical maritime area comprising Isla Grande, Old San Juan, Puerto Nuevo, and Puerta de Tierra (as shown in Figure 3.2). The Port of San Juan offers a variety of services to the shipping industry that includes tugs, pilotage, fuel delivery, water supply, provisions, customs, duty-free shops, public transportation, water supply, and vessel maintenance. The principal cruise and tourism port facilities are on the north side of Isla Grande and the south side of San Juan Island (Old San Juan). Container cargo terminals spanning 25 acres are located at Puerto Nuevo, in the southeast part of the bay.³ These port terminals serve as an exchange site where cargo is unloaded from ships and transferred to trucks because there is no freight rail system. The port has nine Panamax cranes, two Post-Panamax cranes, and one of two federally maintained navigation channels in Puerto Rico.⁴ Figure 3.2 is a map of the facilities.

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² This work, led by Katherine Touzinsky of USACE, provided vessel track maps as well as counts of individual vessel movements. The analysis is described in more detail in the Prestorm Conditions and Challenges, Vessel Calls section of this chapter.
⁴ As of 2016, several larger classes of ships can move through the Panama Canal, as a major expansion project has allowed the canal to handle substantially larger vessels than it could previously. These ships are taller, require deeper channels, and carry more containers. The BTS currently defines five classes of container vessels; in order of size, these are Panamax (ships that could fit through the previous Panama Canal dimensions); Post-Panamax, Super Post-Panamax, and Neo Panamax (three types that are increasingly larger in size, but all can traverse the expanded canal); and Megaships (those that are too large even for the expanded canal). BTS, 2018c, Table 4-1; World Port Source, “Port of San Juan: Port Commerce,” webpage, undated b.
Figure 3.2. Annotated Map of the Port of San Juan Area

SOURCE: World Port Source, undated b.
Among the 16 piers in the San Antonio Canal, the Port of San Juan has four piers dedicated to cruise ships and can berth eight mega cruise ships at one time. The cargo facilities allow for more than 500,000 ft$^2$ of space for loading and unloading cargo. This includes 22,700 ft$^2$ of docking space; 1,100,000 ft$^2$ of storage space; and 1,500,000 ft$^2$ of open space. Figure 3.3 shows the distribution of vessel traffic throughout the facilities, based on AIS data.

**Figure 3.3. Vessel Tracks for the Port of San Juan, 2015–2017**

Ponce: The Rafael Cordero Santiago Port of the Americas has the cargo capacity for 1.5 million TEU containers per year. At a depth of 50 ft, the Port of the Americas is one of the

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5 World Port Source, undated b.

6 More information on AIS data is provided in the “Vessel Calls” subsection of “Prestorm Conditions and Challenges, Context and Recent Trends” section. A write-up of these data has been provided in USACE, Engineer Research and Development Center, Coastal and Hydraulics Laboratory, “USACE Analysis of Vessel Traffic (AIS) Within the Puerto Rican Maritime Transportation System (2015–2017),” Washington, D.C.: USACE, September 24, 2018, unpublished manuscript, provided to Homeland Security Operational Analysis Center under subcontract.
deepest ports in the Caribbean, the second largest port in Puerto Rico in terms of land area, and the only port in Puerto Rico capable of supporting Super Post-Panamax ships.\(^7\) Facilities have also been developed to accommodate cruise ships; Celebrity Cruises, Holland America Line, and Royal Caribbean International make occasional stops in the port.\(^8\) The Port of the Americas has two piers and four docks and contains the other of the two federally maintained navigation channels. A map of the facilities is provided in Figure 3.4.

**Figure 3.4. Annotated Map of the Port of Ponce**

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\(^7\) Port of Americas Puerto Rico, “About the Project: Overview,” webpage, 2006; *American Shipper* staff, “Puerto Rico Port Tries to Lure Private Operator,” *American Shipper*, October 15, 2014. Super Post-Panamax ships are one of the classes of ships that can move through the Panama Canal since 2016, after the expansion project. These ships are taller, require deeper channels, and carry more containers.

\(^8\) Celebrity Cruises, Inc., “Cruise to Ponce, Puerto Rico,” webpage, undated; Cruise Compete, homepage, undated.
In Ponce, the vessel traffic is predominantly sailing, cargo, and tanker vessels. The vast majority of sailing vessels moor at the harbor on Isla Mata la Gata, while many of the cargo and tanker vessel anchor in the vicinity of terminals located at the Rafael Cordero Santiago Port of the Americas. Figure 3.5 shows vessel tracking for the Port of Ponce.

**Figure 3.5. Vessel Tracks for the Port of Ponce, 2015–2017**

![Vessel Tracks for the Port of Ponce, 2015–2017](source: USACE, 2018)

**Mayagüez:** The Port of Mayagüez is the third-busiest port on Puerto Rico and consists of three piers. Its main canal is 800 yds wide, and its depth ranges from 47 ft to 120 ft; the water’s depth along the piers exceeds 25 ft. During the winter 2010–2011 cruise season, the port was visited periodically by Holland America Line cruise ships, but there do not appear to be any current cruise ships operating to Mayagüez.9 Ferry service to the Dominican Republic has been discontinued.10 A map of the Port of Mayagüez facilities is provided in Figure 3.6.

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Mayagüez was once home to tuna fisheries. Now the majority of the traffic in and out of the Bahía de Mayagüez is of sailing vessels. As shown in Figure 3.7, traffic in Mayagüez is relatively sparse compared with other ports; it consists largely of sailboats, with a far smaller number of towing, tanker, and cargo vessels. In the northern part of the bay are several small terminals where towing, tanker, and cargo vessels make occasional calls (in 2016 there were fewer than 15 towing vessels, five tankers, and no cargo vessels).
Ceiba (Roosevelt Roads): The port located at Ceiba facilitated the growth of the sugarcane industry before it hosted Naval Station Roosevelt Roads (now decommissioned) in the twentieth century. There are three piers located on the east side of the harbor with alongside depths of 30 to 42 ft, as well as a fuel pier. Today the inlet, along with a civilian airport, is the focus of local tourism and the fishing industry. The town of Ceiba is home to a sailing marina and multiple island excursion companies in the north, while Roosevelt Roads is in the south.

Roosevelt Roads has been considered for reinvestment as a Promise Zone to mitigate the economic impact of the naval base closure.11 In January 2018, then-Governor Ricardo Rosselló announced a plan to renew Ceiba and Roosevelt Roads with a technology park, an aerospace industrial park (Space X considered this location in 2012), a wellness district and retirement community that would cater to the health industry and retirees, a hippotherapy center (employing

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horseback riding in therapeutic or rehabilitative treatment), and a renewable energy center to support the island. The plan also included a new maritime route into Puerto Rico to support trips to other Caribbean islands (including Culebra and Vieques) and a megayacht marina. At the time of this writing, the government was planning to move ferry service serving Culebra and Vieques from Fajardo to Ceiba in order to make it the new hub for ferry operations to the U.S. Virgin Islands and other nearby destinations.\textsuperscript{12} A map of the Roosevelt Roads facilities is provided in Figure 3.8.

\textbf{Figure 3.8. Annotated Map of Roosevelt Roads}

\begin{center}
\includegraphics[width=\textwidth]{roosevelt_roads_map.jpg}
\end{center}

The majority of traffic in and out of Ceiba is that of sailing vessels (Figure 3.9). Total trip numbers for Ceiba in 2015, 2016, and 2017 are small compared with other marinas and ports in Puerto Rico (fewer than 75 vessels per year), and the fleet has a relatively high ratio of unique vessels to total vessel counts, typical of recreational sailing.

**Figure 3.9. Vessel Tracks for Ceiba (Roosevelt Roads), 2015–2017**

![Vessel Tracks for Ceiba (Roosevelt Roads), 2015–2017](source)

**Fajardo:** Fajardo is a hub of recreational boating in Puerto Rico and a popular launching port to Culebra, Vieques, and other outlying islands. It is also the home to the Puerto del Rey marina. Due to its proximity to smaller islands on the east of mainland Puerto Rico, Fajardo is known for passenger ferry service and fishing.\textsuperscript{13} Figure 3.10 shows the density of passenger ferry service and sailboats in Fajardo.

\textsuperscript{13} Grupo Editorial EPRL, Fajardo Municipality, Encyclopedia of Puerto Rico webpage, undated.
Vieques: The island of Vieques lies about 8 mi east of the Puerto Rican mainland, and hosts a national wildlife refuge and numerous beaches that are commonly listed among the top beaches in the Caribbean. The seaport contains a dock and building that supports the ferry service (on the north shore of the island, as shown in Figure 3.11), as well as anchorages and a pier for pleasure craft and fishing vessels in the south. Vieques has a single-passenger ferry terminal located on the north shore of the island. This ferry terminal, along with sailing on the south shore, generally dominates the vessel traffic on the island, with a total of 1,165 vessel entries made in 2017 by only 26 unique vessels.

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Figure 3.11. Vessel Tracks for Vieques, 2015–2017

Culebra: This outlying island is approximately 17 mi east of the Puerto Rican mainland, 12 mi west of St. Thomas, and 9 mi north of Vieques. Culebra is a popular weekend tourist destination for mainland Puerto Ricans, tourists, and residents of Vieques. The island relies on the port and airport for all passenger and goods movement. The seaport is only a small dock and building that supports the ferry service. There is an inner harbor that supports pleasure craft and fishing vessels, as well as a water taxi service.15 Most of the traffic is dominated by sailing vessels, with over 160 entering the area in 2016 (though many more pleasure craft likely do not have AIS onboard and would not be tracked). There is a ferry terminal at the southwest corner of the island, but vessel tracks show very little ferry traffic. This is either because the batch data did not capture these regular vessels or perhaps these vessels are not operating with AIS onboard. Figure 3.12 shows vessel tracks for Culebra.

15 Carmen Gloria Ortiz, “Culebra,” webpage, undated.
**Yabucoa:** The port offers over 4 million barrels of storage for crude oil, fuel oil, and refined products. The terminal has two tanker docks and a high-volume truck-loading rack for supplying gasoline, diesel, and aviation fuels for local demand. It also supplies residual fuel oil for bunker fuel and power generation to nearby nations including the Dominican Republic and Haiti.16

**Guayama:** The man-made Las Mareas Harbor was built for the receiving and shipping of chemical products for Chevron Petroleum. The plant was discontinued and sold for scrap in 2008.17

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**Aguirre:** In the past, Aguirre’s main economic support came from a local sugar factory, but currently the economy centers around employment at the electric energy plant owned by the Puerto Rico Electric Power Authority (PREPA). This is PREPA’s largest plant, with a 900 mW unit burning No. 6 fuel oil. The plant went into service in 1975. The proposed Aguirre Offshore Gasport Project would create a floating offshore liquefied natural gas (LNG) regasification facility off the south coast of Puerto Rico. The facility would provide fuel to PREPA’s Central Aguirre power plant.\(^\text{18}\)

**Peñuelas (Tallaboa Pier):** Peñuelas is associated with the Port of Ponce and has an LNG terminal located offshore operated by EcoEléctrica. The Peñuelas complex occupies a 36-acre site in Guayanilla Bay. The desalinization plant located there produces 2 million gallons of water per day: 1 million is used for the Peñuelas complex, around 580,000 gallons are delivered to the Costa Sur power plant for make-up purposes, and the excess supplies the Puerto Rico Aqueducts and Sewers Authority. The regasification plant has an unloading terminal that can hold LNG tankers of up to 140,000 m\(^3\) and has a 160,000 m\(^3\) storage tank. Additionally, Peñuelas maintains the Tallaboa Pier facility composed of one pier and an adjacent lot leased to a private company named Puerto Rico Terminal.\(^\text{19}\)

**Guayanilla:** On the south coast of Puerto Rico is Guayanilla Bay, one of the largest natural harbors in Puerto Rico. The port currently contains abandoned oil terminals, refineries, and storage. The port is used for loading and unloading chemicals, asphalt, fuels, and propane gas. There has been discussion on remediating this area to use it for chemical and oil production.\(^\text{20}\) The Port of Guayanilla hosts a terminal almost exclusively for liquid bulk and tanker ships, with an EcoEléctrica natural gas power plant located at the end of Punta Guayanilla, the Costa Sur power plant complex on the northeast side of the inlet, and several oil and chemical industrial companies in the port area.\(^\text{21}\) The use of this port is clear because the vessel tracks for 2015–2017 are almost exclusively tankers, towing, and pilot vessels guiding tankers to their terminal locations. In total, 167 vessel calls were made at Guayanilla in 2017, of which 71 were tankers. Figure 3.13 shows both Guayanilla vessel tracks (almost all tankers and tugboats) on the left, and tracks at the much less busy Peñuelas pier on the right.

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\(^{20}\) “Limpiarán el área de la CORCO” [“Clean-up of the CORCO Area”], *El Nuevo Dia*, May 18, 2013.

**Figure 3.13. Vessel Tracks for Guayanilla and Peñuelas (Tallaboa Pier), 2015–2017**

**Guanica:** The harbor resembles a tropical fjord, narrow and bordered by rugged hills, barely a quarter mile wide, but stretching about 2 mi from its mouth to the town. An oil terminal is located at the port. The port is rarely used but imports grain and raw material to create fertilizer. Tugboat and port services are available 24 hours per day.22

**Aguadilla:** Aguadilla was the site of the U.S. military’s Ramey Air Force Base for almost five decades. The base was abandoned, but its pier infrastructure remains and is now in disrepair. The U.S. Coast Guard (USCG) retains an air station at the location.23

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22 PRPA, undated.
**Arecibo:** This port contains a single pier and imports only fuel oil.\(^{24}\)

Much of the information about Puerto Rico’s port cargo-handling capacity is unknown or not available for consideration in recovery planning efforts. Elements of the MTS include terminals and piers that are privately owned and operated. The Port of San Juan relies on private contractors to evaluate navigable waterway safety and functionality and to maintain the waterway. Agencies responsible for seaports are provided in Table 3.1.

Other agencies with roles in the island’s MTS are identified in Table 3.2.

### Table 3.1. Agencies Responsible for Seaports

<table>
<thead>
<tr>
<th>Agency</th>
<th>Public, Private or Nonprofit?</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRPA</td>
<td>Government of Puerto Rico</td>
<td>The largest port authority is the PRPA, which controls operations at the ports of San Juan, Ceiba (Roosevelt Roads), Fajardo, Vieques, Culebra, Yabucoa, Guayama, Aguirre, Penuelas, Guanica, Guayanilla, Peñuelas, Aguadilla, and Arecibo.</td>
</tr>
<tr>
<td>Ponce Port Authority</td>
<td>Local government</td>
<td>The Rafael Cordero Santiago Port of the Americas in Ponce is controlled by the Ponce municipal government through the Ponce Port Authority.</td>
</tr>
<tr>
<td>Port of the Americas Authority</td>
<td>Local government</td>
<td>Entity created to administer the transition of the Port of Ponce to transshipment port; at the time of this writing, it was in the process of merging with the Ponce Port Authority(^a)</td>
</tr>
<tr>
<td>Portek International Pte. Ltd.</td>
<td>Private</td>
<td>This private firm had a three-year contract (2015–2018) to operate the Port of the Americas.</td>
</tr>
<tr>
<td>Mayagüez Port Commission</td>
<td>Local government</td>
<td>The Port of Mayagüez is controlled by the city of Mayagüez through the Port Commission.</td>
</tr>
<tr>
<td>PRIDCO</td>
<td>Government of Puerto Rico</td>
<td>PRIDCO owns a portion of the land at the Port of Mayagüez.</td>
</tr>
<tr>
<td>ATM</td>
<td>Government of Puerto Rico</td>
<td>The agency within DTOP is responsible for providing passenger ferry service.</td>
</tr>
</tbody>
</table>

\(^a\) Ponce Port Authority meeting between staff and HSOAC team members Liisa Ecola, Kenneth Kuhn, and Thomas F. Atkin, April 2018.

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Table 3.2. Key Stakeholders Identified for Seaports

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type</th>
<th>Role(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USCG</td>
<td>Government</td>
<td>Captain of the port, Area Maritime Security Committee chair, federal on-scene coordinator, officer in charge, marine inspector, search and rescue mission coordinator</td>
</tr>
<tr>
<td>USACE</td>
<td>Government</td>
<td>Waterway navigation, channel development and maintenance</td>
</tr>
<tr>
<td>FEMA</td>
<td>Government</td>
<td>Disaster response and recovery coordination</td>
</tr>
<tr>
<td>DHS Office of Infrastructure Protection</td>
<td>Government</td>
<td>Vulnerability assessments and resiliency recommendations</td>
</tr>
<tr>
<td>DHS Transportation Security Administration</td>
<td>Government</td>
<td>Implementing the Transportation Worker Identification Card program for port employees, supporting the USCG in its maritime security efforts, and focusing on passenger security and intermodal connectivity to ports</td>
</tr>
<tr>
<td>Puerto Rico Emergency Management Agency (PREMA)</td>
<td>Government</td>
<td>Disaster response and recovery coordination</td>
</tr>
<tr>
<td>Puerto Rico Homeland Security</td>
<td>Government</td>
<td>Vulnerability assessment and resilience</td>
</tr>
<tr>
<td>DTOP</td>
<td>Government</td>
<td>Managing ferry systems; head of DTOP serves on the board of the PRPA</td>
</tr>
<tr>
<td>TraFon Group</td>
<td>Private</td>
<td>Import-export industry of food products, services, and logistics solutions</td>
</tr>
<tr>
<td>Puerto Rico Towing and Barge Co.</td>
<td>Private</td>
<td>Freight movement, towing, barge operation, ship owning</td>
</tr>
<tr>
<td>International Shipping Agency, Inc.</td>
<td>Private</td>
<td>Freight movement, ship owning</td>
</tr>
<tr>
<td>Crowley Maritime Corporation</td>
<td>Private</td>
<td>Ship management, freight movement, storage, towing, barge operation, ship owning</td>
</tr>
<tr>
<td>Puerto Rico Shipping Association</td>
<td>Private</td>
<td>Representation of companies dedicated to numerous sectors of the maritime business</td>
</tr>
<tr>
<td>Luis Ayala Colon Sucrs., Inc.</td>
<td>Private</td>
<td>Operating as shipping agency, terminal services provision, and stevedoring</td>
</tr>
<tr>
<td>Florida-Caribbean Cruise Association</td>
<td>Nonprofit</td>
<td>Nonprofit trade organization composed of 18 member cruise lines operating nearly 200 vessels in Floridian, Caribbean, and Latin American waters; mandate is to provide a forum for discussion on tourism development, ports, safety, security, and other cruise industry issues</td>
</tr>
</tbody>
</table>

Ferries

The ATM oversees maritime transportation for passengers within Puerto Rico and the island municipalities of Culebra and Vieques. The agency is part of the DTOP. According to Hill International,

ATM was created in 2000 as a public corporation that operates the Commonwealth of Puerto Rico’s two ferry services. ATM operates ferryboat service within San Juan Harbor and to the outlying island municipalities of Culebra and Vieques with a fleet of 13 ferryboats. The ferry operation consists of two segments. The Island service provides passenger only and passenger/cargo ferry service between Fajardo and the island municipality of Culebra, and between Fajardo and the island municipality of Vieques. The Metro service
provide[s] passenger only service between terminals in Old San Juan and Cataño across San Juan Bay. Another route between Old San Juan and Hato Rey has been abandoned since October 2014.\textsuperscript{25}

Several passenger and vehicle ferries service the outlying islands of Puerto Rico, as well as the Virgin Islands. Ferry services from the various ports are outlined in Table 3.3.

\begin{table}[h]
\centering
\caption{Ferry Services Operating in Puerto Rico, Spring 2018}
\begin{tabular}{lllll}
\hline
Port & Destination & Service/Provider Name & Service Frequency & Number/Types of Vessels \\
\hline
San Juan & Cataño & Metro (ATM) & Daily; runs every 30 minutes, 6:00 a.m.–9:00 p.m., and every 15 minutes during peak hours & 100-seat catamarans\textsuperscript{a} \\
Fajardo & Culebra & ATM & Daily; three trips per day & Ferry\textsuperscript{b} \\
Fajardo & Vieques & ATM & Daily; four trips per day & Ferry\textsuperscript{b} \\
Fajardo & U.S. Virgin Islands & N/A & Once per month (plus other special occasions) & 150-person ferry (number not available)\textsuperscript{c} \\
Ponce & Caja de Muerto island & Island Venture & Twice a week (mostly); one trip per day & One privately owned ferry\textsuperscript{d} \\
Guanica & Cayo Aurora & N/A & Daily; every 30 minutes & One privately owned small ferry\textsuperscript{e} \\
\hline
\end{tabular}
\end{table}

\textbf{SOURCES:} Island Venture, homepage, undated; “Puerto Rico Ferries: An Inexpensive Way to Go Island Hopping,” Islands of Puerto Rico, undated; Virgins Island This Week, “Ferry Schedules,” webpage, 2018. Ferry schedules were also obtained from the Autoridad de Transporte Marítimo [ATM] website but service provision may have changed since this report was written.

\textbf{NOTES:}
\textsuperscript{a} San Juan to Cataño: Six-minute trips at a fare of $1; used by locals who commute back and forth between the residential and industrial community and tourists going to the Bacardi rum distillery.
\textsuperscript{b} Fajardo to Culebra and Vieques: Ninety-minute crossing. Vehicle transport available for an extra charge. According to Hill International, 2018, the ATM has 13 ferryboats serving these two routes.
\textsuperscript{c} Fajardo to U.S. Virgin Islands: Two-hour crossing; $100–$150 round-trips; fees and luggage shipment. Vehicle transport available for an extra charge.
\textsuperscript{d} Ponce to Caja de Muerto island, a nature reserve: Generally, weekends only; 30- to 40-minute crossing, depending on weather.
\textsuperscript{e} Guanica to Cayo Aurora, a cluster of mangrove islands also known as Gilligan’s Island; fares under $10.

Ferry service was previously available from both Mayagüez and San Juan to the Dominican Republic, but this was discontinued following a large fire aboard the ferry on August 17, 2016, that rendered the vessel inoperable.\textsuperscript{26}

\textsuperscript{25} Hill International, 2018, p. 9. ATM, which stands for Autoridad de Transporte Maritimo, is the Spanish abbreviation for the MTA.

\textsuperscript{26} Direct Ferries, undated; Nick Blenkey, “‘Poor Safety Culture’ Cited in Baja Ferries’ RO/RO Fire,” \textit{MarineLog}, June 6, 2018.
Prestorm Conditions and Challenges

Context and Recent Trends

Seaport use can be measured in several ways. For all ports, use can be measured in vessel calls (the number of ships docking in a port, generally on an annual basis). Use of cargo ports is typically measured in short tons of cargo (regardless of the type of cargo) or TEU containers. Not all ports can accommodate containers, so comparing all ports requires the use of short tons. Use of cruise ports can be measured in the number of passengers who arrive by cruise ship and cruise vessel calls, as can use of ferry terminals by passengers.

Vessel Calls

HSOAC contracted with the USACE Engineer Research and Development Center Coastal and Hydraulics Laboratory to conduct an analysis of vessel traffic to Puerto Rico’s ports using USCG electronic position data (AIS), from January 1, 2015 through June 30, 2018.

AIS data are collected by the USCG and standardized by the International Telecommunication Union. Properly installed and operating Class A or Class B AIS devices are required for, among others, self-propelled vessels of 65 ft or more in length, towing vessels of 26 ft or more in length and more than 600 HP engaged in commercial service, self-propelled vessels certified to carry more than 150 passengers, self-propelled vessels engaged in dredging operations, self-propelled vessels moving certain hazardous cargo, fishing industry vessels, vessels over 300 gross tons on an international voyage, and vessels over 150 gross tons when carrying 12 passengers on an international voyage. AIS data include information about a vessel’s position, identity, type, speed, and navigation status. In the past several years, AIS data have been analyzed to understand how U.S. and international waterways are used and provide insights into how shipping traffic reacts to disruptions.

For the three-and-one-half-year time period, from January 2015 to June 2018, USACE analysts tallied total and unique vessel counts by month and vessel types at eight ports and

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harbors: San Juan, Ponce, Mayagüez, Ceiba, Fajardo, Vieques, Culebra, and Guayanilla. These ports were selected based on information provided in *U.S. Coast Pilot*, the World Port Index, World Port Source, and the relative level of historical maritime activity. We focused on eight vessel types that indicate commercial and tourism use:

- **cargo**—vessels carrying containers, palletized or break-bulk cargo
- **fishing**—all commercial fishing vessels, vessels for hire, and charter boats
- **passenger**—ferries and cruise line vessels
- **port tenders**—work boats or supply vessels that normally provide logistic support within the port and provide services to anchored or moored ships.
- **sailing**—all types of sail-powered vessels, including charter, recreational, and auxiliary sail craft
- **tankers**—vessels carrying liquid petroleum cargo (gasoline, diesel, fuel oil, heating oil, or crude oil distillates)
- **towing**—tug and barge combinations in various configurations and other marine operations that are actively engaged in towing
- **tug vessels**—towing vessels that are not engaged in towing.

While AIS data are generally very accurate, they are transmitted from the vessels to land-based receivers, some of which suffered damage during Hurricane Maria; USCG data experts indicated that many receivers across the island were either damaged or their functionality was limited by a loss of network connectivity and/or electrical power following the hurricanes. For the four months following Maria, from September 20, 2017 to January 31, 2018, connection to the land-based AIS system was inconsistent and/or intermittent. While some data were transmitted when the network was online, their accuracy cannot be verified. According to the USCG, the receivers were fully back online by February 2018. The USACE analysis includes the months that were impacted by Maria in late 2017 and early 2018. Information about the types of vessels arriving at the ports is available in the data that were successfully recovered. However, because there is no way to verify whether or not that the data set was complete, any information

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29 *Unique vessel count* is the number of vessels transiting a designated area of interest that have different Maritime Mobile Service Identity numbers used in AIS that are tied to a specific vessel. *Total vessel count* is the number of times any vessel transited in and out of the area, regardless of the number of individual (or unique) vessels. For example, if a harbor only has two passenger vessels that make arrivals twice daily, then the monthly unique vessel count would be two and the total monthly vessel count would be 62. USACE, 2018.

30 These definitions mean that the same vessel could be characterized as towing in one instance and a tug in another, depending on the vessel’s use at the time the data were captured.

31 USACE discussed the issue of damaged AIS receivers directly with the USCG representatives; HSOAC did not independently verify this information.
obtained between September 20, 2017 and February 1, 2018 may be incomplete. Actual vessel traffic may have been higher than the AIS data set indicates.  

Figure 3.14 is a vessel traffic heat map based on signal density, which indicates the volume of vessel traffic, for 2016. USACE used this to define areas of interest for the eight selected ports. The areas of interest were then used to bound the individual AIS tracks in order to calculate the number of vessels entering and exiting a port area and characterize each port’s vessel activity by category or type of vessel traffic within each area of interest.  

This figure clearly shows the dominance of San Juan in terms of sheer maritime traffic volume, substantial ferry traffic between Fajardo and Vieques, and a fair amount of activity along much of the south coast, but no activity at all between Mayagüez and San Juan. The lighter blue areas depict common ocean routes and coastwise track lines to and from the island, as well as vessels transiting Puerto Rico’s territorial sea. Pink and red represent greater concentrations of vessel traffic, and the brightest or white colors indicate the greatest concentrations of vessel activities. Another trend is presumably tanker or fuel barge traffic (petroleum products) from Guayanilla to other Puerto Rican ports.  

Figure 3.15 shows vessel track lines for all ports in 2016, which illustrates both the primary uses of individual ports and the direction of their traffic. For example, cargo and cruise ships are the primary vessel types making calls at San Juan, on the north coast of the island. The vessel track lines show that cargo is predominantly coming from the southwest and northwest, which is consistent with other Caribbean shipping trend analysis. In the south, traffic is dominated by tanker and fishing vessels. In the east, sailing vessels predominate, along with specific passenger vessel routes between Culebra, Fajardo, and Vieques, which aligns with ferry traffic and a smaller number of tanker and cargo vessel arrivals. In terms of the concentration of maritime activity,  

- cargo ship activity is predominantly from the northwest (presumably the continental United States) and southwest (presumably the Panama Canal) into San Juan, with some notable regional traffic to the eastern Caribbean  
- the vast majority of tanker traffic (petroleum products) is south of the island, transiting east or west along the south coast  
- sailing vessel traffic is concentrated along the south and east coasts of the island, with notable activity from the northwest (presumably from the continental United States) and to and from the eastern Caribbean  

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32 Vessel traffic could not be lower than these figures, unless there was deliberate manipulation, which we do not believe to be the case.  
34 The territorial sea is the nautical area within 12 mi around an island.  
- the greatest concentrations of fishing vessel activity are in the waters off the southeast, south central, and (to a lesser degree) southwest
- passenger (ferry and cruise ship) traffic is heavily concentrated along the north and east coasts, with notable traffic passing the island to the north, presumably to and from the continental United States to other eastern Caribbean destinations and points south.

**Figure 3.14. Automatic Identification System Vessel Signal Density Across Puerto Rico, 2016**

![Map of Puerto Rico with vessel signal density](image)

**SOURCE:** USACE analysis.

Figure 3.16 graphically shows the same information that is imparted in Table 3.4: total vessel port arrivals by type and location over the entire three-year period (2015–2017). Ceiba and Culebra traffic is dominated by sailing vessels. On the south coast, the vessel activity is dominated by tanker vessels supplying fuel for the primary power generation sites for the island. As three of the four top petroleum-fueled power plants are located in Guayanilla and Salinas, much of the traffic at Guayanilla (and to a lesser extent, Ponce) is that of tanker vessels. In addition, there are major fishing areas south of the island, with many of the fishing boats making calls in Ponce and San Juan. Figure 3.17 shows the unique vessel counts for each port.
While it appears that both Fajardo and Vieques saw substantial increases in total vessel counts—almost all of which are attributable to passenger ferry service—it is possible that missing data account for part of this apparent increase. This may not represent a meaningful trend and may be an indicator of limited AIS coverage in the area. The vast majority of these vessel calls are passenger ferries, which explains the difference between the two figures. Figure 3.17 also shows a high number of unique sailing vessels.

The raw data for passenger vessels calling at Culebra, Fajardo, and Vieques show only one vessel, the *Isla Bonita*. The data also show that there was essentially no vessel traffic at Fajardo and Vieques from January to April 2015, again from September 2015 to June 2016, and very low or no passenger vessel calls at Culebra throughout the entire three-year period (zero in many months). Given our previous information that these ferries both ran regularly, the authors and USACE believe that either AIS passenger vessel transmitters or (more likely) land-based receivers may not have been functioning properly and that passenger vessel counts for ferry service were undercounted for many months. It is unknown whether the source of underreporting was due to malfunctioning, disabled, or missing equipment on the ferries or AIS receivers positioned ashore.
Seaports: Cargo Shipping

By any measure, San Juan is the most important port in Puerto Rico and the dominant shipping hub. In 2017 it was the thirteenth largest port in the United States by TEU, and in 2015 the eleventh largest in Latin America and the Caribbean in terms of container throughput. In 2015, 80 percent of all ship visits of cargo vessels exceeding 1,000 gross tons were to San Juan. In 2016 it saw 1,501 cargo vessel calls, including 254 container ships, 27 dry bulk vessels, 455 dry bulk barges, 711 other freight vessels, and 55 other freight barges.

SOURCE: USACE analysis.

37 BTS, 2018c, Figure 3-4; Economic Commission for Latin America and the Caribbean, “Ports Ranking: The Top 20 in Latin America and the Caribbean in 2015,” webpage, May 2016.
39 The BTS defines “other freight vessels” as including “crude oil tankers, liquefied natural gas (LNG) tankers, chemical tankers, general cargo vessels, and vehicle or Ro/Go carriers. The combination of ‘Other freight vessel’ calls and ‘Other freight barge’ calls represent overall cargo tonnage minus container and dry bulk cargo tonnage.” BTS, 2018c, pp. 3–9.
### Table 3.4. Vessel Types Across All Ports, Totals for 2015–2017

<table>
<thead>
<tr>
<th></th>
<th>San Juan</th>
<th>Ponce</th>
<th>Mayagüez</th>
<th>Ceiba (Roosevelt Roads)</th>
<th>Fajardo</th>
<th>Vieques</th>
<th>Culebra</th>
<th>Guayanilla</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo</td>
<td>1,630</td>
<td>67</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1,703</td>
</tr>
<tr>
<td>Fishing</td>
<td>69</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>81</td>
</tr>
<tr>
<td>Passenger</td>
<td>1,436</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2,134</td>
<td>2,089</td>
<td>18</td>
<td>0</td>
<td>5,679</td>
</tr>
<tr>
<td>Port Tender</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Sailing</td>
<td>168</td>
<td>102</td>
<td>71</td>
<td>136</td>
<td>136</td>
<td>190</td>
<td>339</td>
<td>0</td>
<td>1,142</td>
</tr>
<tr>
<td>Tanker</td>
<td>497</td>
<td>19</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>252</td>
<td>784</td>
</tr>
<tr>
<td>Towing</td>
<td>1,066</td>
<td>22</td>
<td>24</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>257</td>
<td>1,376</td>
</tr>
<tr>
<td>Tug</td>
<td>550</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>573</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,419</strong></td>
<td><strong>223</strong></td>
<td><strong>115</strong></td>
<td><strong>150</strong></td>
<td><strong>2,274</strong></td>
<td><strong>2,281</strong></td>
<td><strong>359</strong></td>
<td><strong>522</strong></td>
<td><strong>11,343</strong></td>
</tr>
</tbody>
</table>

**SOURCE:** USACE analysis.
The share of inbound shipping entering Puerto Rico via San Juan, as measured in short tons of cargo, has risen steadily for the past 15 years, from 74 percent in 2000 to 88 percent in 2016.\textsuperscript{40} The share of outbound shipping has been much more variable over this same period of time, with San Juan’s share even dropping below 50 percent one year. However, in 2016, 83 percent of exports were shipped from San Juan.\textsuperscript{41}

This growth has come at the expense of other ports. The Puerto Rican government has attempted to create a major transshipment hub, the Rafael Cordero Santiago Port of the Americas, at the Port of Ponce. According to press reports, between $250 million and $300 million was invested in the port over the past decade.\textsuperscript{42} However, both the quantity and share of inbound and outbound shipping have declined over time. Ponce shipped 35 percent of all outbound cargo in 2007 (a total of 900,000 short tons); by 2016, this declined to 9 percent and 175,000 short tons. A similar pattern holds for inbound shipping; for most of 2000–2010, Ponce’s share was 15 to 20 percent, between 2 and 3.5 million short tons per year; by 2016, the share was 10 percent and 1 million short tons. According to AIS data, before Hurricane Maria, Ponce averaged only five cargo or tanker vessels per month, compared with 150 per month at San Juan.

The Port of Fajardo had a sizable share of outbound shipping in the early 2000s, up to 36 percent in 2004 (950,000 short tons), but its share has declined to less than 10 percent in recent years (about 150,000 short tons). The share of inbound shipping has been less than 1 percent in recent years. Arecibo currently sees no shipping at all, and Mayagüez only a tiny fraction, consistent with AIS data.\textsuperscript{43} Figures 3.18 and 3.19 show statistics for outbound and inbound shipping.

Figures 3.18 and 3.19 also show the imbalance between the volume of inbound and outbound shipping, and how both have declined over this period, having fallen by about one-third from their peaks in 2003.

\textsuperscript{40} In this section and throughout, we use the term \textit{inbound shipping} to refer to shipping goods into Puerto Rico, regardless of origin. If they originate from outside the United States, we will specify that they are \textit{imports}. We use similar language for exports.

\textsuperscript{41} USACE, 2018.


\textsuperscript{43} Unfortunately, neither the USACE AIS data nor the USACE Navigation Center data capture the full extent of recent cargo trends. We requested USACE AIS analysis of only eight ports, when clearly Figure 3.14 shows activity at similar levels at a larger number of ports. The USACE Navigation Data Center tracks only six ports, and during the time of this writing, the data ended in 2016. Finally, only the USACE AIS analysis includes Ceiba and Guayanilla, while only the USACE Navigation Data Center includes Arecibo and Guayanes (another name for Yabucoa), so we do not have consistent information on these four ports (although Figure 3.14 shows no maritime activity for the past three years at Arecibo, which is on the northwest coast).
For the period 2000–2016, total petroleum products (by weight) were the largest commodity shipped into Puerto Rico (46 percent) followed by food products (15 percent) and unclassified manufactured products (14 percent). These proportions have remained relatively constant over this period. Figure 3.20 shows imports and exports for these four categories.
Of all inbound cargo, slightly more than half originates from foreign ports, while just under one-third comes from the continental United States. The rest is intraterritorial cargo—goods shipped between Puerto Rican and Virgin Islands ports. These percentages have been fairly stable since 2000. More than half of the foreign imports (by weight) are petroleum products. Of all outbound cargo, approximately half is shipped to foreign ports, 40 percent goes to the continental United States, and the remainder is intraterritorial.

Beginning in the late early 2000s, the small share of inbound and outbound cargo to and from the continental United States for the ports at Arecibo, Mayagüez, and Ponce dropped to zero. With few exceptions, all cargo traffic to and from the continental United States transits through the Port of San Juan (see Figure 3.21).

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44 We have been unable to determine the extent of double counting if inbound intraterritorial cargo from one Puerto Rican port is also considered outbound from a different Puerto Rican port. This data set does not include the origin port for inbound shipments or the receiving port for outbound shipments. It is therefore not possible to calculate transshipments from this data set. We understand that intraterritorial shipments are counted only as inbound when they arrive at their final destination, and not as outbound from the port within the territories that they are shipped from.
Due to the Jones Act, discussed in more detail in the Recovery Plan supplemental report for the economic sector, coastwise shipping (also called cabotage) between U.S. ports must be conducted by U.S. ships and owners.\textsuperscript{45} As of spring 2018, San Juan has scheduled container service via four U.S. companies that support coastwise shipping: Crowley Maritime Corporation, National Shipping, Tote Maritime, and Trailer Bridge, Inc.\textsuperscript{46} The map in Figure 3.22, which was current as of 2013, shows their scheduled service and ports of call in the continental United States. Other firms provide unscheduled barge service (not shown on the map).\textsuperscript{47}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3_21.png}
\caption{Inbound and Outbound Shipping at San Juan and All Other Ports Totals, 2000–2016}
\end{figure}

\textsuperscript{45} The Merchant Marine Act of 1920 (commonly known as the Jones Act for its congressional sponsor) prohibits foreign-flag ships from carrying goods between two U.S. ports.


In addition, dozens of foreign-flag carriers also serve ports in Puerto Rico. Some have extensive international operations, while others are Caribbean feeder services. A sample of these routes is shown in Figure 3.23.

Seaports: Cruise Ships

Worldwide, cruise ship passengers have been generally increasing. In 2016, 24.2 million passengers cruised globally, a 4 percent increase over 2015. Twelve million of these passengers came from North America. In 2017 this number increased to an estimated 25.3 million—a 4.5 percent increase. According to the Florida-Caribbean Cruise Association, “the cruise industry is the fastest-growing category in the leisure travel market. Since 1980, the industry has experienced an average annual passenger growth rate of approximately 7% per annum. Demand for worldwide cruising increased 62% between 2005 and 2015.”

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Figure 3.23. Examples of Foreign Carriers’ Feeder Services Operating in the Caribbean, as of 2013

One-third of the deployed capacity share—approximately 8.16 million people—went to the Bahamas and the Caribbean in 2016. These individuals likely visited many islands on a single trip. About 1.4 million people visited Puerto Rico on cruise ships in 2016, for a ranking of seventh in the region behind the Bahamas (4.8 million), Cozumel, Mexico (3.4 million), St. Maarten (2 million), U.S. Virgin Islands (2 million), Cayman Islands (1.6 million), and Jamaica (1.4 million). In 2017, the fastest-growing Caribbean markets were Barbados (18.3 percent growth in visitors), Cuba (17.0 percent), Guadeloupe (10.8 percent), Aruba (8.4 percent), and Haiti (8.2 percent). Figure 3.24 indicates that the number of passengers visiting San Juan has increased steadily since its low point in 2012, but overall has remained relatively flat since 2000, particularly when compared with increases in global cruise ship passenger growth. The data also reflect the trend to build larger cruise ships to carry more people and reduce the number of individual ship visits.
Figure 3.24. Number of Cruise Ship Passengers and Vessel Calls to San Juan, 2000–2017

SOURCES: Unpublished data on vessel calls, air/cruise ship passengers, and air cargo, July 2013–March 2018, provided by PRPA staff to HSOAC in spring 2018; DTOP, 2013b, Table 5.5.
NOTE: Vessel calls as provided to the HSOAC team by the PRPA differ slightly from figures provided by USACE for 2015–2017. USACE AIS data show the numbers were steady in 2015 and 2016 (around 565 calls per year), and experienced a large decline to 300 in 2017.

Ferries

The Hill International report contains some limited information on prestorm conditions of the ferry services. The Fajardo terminal had been condemned before the storms. The piers at Hato Rey were described as being in “derelict condition” and the San Juan ferry terminal in “disrepair,” but further details were not provided.  

Ferry ridership is depicted in Figure 2.7 in Chapter 2. For the past five years, the number of daily riders has fluctuated between 4,500 and 5,500, with no particular linear trend. Breakdowns by island route are not available from FTA.

Funding, Functional, and Operational Challenges

One key recovery challenge is that Puerto Rico’s dependence on its MTS suggests a high probability that the loss of a port, particularly the Port of San Juan, will have significant cascading impacts on its lifeline infrastructure, including fuel, food, and electric power.

50 FTA, 2016b, 2015d, 2014e, 2013f, and 2012g.
Consequently, such a loss will have an appreciable impact on the island’s economy and the health and safety of its population.

Another challenge is the cost of investments to make ports usable for new purposes. An estimate by a MARAD contractor to repair piers and bulkheads at Roosevelt Roads to facilitate usage as an additional seaport (operating at bare minimum capacity) is almost $175 million (as shown in Appendix A, Table A.4). The estimated cost of three options for moving ferry service to Roosevelt Roads from Fajardo were between $55 million and $145 million.

Another challenge is coordinating and collaborating with multijurisdictional entities and the diverse set of owners and operators that are characteristic of the island’s maritime infrastructure. As the Puerto Rico Climate Change Council has noted, “There are no known capital improvement plans for maritime transport by the Puerto Rico Ports Authority as the ports have many different tenants and operations requirements and capital improvement plans would be determined by the individual companies.” As of September 2018 we had not identified any specific recent plans, except for those at Roosevelt Roads.

The principal strategy relating to Puerto Rico’s existing seaports recognizes the importance of island-wide and international cargo movement to the economies of the island and the Caribbean region as a whole, and the essential requirement for efficient distribution of goods. The current strategic approach includes recommendations for facility improvements, capacity expansion, and access improvements at principal seaports.

From the transportation system perspective, landside access to and from the respective airports and seaports is essential for each facility’s ability to be competitive and enhance the local, regional, and island-wide economy. Although specialization of some facilities in specific types of cargo or passenger operations could be beneficial for the economy, not every small seaport (or airport) can or should become a major facility. Investments are needed for efficient cargo and passenger access and should be concentrated where they will achieve the greatest collective benefit to Puerto Rico’s MTS.


54 DTOP, 2013b.
The Statewide Transportation Improvement Program for fiscal years 2014–2017 contains relatively few projects targeting the MTS. Projects include maintenance of existing equipment and systems for dry-docking vessels, security systems, ship lift, ferry operation and maintenance, and dredging projects to maintain port depths that do little to expand overall port capacity or capability.\textsuperscript{55} A review of several other island-wide long-range planning documents reveals few port-related projects or any concerted efforts to expand MTS capability or capacity, with the exception of container-handling capacity in the Port of Ponce.

Another challenge is that while Puerto Rico has had a long-standing goal to develop a transshipment port, it faces competition with other Caribbean ports with similar facilities that have lower costs.\textsuperscript{56}

\textbf{A Previous Resiliency Assessment of the Marine Transportation System}

In 2014 the DHS conducted a resiliency assessment for Puerto Rico as part of its Regional Resiliency Assessment Program.\textsuperscript{57} The department’s Office of Infrastructure Protection conducted the assessment with a primary focus on the island’s dependence on its MTS. There is primary reliance on maritime shipping and supporting functions to maintain economic activity and government services. In addition to delivering several key commodities to sustain the population and support tourism, the pharmaceutical industry—one of the major economic drivers in Puerto Rico—relies on the Port of San Juan to export 85 percent of all pharmaceuticals from Puerto Rico.

The resiliency assessment made several key findings:

- Current emergency plans fail to identify the loss of the Port of San Juan as a significant hazard or to designate alternative transportation routes for critical commodities. With 84 percent of fuel oil, 70 percent of gasoline, 93 percent of food products, and 97 percent of manufactured equipment and machinery coming into Puerto Rico through the Port of San Juan, it is a sole source and key transshipment node for several geographically isolated areas of the island.\textsuperscript{58} Without advance planning, there is a risk of ill-informed

\textsuperscript{55} DTOP, PRHTA, Statewide Transportation Improvement Program (STIP): Fiscal Years 2014–2017, San Juan, P.R.: DTOP, December 4, 2015.

\textsuperscript{56} American Shipper staff, 2014.


decisionmaking. No formal agreements exist designating an alternate port, and there is insufficient information to determine the impact on the island’s economy. Some estimates indicate cascading and significant impacts to food inventories, fuel supplies, and electrical power after three weeks of disruption in the port.

- Loss of the Port of San Juan’s capability to receive petroleum products and food supplies would have significant effects on the island’s energy supplies and ability to feed its population. The three fuel docks in San Juan Harbor receive 70 percent of all inbound petroleum product shipments and the vast majority of total food supplies. Planning efforts do not fully address the effects of the loss of these shipments in the event of a port closure. Due to a just-in-time inventory policy and very limited emergency storage capacity, perishable food supplies would be significantly impacted.

- Contingency planning for the Port of San Juan is not fully coordinated with all critical stakeholders. Comprehensive coordination of response activities has not been accomplished. There is both a lack of coordination and documentation of multijurisdictional activities that have been identified as significant for effective emergency management. Any disruption to the MTS into the Port of San Juan will severely impact fresh food inventories.

The *Maritime Infrastructure Recovery Plan* acknowledges the importance of the roles both public and private partners play in the decisionmaking that facilitates port and overall MTS recovery. Much of the information about Puerto Rico’s port cargo-handling capacity is unknown or not available for consideration in recovery planning efforts. Elements of the MTS include terminals and piers that are privately owned and operated. The Port of San Juan relies on private contractors to evaluate navigable waterway safety and functionality and to maintain the waterway. The *Area Maritime Security Plan* is missing some essential elements of information that detail the role of the USCG’s Marine Transportation System Recovery Unit and the steps needed to facilitate port recovery or move operations to a secondary port.

As Table 3.5 shows, various emergency operations plans affecting maritime transportation have been developed.

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59 DHS, 2014.
### Table 3.5. List of Plans for Maritime Transportation

<table>
<thead>
<tr>
<th>Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>USCG, Sector San Juan Puerto Rico and the U.S. Virgin Islands Area Contingency Plan, October 2011</td>
</tr>
<tr>
<td>USCG, Sector San Juan Marine Firefighting Contingency Plan, revised 2010</td>
</tr>
<tr>
<td>USCG, Sector San Juan Heavy Weather Plan, Annex C—Port Preparedness, 2018</td>
</tr>
<tr>
<td>DHS, Maritime Infrastructure Recovery Plan, Washington, D.C., April 2006</td>
</tr>
<tr>
<td>PREMA, Emergency Operations Plan, San Juan, P.R., March 30, 2009</td>
</tr>
<tr>
<td>PREMA, “Plan for Mitigation of Natural Hazards of Puerto Rico,” draft for discussion, revision, 2011</td>
</tr>
<tr>
<td>PREMA Emergency Operations Plan, Section I, Basic Plan, v5, 2011</td>
</tr>
<tr>
<td>Puerto Rico Fire Department (PRFD), Operational Plan for Emergencies Caused by Weapons of Mass Destruction, revised August 18, 2012</td>
</tr>
<tr>
<td>PREPA, Guide for Tsunami Planning for Port Operators in the Caribbean, October 2011</td>
</tr>
<tr>
<td>PRPA, Emergency Operations Plan, May 2012</td>
</tr>
<tr>
<td>City of San Juan, Mitigation Plan Against Multiple Natural Hazards, March 2006</td>
</tr>
<tr>
<td>City of San Juan, Emergency Operations Plan, version 2011–2012</td>
</tr>
<tr>
<td>Facility-specific private-sector emergency operations plans</td>
</tr>
</tbody>
</table>

**NOTE:** The last entry refers to specific facility operations plans that are required by the USCG and unique to each facility. These required plans detail how the facility will respond to various emergencies such as oil spills, chemical releases, storms, security breaches, etc. Many of these plans are not publicly available. We did not review these plans for this report for that reason.

## Hurricane Damage

### Emergency Response

#### Seaports

Prestorm preparations and poststorm emergency response operations were carried out in accordance with the Code of Federal Regulations; the National Response Framework, government of Puerto Rico and local regulatory mandates, and area and individual waterfront facility contingency and incident action plans. In accordance with the authority vested in the USCG captain of the port, and in consultation with MTS stakeholders, emergency maritime operations were initiated, monitored, and documented before, during, and after each storm’s passing to minimize damage to port infrastructure and protect navigable waterways. Specific activities included closing ports for safety reasons, determining when to reopen them, conducting

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damage assessments, initiating emergency response to protect further damage to property, and making temporary repairs to commence recovery operations.

The USCG Marine Transportation System’s *Common Assessment and Reporting Tool Executive Summary Report* covers the time period from September 17, 2017 to January 17, 2018.\(^{61}\) As of November 22, 2017, after the passing of Hurricane Maria two months earlier (September 20, 2017), a comprehensive operational assessment of the ports was compiled by the USCG captain of the port. All ports were in an open status, but some still operated under restrictions pertaining to maximum draft due to shoaling. USACE had dredging operations planned or pending for many of the affected ports. Coast Guard Infrastructure Teams determined that 90 percent of all key marine terminals were available and fully operational.

The report provided additional detailed reports on the operational status of each of Puerto Rico’s ports. The ports of Arecibo, Ceiba (Roosevelt Roads), Guayama, Mayagüez, and Yabucoa were all open, in recovery mode, but with restrictions in safe operating draft, and with daylight operations only in the majority of ports. Specific MTS impact was reported as two nonoperational cranes in the Port of Ponce with a repair estimate of 21 days.\(^{62}\)

Additionally, a sunken vessel was reported as blocking safe access to Pier 8 at the Port of Ponce. The report went on to detail the operation status of aids to navigation, channels, waterfront facilities, and marine terminals. The only reported significant degradation to the port area critical infrastructure were the bulk liquid facilities, reporting 67 percent availability. All other facilities were reported as 86 percent available or better. Waterway and navigation systems were assessed as 96 percent available or better.\(^{63}\)

Based on FEMA incident situation reporting, as of March 31, 2018, approximately 6.7 million yd\(^3\) of debris had been cleared across the entire island, including seaports. Additionally, approximately $460 million of funding has been approved for repairs, a portion of which includes ports.

**Ferries**

Ferry service was suspended the night before Hurricane Maria due to concerns that passage would not be safe. Ferry service to Culebra and Vieques was unavailable for several days


\(^{62}\) Interviews with PRPA subject-matter experts indicate that the Port of Ponce’s two large container cranes were nonoperational due to lack of funds for maintenance, not storm damage. Ponce Port Authority, meeting between staff and HSOAC team members Liisa Ecola, Kenneth Kuhn, and Thomas F. Atkin, April 2018.

\(^{63}\) USCG, Marine Transportation System, 2018.
following the hurricane, a major hardship given the lack of other transportation options. Limited daylight service of four round-trips per day was restarted four days after the storm, largely to bring relief supplies to Culebra and Vieques.

While ferry service was operational by the time this report was written, we have not identified any information regarding the scope of any repairs already made. The Hill International report indicated that “repair to functionality” costs were not provided since the terminals were all reopened within five days. The Puerto Rico Marine Transportation Authority has received approximately $37,000, which is a portion of the $17 million provided to the transportation sector.

Seaports: Facility Damage

The hurricanes caused substantial damage to the seaports in Puerto Rico, which in some cases was exacerbated by the already deteriorating condition of some equipment. We have two sources of information about facility damage.

First, the PRPA contracted with the firms Gvelop and Iglesias-Vazquez and Associates to conduct detailed damage assessments to ten ports in its jurisdiction. These reports summarize both emergency and permanent repairs using FEMA categories.

Second, MARAD commissioned extensive damage assessments at 23 piers around the island from two engineering firms: DCM Architecture & Engineering, and Matrix New World Engineering (MNW). These reports, which were provided to the HSOAC team, included structural assessments of breakwaters, piers, and buildings, as well as cost estimates for restoration and/or enhancement of these structures. In some cases they also included estimates for major changes (such as providing ferry service where it was not previously available).

Table 3.6 summarizes the conditions at Puerto Rico’s ports identified by the contractors working for MARAD and the PRPA as of spring 2018, along with two estimates of repair costs: repair to functionality and repair with resilience.

Where multiple assessments were conducted, we used those conducted by contractors working for MARAD, for four reasons: first, they were conducted more recently (May 2018, as opposed to November 2017); second, they appeared to be more thorough; third, they included assessments of underwater structures conducted by divers; and fourth, they provided overall

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assessments of the current condition of the assets they evaluated, using the following standard categories:

- **Good**: No problems or only minor problems noted. Structural elements may show some very minor deterioration, but no overstressing observed. No rehabilitation is required.
- **Satisfactory**: Minor-to-moderate defects and deterioration observed, but no overstressing observed. No rehabilitation is required.
- **Fair**: All primary structural elements are sound; but minor-to-moderate defects and deterioration observed. Localized areas of moderate to advanced deterioration may be present but do not significantly reduce the load-bearing capacity of the structure. Rehabilitation is recommended, but the priority of the recommendation is low.
- **Poor**: Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load-bearing capacity of the structure. Rehabilitation may be carried out with moderate urgency.
- **Serious**: Advanced deterioration, overstressing, or breakage may have significantly affected the load-bearing capacity of primary structural elements. Local failures are possible, and loading restrictions may be necessary. Rehabilitation may need to be carried out on a high-priority basis, with urgency.
- **Critical**: Very advanced deterioration, overstressing, or breakage has resulted in localized failure(s) of primary structural elements. More widespread failures are possible or likely to occur, and load restrictions should be implemented as necessary. Rehabilitation may need to be carried out on a high-priority basis, with strong urgency.\(^{67}\)

In Table 3.6, the “Cost to Repair to Functionality” column is generally the cost to bring the facility up to code and a state of good repair. The “Additional Resilience Measures” column, which presents additional costs (meaning, to make an asset more resilient would require making the expenditures in both columns) is generally meant to harden the infrastructure, or in many cases to raise it to prevent problems with anticipated sea level rise. Where a cell is blank in the “Additional Resilience Measures” column, it may indicate one of two things: either the recommendation was to completely demolish and rebuild the structure, in which case resilience enhancements were already included, or no resilience enhancements were identified. PRPA contractors Gvelop and Iglesias-Vazquez and Associates did not provide resilience estimates or assess the conditions using the scale the MARAD contractors used.

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\(^{67}\) According to MNW documentation, these are taken from Ronald E. Heffron, ed., *Waterfront Facilities Inspection and Assessment Manual*, Reston, Va.: American Society of Civil Engineers, June 2015. Both MARAD contractors used the same scale, making assessments comparable.
### Table 3.6. Damage Summary for Puerto Rico Ports Assessed by MARAD and PRPA Contractors

<table>
<thead>
<tr>
<th>Pier/Structure</th>
<th>Contractor</th>
<th>Date</th>
<th>Assessed Condition</th>
<th>Cost to Repair to Functionality</th>
<th>Additional Resilience Measures</th>
<th>Resilience Need</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>San Juan</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruise Port</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 1</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$52,997,787</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pier 3</td>
<td>DCM</td>
<td>May 2018</td>
<td>Satisfactory</td>
<td>$931,219</td>
<td>$113,400</td>
<td>Repair electrical conduit</td>
</tr>
<tr>
<td>Pier 4</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$131,333,073</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Walkway 2</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$790,059</td>
<td>$218,349</td>
<td>Repair electrical conduit</td>
</tr>
<tr>
<td>Walkway 3</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$410,091</td>
<td>$131,304</td>
<td>Repair concrete cap</td>
</tr>
<tr>
<td>Cruise Port Pier 1 Terminal</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$8,612,900</td>
<td>$651,000</td>
<td>Structures for heating, ventilating, and air-conditioning systems</td>
</tr>
<tr>
<td>Cruise Port Pier 4 Terminal</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$5,400,000</td>
<td>$452,900</td>
<td>Better roof drainage systems, reinforcement of decks</td>
</tr>
<tr>
<td><strong>Loose Cargo Piers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wharf 1</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$750,000</td>
<td>$860,000</td>
<td>New fenders</td>
</tr>
<tr>
<td>Wharf 2</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$300,000</td>
<td>$600,000</td>
<td>New fenders and mooring hardware</td>
</tr>
<tr>
<td>Pier 9</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$2,400,000</td>
<td>$4,800,000</td>
<td>New fenders and mooring hardware</td>
</tr>
<tr>
<td>Pier 10</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$3,500,000</td>
<td>$2,100,000</td>
<td>New fenders and mooring hardware</td>
</tr>
<tr>
<td>Villa Pesquera Pier</td>
<td>Iglesias-Vazquez and Associates</td>
<td>November 2017</td>
<td>(Not provided)</td>
<td>$400,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><strong>Break-Bulk Wharf</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Piers 11–14</td>
<td>DCM</td>
<td>May 2018</td>
<td>Critical</td>
<td>$71,000,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pier 14 Extension</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$340,000</td>
<td>$10,600,000</td>
<td>New concrete pile and concrete deck</td>
</tr>
<tr>
<td>FEMA Warehouse Building</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$1,613,100</td>
<td>$781,705</td>
<td>Better roof drainage systems, reinforcement of decks</td>
</tr>
<tr>
<td>Pier/Structure</td>
<td>Contractor</td>
<td>Date</td>
<td>Assessed Condition</td>
<td>Cost to Repair to Functionality</td>
<td>Additional Resilience Measures</td>
<td>Resilience Need</td>
</tr>
<tr>
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</tr>
<tr>
<td>Navy Frontier Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$21,500,000</td>
<td>—</td>
<td>Better roof drainage systems, reinforcement of decks</td>
</tr>
<tr>
<td>Small craft berth</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$655,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Navy Frontier Terminal</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$2,706,500</td>
<td>$207,870</td>
<td>Better roof drainage systems, reinforcement of decks</td>
</tr>
<tr>
<td>Pan American Docks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan American Docks 1–2</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$12,900,000</td>
<td>$15,000,000</td>
<td>Install concrete deck, repair concrete cap</td>
</tr>
<tr>
<td>Pan American Dock 2 (anchored bulwark)</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor–serious</td>
<td>$8,800,000</td>
<td>$1,700,000</td>
<td>Fender system and electrical repairs</td>
</tr>
<tr>
<td>Terminal Building</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$3,394,400</td>
<td>$2,537,212</td>
<td>Better roof drainage systems, reinforcement of decks</td>
</tr>
<tr>
<td>Baggage Claim Building</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$3,830,300</td>
<td>$1,214,432</td>
<td>Strengthen roof and heating, ventilating, and air-conditioning systems</td>
</tr>
<tr>
<td>Isla Grande Piers</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Pier 1</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor–critical</td>
<td>$13,035,750</td>
<td>$521,000</td>
<td>Raise elevation of pier</td>
</tr>
<tr>
<td>Pier 2</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor–serious</td>
<td>$5,046,875</td>
<td>$23,354,750</td>
<td>Raise elevation of pier</td>
</tr>
<tr>
<td>Dock A</td>
<td>MNW</td>
<td>May 2018</td>
<td>Satisfactory–poor</td>
<td>$11,675,438</td>
<td>$2,545,000</td>
<td>Raise elevation of dock</td>
</tr>
<tr>
<td>Dock B</td>
<td>MNW</td>
<td>May 2018</td>
<td>Fair–poor</td>
<td>$13,256,938</td>
<td>$3,421,875</td>
<td>Raise elevation of dock</td>
</tr>
<tr>
<td>Graving Basin</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor; utilities are critical</td>
<td>$12,152,078</td>
<td>$5,163,750</td>
<td>Raise walls of structure to accommodate sea level rise</td>
</tr>
<tr>
<td>West Wharf</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$8,500,000</td>
<td>$55,000,000</td>
<td>Demolish bulkhead, install new substructure components, install concrete deck</td>
</tr>
<tr>
<td>Buildings A–C</td>
<td>Gvelop</td>
<td>November 2017</td>
<td>(Not provided)</td>
<td>$3,089,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Administration Building</td>
<td>Gvelop</td>
<td>April 2018</td>
<td>(Not provided)</td>
<td>$146,420</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Engineering Building</td>
<td>Gvelop</td>
<td>April 2018</td>
<td>(Not provided)</td>
<td>$23,340</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Siamme Building</td>
<td>Gvelop</td>
<td>April 2018</td>
<td>(Not provided)</td>
<td>$112,700</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Maritime Building</td>
<td>Gvelop</td>
<td>April 2018</td>
<td>(Not provided)</td>
<td>$59,900</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Calle Lindbergh/Muelle</td>
<td>Gvelop</td>
<td>April 2018</td>
<td>(Not provided)</td>
<td>$1,658,848</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pier/Structure</td>
<td>Contractor</td>
<td>Date</td>
<td>Assessed Condition</td>
<td>Cost to Repair to Functionality</td>
<td>Additional Resilience Measures</td>
<td>Resilience Need</td>
</tr>
<tr>
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</tr>
<tr>
<td>Puerto Nuevo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wharves A–C</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious</td>
<td>$5,414,000</td>
<td>$54,933,000</td>
<td>Demolish current wharves; install new concrete structures, deck components, and mooring systems</td>
</tr>
<tr>
<td>Wharves D–O</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair; wharves D and M are poor</td>
<td>$6,286,000</td>
<td>$233,026,000</td>
<td>Demolish current wharves; install new concrete structures, deck components, and mooring systems</td>
</tr>
<tr>
<td>Ponce</td>
<td></td>
<td></td>
<td></td>
<td>Total: $120,674,720</td>
<td>$85,338,228</td>
<td></td>
</tr>
<tr>
<td>Pier 1</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>$17,349,062</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 2</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$12,174,395</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dock 2</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$21,043,500</td>
<td>$1,381,250</td>
<td>Reconstruct bulkhead 2 ft higher</td>
</tr>
<tr>
<td>Dock 3</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>—</td>
<td>(Included with Dock 2)</td>
<td></td>
</tr>
<tr>
<td>Dock 7</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>$12,524,906</td>
<td>$7,735,125</td>
<td>Raise bulkhead and pile-supported platform 18 inches; replace crane rails, supporting equipment, and hydraulic rail ramp</td>
</tr>
<tr>
<td>Dock 8</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>$9,753,375</td>
<td>$22,893,437</td>
<td>Raise deck by 3 ft</td>
</tr>
<tr>
<td>Shoreline A</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$6,660,125</td>
<td>$737,500</td>
<td>Raise revetment and adjacent concrete surface by 2 ft; install new stone revetment</td>
</tr>
<tr>
<td>Shoreline B</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$4,584,375</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33 upland buildings</td>
<td>MNW</td>
<td>May 2018</td>
<td>Satisfactory–critical</td>
<td>$35,784,982</td>
<td>$27,590,916</td>
<td>Additional buildings and site restoration; raise south site 3 ft</td>
</tr>
<tr>
<td>Cranes</td>
<td>(Personal communication)</td>
<td></td>
<td>Not operational</td>
<td>$800,000</td>
<td>$25,000,000</td>
<td>New cranes</td>
</tr>
<tr>
<td>Mayagüez</td>
<td></td>
<td></td>
<td></td>
<td>Total: $181,365,935</td>
<td>$158,948,224</td>
<td></td>
</tr>
<tr>
<td>Municipal dock</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$11,095,000</td>
<td>$59,992,875</td>
<td>Raise elevation by 5 ft and replace bulkhead</td>
</tr>
<tr>
<td>Pier/Structure</td>
<td>Contractor</td>
<td>Date</td>
<td>Assessed Condition</td>
<td>Cost to Repair to Functionality</td>
<td>Additional Resilience Measures</td>
<td>Resilience Need</td>
</tr>
<tr>
<td>----------------------------------------</td>
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<td>--------------------------------</td>
<td>--------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Municipal, 9 buildings</td>
<td>MNW</td>
<td>May 2018</td>
<td>Mostly fair</td>
<td>$4,522,545</td>
<td>$25,195,932</td>
<td>Raise elevation by 3 ft, replace building</td>
</tr>
<tr>
<td>PRIDCO Dock</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$45,489,625</td>
<td>$17,271,375</td>
<td>Raise dock by 3 ft, elevate site, supplement revetment</td>
</tr>
<tr>
<td>PRIDCO, 14 buildings</td>
<td>MNW</td>
<td>May 2018</td>
<td>Mostly fair</td>
<td>$120,258,765</td>
<td>$56,488,042</td>
<td>Raise elevation by 3 ft, replace building</td>
</tr>
<tr>
<td>Ceiba (Roosevelt Roads)</td>
<td>MNW</td>
<td>May 2018</td>
<td>Mostly fair</td>
<td>$4,522,545</td>
<td>$25,195,932</td>
<td>Raise elevation by 3 ft, replace building</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td>$95,881,875</td>
<td>$27,110,328</td>
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</tr>
<tr>
<td>Pier 1</td>
<td>DCM</td>
<td>May 2018</td>
<td>Critical</td>
<td>$13,492,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pier 2</td>
<td>DCM</td>
<td>May 2018</td>
<td>Satisfactory</td>
<td>$3,311,695</td>
<td>$2,305</td>
<td>Mooring cleaning/coating</td>
</tr>
<tr>
<td>Pier 3</td>
<td>DCM</td>
<td>May 2018</td>
<td>Serious/poor</td>
<td>$25,365,382</td>
<td>$5,666,618</td>
<td>Structural jacket</td>
</tr>
<tr>
<td>Fuel Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Satisfactory</td>
<td>$11,624,970</td>
<td>$102,030</td>
<td>Expansion joint</td>
</tr>
<tr>
<td>USCG Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$1,377,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Bulkheads B1, B2, D1, D2</td>
<td>DCM</td>
<td>May 2018</td>
<td>Satisfactory</td>
<td>$4,968,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Bulkhead C</td>
<td>DCM</td>
<td>May 2018</td>
<td>Critical</td>
<td>$1,454,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Dredging</td>
<td>DCM</td>
<td>March 2018</td>
<td>(Not provided)</td>
<td>$1,600,000</td>
<td>—</td>
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</tr>
<tr>
<td>Graving Wharf and Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Critical</td>
<td>$18,361,762</td>
<td>$14,455,625</td>
<td>Elevate pier</td>
</tr>
<tr>
<td>Graving Basin</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$14,326,857</td>
<td>$6,883,750</td>
<td>Raise walls of structure to accommodate sea level rise</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td>$8,191,400</td>
<td>$11,054,875</td>
<td></td>
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<tr>
<td>Yabucoa</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>$6,056,900</td>
<td>$4,840,063</td>
<td>Raise site elevation</td>
</tr>
<tr>
<td>Breakwater</td>
<td>MNW</td>
<td>May 2018</td>
<td>Serious</td>
<td>$238,250</td>
<td>$5,354,812</td>
<td>Raise site elevation</td>
</tr>
<tr>
<td>Navigation access channel</td>
<td>MNW</td>
<td>May 2018</td>
<td>(Not provided)</td>
<td>$1,896,250</td>
<td>$860,000</td>
<td>Deepen to 25 ft</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td>$7,636,750</td>
<td>$12,092,313</td>
<td></td>
</tr>
<tr>
<td>Guayama</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$5,880,750</td>
<td>$12,092,313</td>
<td>Complete replacement of pier and elevate 3 ft</td>
</tr>
<tr>
<td>Ro/Ro rampb</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical</td>
<td>$1,756,000</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Peñuelas (Tallaboa Pier)</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$19,909,343</td>
<td>$3,561,500</td>
<td>Additional increment needed to place pier; this is the recommended alternative</td>
</tr>
<tr>
<td>Pier/Structure</td>
<td>Contractor</td>
<td>Date</td>
<td>Assessed Condition</td>
<td>Cost to Repair to Functionality</td>
<td>Additional Resilience Measures</td>
<td>Resilience Need</td>
</tr>
<tr>
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</tr>
<tr>
<td>Guayanilla</td>
<td>Gvelop</td>
<td>March 2018</td>
<td>(Not provided)</td>
<td>$110,500</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Guanica</td>
<td>MNW</td>
<td>May 2018</td>
<td>Critical–poor</td>
<td>$19,961,243</td>
<td>$2,605,330</td>
<td>Raise site by 3 ft</td>
</tr>
<tr>
<td>Four buildings</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$5,091,875</td>
<td>$9,808,750</td>
<td>Raise dock by 3 ft and elevate the site</td>
</tr>
<tr>
<td>Wharf</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$17,910,000</td>
<td>$1,812,500</td>
<td>Raise bulkhead by 3 ft</td>
</tr>
<tr>
<td>Wharf</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$2,213,750</td>
<td>$30,378,750</td>
<td>Place additional layer of armor stone on existing structure</td>
</tr>
<tr>
<td>Arecibo</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$17,910,000</td>
<td>$1,812,500</td>
<td>Raise bulkhead by 3 ft</td>
</tr>
<tr>
<td>Breakwater</td>
<td>MNW</td>
<td>May 2018</td>
<td>Poor</td>
<td>$2,213,750</td>
<td>$30,378,750</td>
<td>Place additional layer of armor stone on existing structure</td>
</tr>
<tr>
<td>Vieques—Mosquito Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Fair</td>
<td>$3,949,044</td>
<td>$122,931,914</td>
<td>Additional riprap and fill</td>
</tr>
<tr>
<td>Mosquito Pier</td>
<td>DCM</td>
<td>May 2018</td>
<td>Poor</td>
<td>$8,561,262</td>
<td>$6,245,712</td>
<td>Upgrade mooring and berthing systems</td>
</tr>
<tr>
<td>Ro/Ro platform</td>
<td>DCM</td>
<td>May 2018</td>
<td>Satisfactory</td>
<td>$34,143</td>
<td>$3,943,724</td>
<td>Install concrete piers</td>
</tr>
<tr>
<td>Buildings</td>
<td>DCM</td>
<td>May 2018</td>
<td>Good</td>
<td>$2,545,300</td>
<td>$83,400</td>
<td>Upgrade for seismic and wind protection</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$909,758,856</strong></td>
<td><strong>$895,849,095</strong></td>
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</tbody>
</table>

NOTES: Assessments not performed for Aguirre or Walkway 1 at San Juan cruise ship port. Pier 2 at the San Juan cruise ship port is a ferry terminal, and is included in Table 3.7. Estimates for Fajardo are not included because Hill International conducted a more thorough assessment that is included in Table 3.7. Estimates for Isla Caja de Muerto, an uninhabited island, are not included. Estimates performed by Gvelop and Iglesias-Vazquez and Associates include emergency and permanent work. A designation of two conditions (e.g., Critical-poor) indicated that multiple elements were assessed and this represents the highest and lowest assessment. A blank cell (—) indicates that no additional resilience measure was recommended.

a Ponce Port Authority, meeting between staff and HSOAC team members Liisa Ecola, Kenneth Kuhn, and Thomas F. Atkin, April 2018.  
b A Ro/Ro (roll-on/roll-off) ramp is used to load and unload vessels carrying wheeled cargo (cars, trucks, railroad cars, etc.).
Below we summarize the damage that accrued to each of these piers. Unless otherwise noted, summaries may include information from both MARAD and PRPA contractors.

**San Juan Cruise Ship Piers**

- **Pier 1** and Terminal 1 comprise a complex of structures including an entrance gate and canopy area, pedestrian canopy and parking drop-off area, main two-story terminal building, and pier structure. Hurricane damage was mostly to the exterior and interior of the passenger terminal and to the bulkhead and its utilities. The water distribution systems, sanitary sewer systems, electrical systems, security systems, fire water supply systems, and as many as five large square flat fenders were lost at the pier. The bulkhead received impacts that caused damage to the concrete structure. The beams and caps are damaged to the extent that the recommended option is demolition and replacement. The extensive deterioration of the steel beams has affected the load-bearing capacity of the pier. Demolition and replacement is recommended.

- **Pier 3** consists of two concrete access ramps that converge in a concrete platform that projects approximately 3,300 ft into San Juan Bay and contains cruise ship tie-downs connected to the platform through four aluminum bridges (catways). This pier has no terminal building, just two aluminum security guardhouses. Hurricane damage includes destruction of approximately 650 linear ft of structural steel railings, aluminum entrance gates, the pier expansion joint, and a broken window and air conditioner at the guardhouse. A catway was destroyed at the end of the pier, and another was severely damaged (length approximately 105 ft). The electrical distribution system of the pier was severely damaged and removed for safety concerns.

- **Pier 4** is a complex of structures that serve as a home port for cruise ships. The complex comprises the entrance gate and canopy area, pedestrian canopy and parking drop-off area, main two-story terminal building, passenger access bridge, wharf, and pier structure. Hurricane damage was limited mostly to the bulkhead and its utilities; the water distribution systems, sanitary sewer systems, and fire water supply systems were completely nonfunctional. Additionally, ten fenders were missing from the length of the piers. The bulkhead received impacts that caused damage to the concrete structure. This damage is extensive and has left the pier unsuitable for bearing loads. Demolition and replacement is recommended. Pier 4 has catways to access the tie-downs at the pier. Most of the security railings on the catways were missing or had been destroyed, and one catway was missing completely.

**San Juan Loose Cargo Piers**

- **Wharf 1** is situated between Pier 9 and Pier 10 and is in fair condition. At the time of this writing, the damage did not affect the load-bearing capacity. The mooring hardware has deteriorated and is the only item that affects the operational capacity of the structure. Some bollards need replacement, steel sheet piles require further protection from corrosion, and some concrete caps require minor repairs.

- **Wharf 2** is situated to the north of Pier 9. It is in poor condition, suffering spalling, exposed reinforcing, and section loss to bent caps and fascia beams. Some piles are missing, and it is recommended they be reinstalled.
• **Pier 9** is a rectangular platform that projects into San Juan Bay with a storage yard. This pier has no terminal building, and the only structure on it is the guardhouse at entrance. The east berth suffered a total of nine broken piles, which require replacement, in addition to deteriorated mooring hardware. Other hurricane damage was limited mostly to destruction of a chain-link fence, the guardhouse, electrical systems, and missing fenders at the pier.

• **Pier 10** is a Z-shaped, 600-ft pier dedicated to the movement of multiple types of merchandise to eastern Caribbean islands in small vessels. Damage and deterioration to the concrete deck and piles has severely impacted the load-bearing capacity of Pier 10. Other damage includes destruction of a chain-link fence, damage to a guardhouse electrical system, and missing fenders at the pier.

• **Villa Pesquera Pier** is a little space located between Piers 10 and 11. The facilities include six wood structural modules; one is used for administration, and the rest are used for fishing instruments and equipment storage. Hurricane damage was limited mostly to destruction of an ornamental fence and gate, roof damage, and a wood terrace at community activities area. Several sections of wood and concrete pier were damaged beyond repair.

San Juan Break-Bulk Wharf

• **Piers 11–14 and the Pier 4 Extension** were inspected together. They are located along a waterfront that parallels the San Antonio Canal. The combined piers have a continuous length of approximately 2,500 ft and were in an advanced deteriorated state prior to the hurricanes. Piers 11–13 were assessed to be in a critical state for engineering assessment rating with restrictions for deck loading, vessel mooring, and vessel berthing. Deterioration includes exposed and corroded reinforcing steel and extensive broken portions of the deck. Portions of Piers 12 and 13 exhibited approximately 1 ft of vertical settlement and 1.5 ft of lateral displacement. Pier 14 had a fair rating for engineering assessment and has restrictions for vessel mooring; mooring hardware and connections exhibited moderate-to-severe deterioration.

• **Pier 11** has a wharf approximately 550 ft in length and a yard (approximately 2.20 acres) that is used to store container trailers, chemicals, and fuel in transit. The platform of the pier is in an advanced deteriorated state. Hurricane damage includes destruction of fire extinguishers, signage, cylindrical rubber fenders, and fencing.

• **Pier 12** has some concrete structures that have collapsed or have begun to collapse. Hurricane damage includes destruction of chain-link fence, signage, and tire fenders.

• **Pier 13**’s wharf is a port facility with 500 ft of pier space that include a warehouse building and an entrance guardhouse. The warehouse includes an accessory building with a fire water pump station to feed the warehouse sprinkler system and a fire hose station. Hurricane damage includes destruction of chain-link fence, rubber tire fenders, and large rolling doors at the warehouse, along with steel siding, steel decking, interior insulation, electrical poles, and roof drainage.

• **Pier 14** is approximately 380 ft in length, with a small yard and a deteriorated concrete platform. The yard is currently used to store different types of materials, including some vehicles. Hurricane damage includes destruction of signage, cyclone fence, pavement areas, tire fenders, lighting poles, and the concrete wharf edge.
• **Pier 14 Extension** is approximately 450 ft with a 4.15-acre storage yard. The yard has a staffed entrance with guardhouse facilities, and it stores multiple types of materials and equipment, including vehicles and trailers. Hurricane damage includes destruction of signage, chain-link fencing, pavement areas, fenders, water distribution and fire suppression systems, lighting poles, and concrete wharf edge.

• **The FEMA Warehouse Building** is in fair condition. The majority of the damage is structural, with various components of the building envelope and main structure requiring attention. Roll-up doors on the exterior walls are missing or inoperative. There is some minor mechanical and electrical system damage.

San Juan Navy Frontier Wharf

• **Navy Frontier Pier** is a large complex formed by a 900-ft reinforced concrete wharf, a 5.5-acre storage yard, and a large storage building. The main building is a steel-framed building with a steel roof deck and concrete block at the exterior walls. Hurricane damage included the guardhouse, entrance gates, fences, mechanical, electrical, and plumbing systems. Significant damage was noted to the roof, fascia, gutters, and decking of the main building, and the air-conditioning system was destroyed. The piers were missing several fenders. The wharf exhibited advanced deterioration in the steel sheet pile bulkhead and concrete pad.

San Juan Pan American Docks

• **Pan American Dock and Terminal #1** is a complex comprising three main structures and three minor ones. Elements with damage include the roof covering the steel decks; drainage, mechanical, and electrical systems; drain spots; air-conditioning ducts and condensing units; the building envelope; a runway detached from the main structure; broken fences; and damaged fire suppression and water distribution systems. There are also missing fenders, glass windows, and signage. Main structural components of the cruise passenger bridge were lost or severely corroded. The dock is also in poor condition, with widespread deterioration of the bulkhead and relieving platform.

• **Pan American Pier and Terminal #2** is a complex comprising three main structures and two minor ones. Elements with damage include the roof covering steel decks, drainage system, drain spots, air-conditioning ducts and condensing units, the building envelope, a runway detached from the main structure, broken fences, fire suppression and water distribution system damage, and a damaged entrance control device. There are also missing fenders, glass windows, and signage. The dock is in poor condition, with widespread deterioration of the bulkhead and relieving platform.

San Juan Isla Grande Piers

• **Isla Grande Pier 1** is in critical condition. Pier 1 has suffered severe spalling, and there has been section loss among the deck, beams, pile caps, and piles. The concrete deck is in danger of collapse, while some of the supporting concrete piles have failed completely. Mooring hardware shows corrosion and section loss. The majority of fenders are missing, and the remainder are damaged. Two crane rails are corroded, the warning beacon has minor displacement, and the utility pipelines and support hangers are broken and nonfunctional.
• **Isla Grande Pier 2** is in poor condition. The pier has damage to all concrete elements of the structure, corroded steel reinforcement, and five broken concrete piles. The mooring hardware has minor corrosion, while portions have more advanced deterioration. The majority of fenders are missing, and the remainder are damaged. The utility pipelines have moderate corrosion, and portions of the pipeline are completely missing. The steel support hangers are largely missing, while those remaining are severely corroded.

• **Isla Grande Dock A** is in satisfactory to poor condition. The bulkhead exhibits major corrosion and portions of the bulkhead are failing, causing sinkholes in localized areas of the dock. Mooring hardware has moderate corrosion and some section loss. The fendering has minor corrosion, with many timber fenders missing or showing moderate-to-severe aging, cracking, and section loss. The retaining wall has widespread minor spalling, while the fence atop the wall has damaged fence posts and loss of barbed wire. The dock surface has widespread rutting and deterioration, with large cracks and sinkholes noted.

• **Isla Grande Dock B** is in fair to poor condition. The bulkhead has some isolated areas of major impact damage, while the steel channel wales and tie-back rods exhibit major corrosion. The flanges of the wale channels suffered complete corrosion and section loss in isolated areas, and the wale is completely detached from the bulkhead in a 100-ft section. Mooring hardware is in poor to critical condition, with broken bollards and cleats along with moderate corrosion and section loss. The fendering exhibits moderate wear, with minor corrosion of anchoring chains and bolts, as well as moderate aging and section loss. One emergency access ladder is severely corroded and has some section loss. The dock surface is moderately worn and has minor-to-moderate cracking.

• **Isla Grande Graving Basin** is in poor condition, largely due to the condition of the utilities and caisson. The concrete gravity wall displays moderate corrosion and cracking, while the staircases have minor-to-moderate cracking and spalling. The crane rail system is severely corroded, the rail stops are broken or missing, rail switch points are broken, and switch actuators are nonfunctional. The mooring hardware ranges from satisfactory to critical, with some bollards exhibiting moderate section loss and corrosion; additionally, a cleat and all capstans are in critical condition. The fendering is generally in fair condition, with minor section loss, except for the basin, where all other fenders are missing. The utilities were mostly buried and inaccessible for inspection. The utilities that are available are in critical condition, and it is assumed that all utilities are in critical condition. The roof of the pump house is missing, and the structure is filled with seawater. Electrical wiring is missing from conduits, service panels are missing, and some pipes have been severed along the basin wall. The underlying steel of the caisson is severely corroded, and the valving and caisson utilities are assumed to be nonfunctional because they have been left exposed for an unknown period of time. The deck railing and mooring hardware exhibit moderate to severe corrosion. Almost all of the safety railing around the graving dock is missing. The ladders around the basin exhibit moderate to severe corrosion, and some portions exhibit complete section loss. The pavement is in serious condition overall, with large portions of severe edge cracking, potholes in several locations, and severe weathering of asphalt.

• **Isla Grande West Wharf** is located west of the Pan American Wharf and Terminal #1 and includes a main building and a pier. The pier is in poor condition but has no operational restrictions. Damage at the wharf includes a deteriorated bulkhead, steel sheet
This section does not include the assessment conducted of the pier at Isla Caja de Muertos, an uninhabited island.
gravity wall have collapsed, and the revetment has debris scattered throughout. Shoreline B is severely eroded and unprotected. It is recommended that a revetment be installed to protect the shoreline.

Mayagüez

- **Municipal dock**: The concrete cap of the municipally owned facility is in serious condition, with large areas of spalled concrete and exposed, corroded rebar. The fendering has some minor deterioration, and the bollards exhibit corrosion to the underlying steel.
- The **PRIDCO Dock** is in critical condition. The bulkhead has widespread severe deterioration of the steel sheet piles. A large portion of the bulkhead has completely collapsed. The east pier has frequent corrosion holes at the top of the steel pipe piles below the concrete deck. The west pier has serious spalling on the pier soffit. The fendering is largely missing or deteriorated, while the mooring hardware also exhibits severe deterioration. The revetments are displaced in large sections, damaging the upland roadway behind the revetment.

Ceiba (Roosevelt Roads)

- **Pier 1** is in critical condition. Almost all reinforced concrete encasement of steel beams and pile caps have deteriorated since previous inspection.
- **Pier 2** is in fair condition. One pile has failed, and three have had significant loss of sections. There is some delamination, concrete cover spalling, and heavy corrosion. The utilities have failed or are destroyed, and fender piles and appurtenances have reached the end of their design life.
- **Pier 3** is in poor condition. The prestressed concrete piles exhibit substantial damage and overstress.
- **The Fuel Pier** has minor damage in the piles, caps, diaphragms, and underside of the deck. The pier’s ancillary facilities exhibit widespread failure, and the pier’s load capacity is reduced.
- **Bulkheads B1 and B2** are in satisfactory condition. There is some surface corrosion present in the fendering and bollards.
- **Bulkhead C** is in critical condition. An interlock has separated; pavement and surfaces adjacent to the bulkhead concrete cap are worn and exhibit signs of water intrusion. Small areas of fenders exhibit hardware failure and surface corrosion. Mooring hardware has significant corrosion also.
- **The former USCG Pier** is in satisfactory condition. Utilities across the facility are broken or missing. Mooring hardware is in an advanced state of deterioration.
- **The Graving Pier** is in critical condition. Portions of the wharf deck have collapsed completely due to failed piles, pile caps, and deck planks. The graving pier deck has suffered similar damage, with portions having collapsed, severe spalling on H-piles, and significant corrosion on steel reinforcement. There is heavy corrosion on the coffer cells, with failed portions of concrete cap and section loss in the steel sheet piles. The mooring hardware has suffered moderate section loss, and the fendering is completely missing.
- **The Graving Basin** is in fair condition. The above-water portion of the gravity wall requires maintenance, the crane rail system is severely corroded, switch points in the rail system are bent or broken, and rail actuators are nonfunctional. The mooring hardware has substantial corrosion and minor-to-moderate section loss. The capstans are
significantly corroded and likely to be nonfunctional. The safety fence along the dock wall is completely missing, and a fence along the landward edge of the berth is severely corroded. The caisson has minor spalling and cracking, its mooring hardware is in poor condition, and the utilities are assumed to be nonfunctional.

Smaller Ports

- **Yabucoa**: The port consists of a wharf and breakwater. The bulkhead of the wharf is severely corroded and has widespread section loss. The fenders are significantly worn, with some section loss. Mooring hardware has minor corrosion and section loss. The Ro/Ro ramp has minor cracking and spalling. The upland area has some fence damage, a missing light pole, and a damaged stormwater catch basin. The armor stone of the breakwater is displaced.

- **Guayama**: The main pier was in immediate danger of collapse due to severe corrosion and sheared anchor bolts. Navigational transit and breakwater markers were destroyed, along with damage to beacon lights. The product line at the primary loading platform has segments missing, and electrical service was not connected to the pier. Doors and windows are missing or broken from multiple small buildings. The Ro/Ro ramp is in critical condition, with part of the bulkhead having collapsed and several sections of the concrete deck broken.

- **Peñuelas (Tallaboa Pier)**: Most damage observed was due to hurricane winds and seawater surge. A pier fender was detached from its anchors and sent to shore, and the roof of the machine room was compromised. One storage tank in Puerto Rico Terminal’s facilities lost its sheet roofing and insulation.

- **Guayanilla**: The utility post snapped due to high winds, and the point of connection with the utility’s main service line was damaged by water exposure. Approximately 50 linear feet of chain-link fence was damaged. A significant amount of erosion from storm surge on the corroded sheet piling, occurred along the two docks. There was no structural damage to any buildings.

- **Guanica**: Falling trees caused most of the damage, including that of the facility’s primary electric power line, the surrounding pavement, and a segment of chain-link fence. The buildings have no major structural damage, but the exterior wooden stairs that lead to the second floor, where the main offices are situated, are severely damaged and have been rendered unfit for use. In addition, two buoys used for navigational guidance have been lost, and although the dock itself is not damaged, two of its fenders need replacing, as they have been damaged beyond repair.

- **Arecibo**: While most of the damage at the Port of Arecibo stems from gradual deterioration that existed prior to the 2017 hurricanes, there is wind damage to the buildings. The breakwater structure has observed displacement of its armor stone.

- **Vieques**: Mosquito Pier is in good condition. The most costly line items are regarding repairs to the building envelope and the electrical system.69

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69 The existing ferry terminal on Vieques is included in the section on damage to ferry terminals. Due to a potential project to move ferry service to the Mosquito Pier, MARAD conducted an assessment of this pier.
Seaports: Vessel Damage

The Puerto Rico Department of Natural and Environmental Resources and the USCG, in conjunction with the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration, have reported that under Emergency Support Function 10 they formed interagency response teams that completed the following in their effort to reduce the potential impact to Puerto Rico’s marine environment:

- assessed 377 sunken or beached vessels and mitigated 376 vessels (a single vessel was pending for mitigation of pollutants)
- removed approximately 25,000 gallons of oily water
- disposed of over 2 million pounds of solid vessel waste material.\(^7\)

An example of vessel damage is shown in Figure 3.25.

The ATM experienced significant damage to many of its facilities, including the sinking of one ferry and damage to three other ferries during Hurricanes Irma and Maria. In addition to the ferries and terminals, the maintenance base was also damaged during the hurricanes and will impact the ability of the ATM to sustain operations until repaired. While several of the ferry terminals where embarkation and disembarkation of passengers occurs were in disrepair before the hurricanes, the additional damage was extensive. Table 3.7 lists the damage.

Damage to the passenger MTS (ferries, ferry terminals, and maintenance facilities) was assessed by Hill International. The assessments offer three different estimates for repair costs: repair to functionality, repair to code and standard, and repair with mitigation. Repair to functionality is generally the least costly, while repair with mitigation is generally the most costly. Repair to functionality estimates were not provided for any maritime public transportation systems.\(^*\)

Repair costs estimated for the passenger maritime transit systems total $38.4 million to repair to code and standard, while total costs including additional resiliency measures are estimated at $140.8 million. The ferry fleet and terminals in Fajardo and San Juan would be among the most costly repairs. Assessments to the two ferry terminals at Fajardo and San Juan were also conducted by a different contractor, Gvelop, working for the PRPA. Gvelop’s estimated costs are significantly lower than Hill International’s, but its assessments are far less detailed.

**Seaports: Impacts on Passenger Traffic and Cargo Operations, Port of San Juan**

To evaluate the extent to which Hurricanes Irma and Maria impacted operations at Puerto Rico’s ports, we studied several usage indicators for the ports, comparing trends in those indicators before the hurricanes took place to the months during and immediately after the storms. This analysis relies on time series regression analysis of unpublished, monthly data (July 2013 through March 2018) provided by the PRPA.

Figure 3.26 depicts a time series graph of the number of cruise ship passengers arriving at the Port of San Juan. The black line in the figure shows the number of arriving passengers by month, and the red vertical line indicates September 2017, when Irma and Maria made landfall in Puerto Rico.

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\(^*\) The explanation provided is that “there were no Repair to Functionality costs as the terminals were returned to use within five days after Hurricane Maria, at which time limited daytime operation approval was given by the United States Coast Guard”; Hill International, 2018, p. 62.
Table 3.7. Damage Summary for Puerto Rico Ferry Terminals

| Facility            | Major Areas of Damage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Estimated Repair Costs | Resilience Need                                                           |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ATM Ferry Fleet     | **Culebra II**—sunk  
Caribeña—damaged  
Covadonga—minor damage  
La Decima—minor damage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | $10,650,000  
(None)                                                                 | Redesign embarkation/debar  
dock area; new fendering            |
| Cataño Ferry Terminal | The east side embarkation ramp was destroyed, the west side embarkation ramp roller bearings need to be replaced, employee parking electric gates are damaged, roof-mounted solar panels are either missing or damaged, and three air-conditioning units on the roof were blown over.                                                                                                                                                                                                                                                                                                                                                                                   | $6,445,266  
$12,000,000                                                                 | Repair or replace air-conditioning in terminal building            |
| Culebra Ferry Terminal | The Ro/Ro ramp needs to be rebuilt, and the waterfront needs rehabilitation. The terminal was in disrepair before the arrival of the hurricanes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | $152,066  
$7,000,000                                                                 | Replace generator, demolish and rebuild site buildings            |
| Fajardo Ferry Terminal | The terminal was condemned prior to Maria. Costs are to repair existing terminal and return to current codes/standards. There is storm surge, water damage, and roof damage to the warehouse (with loss of inventory) and the administration and ticket office building. The pier bulkhead east of the terminal building has destroyed fenders and retaining walls, and there are windows broken on the two-story auxiliary office building and machine shop/office space. The electronic fuel-pumping system is found to have short-circuited when flood waters inundated the wiring conduit.                                                                                                                                                                                                 | $10,733,461  
$15,000,000                                                                 | Replace generator, demolish and rebuild site buildings            |
| Hato Rey Ferry Terminal | The two abandoned finger piers, which were in derelict condition before the hurricane, were damaged. The roof was peeled off from the east and west piers. The electrohydraulic gangway pumps require replacement.                                                                                                                                                                                                                                                                                                                                                                                                                                                        | $1,328,345  
(None)                                                                 | Demolish and rebuild terminal; better drainage and roof            |
| San Juan Terminal   | The San Juan Terminal was in disrepair prior to Hurricane Maria. Costs are to repair the existing terminal and return to current codes/standards. Several panes of glass were broken from the glass solarium/roof near the entrance of the terminal, allowing several hours of drenching rain to inundate the terminal. The solarium’s interior fascia has also failed due to water damage. The entire main terminal ceiling area has failed or is near failure because of water damage. Damage to light fixtures has also been observed. Approximately 50 ft of cap fendering was lost or is loose. Flood waters from streets inundated both bathrooms.                                                                                                                                                                                                 | $7,892,579  
$35,000,000                                                                 | Demolish and rebuild terminal; better drainage and roof            |
<table>
<thead>
<tr>
<th>Facility</th>
<th>Major Areas of Damage</th>
<th>Estimated Repair Costs</th>
<th>Resilience Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vieques Ferry Terminal</td>
<td>Storm surge on the first floor and rainwater through leaky aluminum jalousie windows destroyed the carpeting, rendering the entire second floor unusable. The roof structure attached to the front of the main terminal building has been destroyed. A length of 150 ft of security fencing is damaged, and the cargo area/parking lot asphalt pavement and curb have been damaged by an uprooted tree.</td>
<td>$488,442</td>
<td>$20,000,000 Enlarge the terminal building</td>
</tr>
<tr>
<td>Isla Grande Maintenance Base</td>
<td>The electrical transformer bank and distribution panels sustained damage, but the impact will be unknown until the restoration of power. Two electric roller doors to the workshop are broken. Jalousie windows on administration, worker lounge, and adjunct administration buildings all leak. The roof on the administration/warehouse building has leaky vents and drains. In the fueling station, equipment and the cover are broken.</td>
<td>$697,204</td>
<td>$13,500,000 Upgrade the power system; energy-efficient windows</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$38,387,363</td>
<td>$102,500,000</td>
</tr>
</tbody>
</table>

Several features of this line are noteworthy. First, the number of arriving passengers is highly seasonal. For instance, from 2013 to 2016, the average number of passengers arriving each September (approximately 59,700) is substantially lower than the average number of passengers arriving each December (roughly 169,000). This is presumably a function of tourism. Second, the number of cruise ship passengers arriving at the Port of San Juan appears to fall substantially in September 2017, even more than in other Septembers in the data, and it only seems to recover to pre-September 2017 levels in December 2017. However, even in December 2017, arrivals are approximately 11 percent lower than average December arrivals.

To estimate the impact of the hurricanes, we used regression analysis to seasonally adjust the data and remove annual trends.\textsuperscript{72} We then compared the seasonally adjusted average number of passengers arriving before September 2017 to the performance of that adjusted average from

\textsuperscript{72} More specifically, we used a linear time series regression to estimate the impacts of Irma and Maria on arrivals into Puerto Rico’s seaports. We regressed the time series of passenger arrivals on year indicators (to control for overall trends), calendar-month indicators, and an indicator for whether the month was greater than or equal to September 2018. Statistical significance was determined using robust standard errors.
September 2017 to March 2018 (the latest available month for which we had data at the time of this writing). The blue dashed lines represent this seasonally adjusted monthly average number of arriving passengers before the hurricane (roughly 114,800), which falls to less than 40,000 in the September–December 2017 period. The difference between these two blue dashed lines gives us an impact estimate, which is a reduction of approximately 74,800 passengers per month, or a 65-percent reduction in passenger arrivals—a massive effect.

One encouraging sign from Figure 3.26 is that the hurricane impacts appear to be temporary. To illustrate this, the gray dashed line in Figure 3.26 plots the predicted values of cruise ship arrivals, using only data from before September 2017. From October to December 2017, the actual cruise ship series falls well below this predicted line, but by January 2018, the number of cruise ship arrivals was greater than expected, a trend that continued through March 2018. This suggests that by the first quarter of 2018, the cruise ship passenger arrivals had recovered to pre-Maria trends.

Table 3.8 reports the temporary impact estimate for cruise ship passengers, and similarly obtained estimates for the impact of the hurricane on the number of cruise vessel calls and cargo tonnage arriving at the Port of San Juan. Overall, the cruise industry seems to have been substantially scared off by Irma and Maria from visiting the Port of San Juan, with the number of passengers falling by 65 percent in September–December 2017, and the number of vessel calls falling by 56 percent in the same period. In addition to the hurricanes degrading critical port infrastructure, this suggests that they also caused significant lost revenue from cruise ship passengers and vessel calls. The lost revenues from the decrease in cruise passengers represent not only lost revenues for the cruise ship industry itself but also a significant hit to the larger tourism economy in Puerto Rico.

<table>
<thead>
<tr>
<th>Impact Estimate</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise Ship Passengers</td>
<td>−65.2%</td>
<td>−87.5%</td>
</tr>
<tr>
<td>Total Vessel Calls</td>
<td>−55.8%</td>
<td>−76.3%</td>
</tr>
<tr>
<td>San Juan Cargo Tonnage</td>
<td>13.1%</td>
<td>−7.0%</td>
</tr>
</tbody>
</table>

SOURCE: PRPA data on cruise ship passengers, vessel calls, and cargo tonnage.
NOTE: These percentage changes are estimated from a time series regression, in which the various outcome measures are regressed on a series of year and calendar-month indicators, and an indicator for September–March 2018. Gray cells denote that these estimated impacts are not statistically indistinguishable from 0 at the 95 percent confidence level. With 95 percent confidence, the true impact estimate lies within the reported lower and upper bounds (the 95-percent confidence interval).
Despite the decline in cruise ship activity at the Port of San Juan, there was no significant negative impact in the cargo tonnage processed at that port as a consequence of the hurricanes. If anything, tonnage appears to have actually increased, but some of this could be due to the increased needs for supplies to support the recovery efforts.

**Seaports: Impacts on Vessel Calls, Eight Ports**

Figure 3.27 shows monthly vessel entry counts across all ports. In the years preceding the storms, it is clear that monthly vessel counts are highly variable throughout (and between) years. The decline in vessel counts due to impacts from the storms, however, is visible across all eight ports. By early February 2018, when AIS infrastructure was fully back online, a surge in vessel entry counts occurs especially for the Port of San Juan, for the Fajardo–Vieques passenger vessel line, and for Ceiba (Roosevelt Roads).

Figure 3.28 isolates the six-month period from January to June to demonstrate how 2018 data compare to the same periods in previous years. The early months of 2018 saw high activity, with a drop-off in vessel calls in April and May. However, this graphic is dominated by activity at the Port of San Juan; trends at other ports are subsumed by the much larger volumes at San Juan.

Table 3.9 provides a monthly comparison across all eight ports. The values are the percentage change from the three-year average values (2015–2017) to 2018 values. The effects of the hurricanes on vessel traffic varied quite substantially by port. San Juan’s vessel counts were relatively unchanged, with mostly modest decreases of 10–25 percent from the previous three-year average, well within prestorm variation.

Ceiba and Ponce experienced a major surge in activity for the early months of 2018, although both were starting from a low baseline vessel count. Ponce became a major hub for supplies for power grid restoration and recovery, whereas most prehurricane vessels were sailing, as well as some cargo. After a major surge of activity in January and February, by June most missions had ended and vessel traffic was 70 percent lower than in the preceding June. At Ceiba, Naval Station Roosevelt Roads was reopened to allow calls by nonsailing vessels, and 38 nonsailing vessels called in the area during January 2018 alone (as opposed to one nonsailing vessel call for the previous January). This increase in traffic was generally sustained, with June 2018 traffic several times greater than in previous Junes.

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73 We do not have data to conduct a similar analysis at other ports.
Figure 3.27. Vessel Entry Count for Puerto Rican Ports, January 2015–June 2018

Source: USACE analysis.

Figure 3.28. Year-over-Year Total Vessel Counts, January–June

Source: USACE analysis.
Table 3.9. Percentage Change in Total Vessel Counts from 2015–2017 (Three-Year Average) to 2018

<table>
<thead>
<tr>
<th>Port</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Juan</td>
<td>15%</td>
<td>-19%</td>
<td>-23%</td>
<td>-21%</td>
<td>-25%</td>
<td>-18%</td>
</tr>
<tr>
<td>Ponce</td>
<td>292%</td>
<td>104%</td>
<td>15%</td>
<td>38%</td>
<td>24%</td>
<td>-40%</td>
</tr>
<tr>
<td>Mayagüez</td>
<td>-100%</td>
<td>-63%</td>
<td>-43%</td>
<td>-84%</td>
<td>-45%</td>
<td>-100%</td>
</tr>
<tr>
<td>Ceiba (Roosevelt Roads)</td>
<td>579%</td>
<td>225%</td>
<td>140%</td>
<td>-14%</td>
<td>71%</td>
<td>425%</td>
</tr>
<tr>
<td>Fajardo</td>
<td>83%</td>
<td>129%</td>
<td>79%</td>
<td>-80%</td>
<td>-87%</td>
<td>40%</td>
</tr>
<tr>
<td>Vieques</td>
<td>77%</td>
<td>93%</td>
<td>53%</td>
<td>-94%</td>
<td>-89%</td>
<td>28%</td>
</tr>
<tr>
<td>Culebra</td>
<td>-85%</td>
<td>-23%</td>
<td>-37%</td>
<td>-13%</td>
<td>-78%</td>
<td>138%</td>
</tr>
<tr>
<td>Guayanilla</td>
<td>-16%</td>
<td>-21%</td>
<td>-3%</td>
<td>45%</td>
<td>-32%</td>
<td>-26%</td>
</tr>
</tbody>
</table>

Key:

- Increase in vessel traffic
  - 200% or more
  - 100–200%
  - less than 100%
- Decrease in vessel traffic
  - less than 50%
  - 50–100%
  - 100%

Other ports saw vessel activity decrease. Traffic was already fairly low in Mayagüez, and the posthurricane months saw not more than four vessels per month. As of June 2018 Mayagüez had not yet returned to its prestorm vessel activity level, and in both January and June 2018 no vessels with AIS onboard called there at all. Guayanilla saw modest decreases in vessel counts on the order of 15–30 percent, but from a much higher base of vessel traffic than at Mayagüez. Large changes were also apparent at Culebra, Fajardo, and Vieques, but because of the data issues noted previously, it is less clear that these represent actual changes in vessel traffic.

The following pages summarize posthurricane changes in vessel traffic at each of the eight selected ports.

San Juan

At the Port of San Juan, total vessel calls hover around 2,000 per year, with a decline to 1,500 in 2017, likely due to lost AIS signals during the posthurricane period. The major vessel types in the port are cargo and passenger vessels: around 500–600 per year of both vessel types make calls, with various support boats like towing and tugs coming in third and fourth place, respectively. In San Juan, between 100 and 200 tankers per year have made calls over the last three years.

After Hurricane Maria, the Port of San Juan was able to recover relatively quickly. The impacts from Maria brought vessel counts down to their lowest point in three years. However, the length of recovery time or the surge in vessel counts after the storm are no greater than what is typically observed during post-Christmas months in 2015, 2016, and 2017. The proportions of vessel types remain similar to prestorm observations, with a general increase in numbers starting...
in January 2018 followed by a decreasing trend for February–June. However, this decrease is also present in 2015, 2016, and 2017. Figure 3.29 shows the vessel counts for San Juan.

**Figure 3.29. Vessel Counts by Month, San Juan, January 2015–June 2018**

Ponce

The Port of Ponce is situated close to the major power plants located at the south of the island and is one of a few ports in the south equipped for major cargo operations, allowing access to southern cities and townships when road infrastructure was impassable. For this reason, it played a major role in the response and recovery of the electrical power grid after Hurricane Maria. While the Port of San Juan was overwhelmed with commercial and recovery cargo and the mountain roads were blocked with debris, the Port of Ponce became a focal point for the power restoration effort. After Maria, there was a major increase in towing, tug, and port tender vessels making calls at the port, as shown in Figure 3.30.
Mayagüez

Mayagüez was severely impacted by Hurricane Maria. The only vessels recorded in the area were towing and passenger vessels (fewer than four monthly), below even previously low levels of vessel traffic. No traffic at all was captured in AIS data for the period following the hurricanes, as well as in June 2018; it is not clear if this is due to the failure of the landside AIS equipment or whether there were entire months with no vessel traffic at all. Figure 3.31 shows vessel counts for Mayagüez.

Ceiba (Roosevelt Roads)

After Hurricane Maria, Naval Station Roosevelt Roads was reopened to increase maritime capacity, while many Puerto Rican ports were damaged or unable to receive their usual volumes. As a result, there is a clear spike in towing, tug, and tanker vessels in the area poststorm, as can be seen in Figure 3.32.

Guayanilla

After Hurricane Maria, no major differences in traffic type are observable, but average vessel counts appear to be down for the area, as can be seen in Figure 3.33.
Figure 3.31. Vessel Counts by Month, Mayagüez, January 2015–June 2018

Figure 3.32. Vessel Counts by Month, Ceiba (Roosevelt Roads), January 2015–June 2018
Given the problems noted earlier with passenger ferry data, it is difficult to say whether the period following the hurricanes was associated with a decrease in ferry traffic. Figure 3.34 shows ferry service down in April and May 2018, but this may be related to data that were not captured by AIS.

### Vieques

After Hurricane Maria, the data show a decline in ferry vessel traffic through the end of May 2018, but this mirrors the decline in Fajardo ferry traffic and may be related to data unreliability. There were also several towing vessels in the area, possibly in relation to the power restoration and recovery efforts on the island. Figure 3.35 shows the vessel counts for Fajardo.
Culebra

After Hurricane Maria, vessel traffic to Culebra slowed significantly and was slow to return to prestorm average levels before the end of the period of analysis. However, as has been noted previously, we consider AIS ferry data unreliable—and there are likely coverage issues—as it is difficult to believe that an island would experience entire months with absolutely no ferry traffic, as Figure 3.36 suggests (July and September 2015 and September 2016 show no vessel calls at all).

Figure 3.36. Vessel Counts by Month, Culebra, January 2015–June 2018
4. Damage Assessment: Air Transportation

Key Assets and Governance

The FAA’s Office of Airports lists ten airports in Puerto Rico that serve commercial flights or are public facilities for general aviation traffic. The names, FAA location IDs, locations, and operational characteristics of these ten airports are listed in Table 4.1. Three other small airports—Fajardo, Patillas, and Santa Isabel—are not in current operation and are not discussed further.

Descriptions of each operational airport are provided after Table 4.1, and a map is provided in Figure 4.1. Additional information on traffic levels at the airports in recent years is provided in the “Prestorm Conditions and Challenges” section.

**Luis Muñoz Marín International Airport** (hereafter SJU for its location ID) is the busiest airport in Puerto Rico based on the number of annual passenger movements. The airport served over 9 million passenger movements in the year between July 1, 2016 and June 30, 2017—roughly 90 percent of Puerto Rico’s total, according to numbers provided by the PRPA. Eight major U.S. carriers serve the airport. Domestic flights are primarily to or from Atlanta, Fort Lauderdale, Miami, Newark, New York City, and Orlando. The airport also serves many international passenger and cargo flights. It is the only airport in Puerto Rico for which Aviation System Performance Metrics data are available from the FAA. The Muñiz Air National Guard Base, the home base for the Puerto Rico Air National Guard, is located on the grounds of the airport. SJU is the only airport in Puerto Rico with two runways, as opposed to just one.

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2 According to press reports, the PRP3A intends to sell these airports; see Gloria Ruiz Kuilan, “P3 for Transportation from Caguas to San Juan,” El Nuevo Dia, February 26, 2018.
3 BTS, “San Juan, PR: Luis Munoz Marin International (SJU),” webpage, data for August 2018.
4 BTS, 2018.
Table 4.1. Characteristics of Airports in Puerto Rico

<table>
<thead>
<tr>
<th>Airport Name (Location ID)</th>
<th>Location</th>
<th>Aircraft Operations</th>
<th>Average Flights (per day)</th>
<th>Passenger Movements (7/1/2016–6/30/2017)</th>
<th>Runway Lengths (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luis Muñoz Marín International Airport (SJU)</td>
<td>Carolina</td>
<td>48% air taxi, 40% commercial, 10% transient general aviation, 1% military, &lt;1% local general aviation</td>
<td>467</td>
<td>9,159,587</td>
<td>3,170 × 61, 2,443 × 46</td>
</tr>
<tr>
<td>Fernando Luis Ribas Dominicci Airport (SIG)</td>
<td>Isla Grande</td>
<td>45% transient general aviation, 39% local general aviation, 13% air taxi, 3% military</td>
<td>262</td>
<td>50,015</td>
<td>1,688 × 30</td>
</tr>
<tr>
<td>Rafael Hernández International Airport (BQN)</td>
<td>Aguadilla</td>
<td>32% local general aviation, 27% military, 23% transient general aviation, 10% commercial, 7% air taxi</td>
<td>133</td>
<td>559,989</td>
<td>3,567 × 61</td>
</tr>
<tr>
<td>Benjamín Rivera Noriega Airport (CPX)</td>
<td>Culebra</td>
<td>93% air taxi, 4% transient general aviation, 4% local general aviation</td>
<td>97</td>
<td>82,018</td>
<td>792 × 18</td>
</tr>
<tr>
<td>Antonio Rivera Rodríguez Airport (VQS)</td>
<td>Vieques</td>
<td>66% air taxi, 28% commercial, 6% transient general aviation, 2% military, &lt;1% local general aviation</td>
<td>85</td>
<td>129,125</td>
<td>1,311 × 23</td>
</tr>
<tr>
<td>José Aponte de la Torre Airport (RVR)</td>
<td>Ceiba</td>
<td>88% air taxi, 7% local general aviation, 5% transient general aviation, &lt;1% military</td>
<td>34</td>
<td>99,939</td>
<td>3,353 × 46</td>
</tr>
<tr>
<td>Mercedita International Airport (PSE)</td>
<td>Ponce</td>
<td>66% local general aviation, 27% commercial, 7% military</td>
<td>17</td>
<td>233,458</td>
<td>2,440 × 46</td>
</tr>
<tr>
<td>Eugenio María de Hostos Airport (MAZ)</td>
<td>Mayagüez</td>
<td>62% air taxi, 19% local general aviation, 10% military, 9% transient general aviation</td>
<td>12</td>
<td>14,605</td>
<td>1523 × 30</td>
</tr>
<tr>
<td>Antonio (Nery) Juarbe Pol Regional Airport (ARE/ABO)</td>
<td>Arecibo</td>
<td>50% transient general aviation, 50% local general aviation, &lt;1% military</td>
<td>10</td>
<td>14,197</td>
<td>1,208 × 18</td>
</tr>
<tr>
<td>Dr. Hermenegildo Ortiz Quiones Airport (HUC/X63)</td>
<td>Humacao</td>
<td>48% local general aviation, 40% air taxi, 10% military, 2% transient general aviation</td>
<td>7</td>
<td>1,114</td>
<td>747 × 18</td>
</tr>
</tbody>
</table>

SOURCE: Location ID, aircraft operations, average flights per day, and runway lengths from GCR Inc., Airport IQ 5010 (searchable online data source based on FAA Airport Master Record Forms), data effective date March 28, 2019; Table 1; passenger movements from unpublished PRPA data.
Fernando Luis Ribas Dominicci Airport, commonly known as Isla Grande Airport, is the closest airport to downtown San Juan. It saw more than 50,000 passenger movements in the 12-month period between July 1, 2016 and June 30, 2017, up from roughly half that figure in 2008, according to data provided by the PRPA. Scheduled passenger service connects the airport with Antonio Rivera Rodríguez Airport in Vieques and Benjamín Rivera Noriega Airport in Culebra. The airport is also a hub for charter air service, according to data provided by the PRPA.

Rafael Hernández International Airport in Aguadilla is the second busiest airport in Puerto Rico, as measured by passenger traffic, according to the BTS. JetBlue Airways, Spirit Airlines, and United Airlines use the airport. Domestic flights are primarily to or from Miami, New York City, and Orlando. The airport is frequently considered an alternative to San Juan and is the main gateway to Porta del Sol. Rafael Hernández International Airport also serves cargo flights. The airport is home to a Lufthansa Technik facility for aircraft maintenance and repair and USCG Air Station Borinquen. The airport is also adjacent to the Punta Borinquen Radar Station, which hosts the 141st Air Control Squadron of the Air National Guard.

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6 BTS, “San Juan, PR: Isla Grande (SIG),” webpage, data for August 2018d.
7 BTS, “Aguadilla, PR: Rafael Hernandez (BQN),” webpage, data for August 2018a.
8 BTS, 2018a.
9 BTS, 2018a.
Benjamín Rivera Noriega Airport in Culebra serves the east side of the main island. Its relatively short 2,600-ft runway cannot accommodate jets.\(^{11}\) Scheduled service links Culebra to Ceiba, San Juan (both SJU and the Isla Grande airport), and Vieques.\(^{12}\)

Antonio Rivera Rodríguez Airport is essential for transportation to and from the island of Vieques, particularly for its large tourism industry. The airport has a relatively short runway, which rules out large jets.\(^{13}\) Most of the airport’s flights are to or from José Aponte de la Torre Airport in Ceiba or one of the two airports in San Juan.\(^{14}\)

José Aponte de la Torre Airport in Ceiba opened as a civilian airport in 2008.\(^{15}\) Commercial air service links the airport with Antonio Rivera Rodríguez Airport in Vieques and Benjamín Rivera Noriega Airport in Culebra.\(^{16}\) This airport hosts the Puerto Rico Aviation Maintenance Institute and Google Loon operations.\(^{17}\) Google Loon began testing its balloons and providing wireless network service at the airport before Hurricane Maria hit the island but now has FCC and Puerto Rican government approval to provide emergency high-speed wireless communications coverage.\(^{18}\)

Mercedita International Airport in Ponce has JetBlue Airways service to New York City and Orlando.\(^{19}\) Commercial passenger air service to Newark and Fort Lauderdale ended in 2008 and 2009, respectively, according to historical BTS data. Mercedita also serves cargo flights.

Eugenio María de Hostos Airport in Mayagüez has regular Cape Air service to SJU subsidized by the federal government’s Essential Air Service program, which provides a subsidy of roughly $1.5 million per year to Cape Air in exchange for 28 nonstop round-trip flights to the airport per week.\(^{20}\)

Antonio (Nery) Juarbe Pol Regional Airport in Arecibo is the main center of “sport aviation” on the island, including skydiving.\(^{21}\)

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\(^{11}\) Airport IQ 5010, undated.

\(^{12}\) BTS, “Culebra, PR: Benjamín Rivera Noriega (CPX),” webpage, data for 2018b.

\(^{13}\) Airport IQ 5010, undated.

\(^{14}\) FAA, 2018.


\(^{16}\) Vieques Air Link, homepage, undated.

\(^{17}\) Puerto Rico Aviation Maintenance Institute, “Welcome to Puerto Rico Aviation Maintenance Institute (PRAMI),” webpage, undated.


\(^{19}\) BTS, “Ponce, PR: Mercedita (PSE),” webpage, data for September 2018f.


\(^{21}\) Xtreme Divers, homepage, undated.
Humacao Airport in Humacao was scheduled to shut down after José Aponte de la Torre Airport opened in nearby Ceiba, but it appears to still be operational, according to data provided by the PRPA. The PRPA’s numbers show 31 passengers arriving at the airport in August 2017. Its relatively short 2,450-ft runway cannot accommodate jets.\(^{22}\)

All airports are ultimately owned by the PRPA. SJU has been operated by Aerostar since 2013 on a 40-year lease.\(^{23}\) Aerostar is jointly owned by Grupo Aeroportuario del Sureste, which is based in Mexico City and primarily operates airports in Mexico; and Highstar Capital, an American infrastructure investor.\(^{24}\) It is the only major privatized airport in the United States.

The agencies responsible for airports are provided in Table 4.2.

### Table 4.2. Agencies Responsible for Airports

<table>
<thead>
<tr>
<th>Agency</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRPA</td>
<td>The PRPA owns the ten airports listed in this report. The PRPA is responsible for operations at all of these airports except SJU.</td>
</tr>
<tr>
<td>Aerostar</td>
<td>Aerostar operates and manages SJU. Aerostar is a P3 that has a 40-year lease that began in 2013.</td>
</tr>
</tbody>
</table>

Other stakeholders with a role in the aviation system or operations are listed in Table 4.3.

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\(^{22}\) Airport IQ 5010, undated.


### Table 4.3. Key Stakeholders Identified for Airports

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Airlines</td>
<td>Private</td>
<td>Major air carrier</td>
</tr>
<tr>
<td>Delta Air Lines</td>
<td>Private</td>
<td>Major air carrier</td>
</tr>
<tr>
<td>JetBlue Airways</td>
<td>Private</td>
<td>Major air carrier</td>
</tr>
<tr>
<td>Southwest Airlines</td>
<td>Private</td>
<td>Major air carrier</td>
</tr>
<tr>
<td>United Airlines</td>
<td>Private</td>
<td>Major air carrier</td>
</tr>
<tr>
<td>Cape Air</td>
<td>Private</td>
<td>Important regional air carrier</td>
</tr>
<tr>
<td>Air Sunshine</td>
<td>Private</td>
<td>Important local air carrier</td>
</tr>
<tr>
<td>M&amp;N Aviation</td>
<td>Private</td>
<td>Important local air carrier</td>
</tr>
<tr>
<td>Seaborne Airlines</td>
<td>Private</td>
<td>Important local air carrier</td>
</tr>
<tr>
<td>Viesques Air Link</td>
<td>Private</td>
<td>Important local air carrier</td>
</tr>
<tr>
<td>Ameriflight LLC</td>
<td>Private</td>
<td>Cargo airline</td>
</tr>
<tr>
<td>Mountain Air Cargo</td>
<td>Private</td>
<td>Cargo airline</td>
</tr>
<tr>
<td>Transportation Security Administration</td>
<td>Government</td>
<td>Implements the Transportation Worker Identification Card program for airport employees and screens passengers and baggage at airports</td>
</tr>
<tr>
<td>Puerto Rico Air National Guard</td>
<td>Government</td>
<td>Manages the 156th Airlift Wing operating out of SJU, and the 141st Air Control Squadron out of Rafael Hernández International Airport</td>
</tr>
<tr>
<td>U.S. Air Force</td>
<td>Government</td>
<td>Controls the Muñiz Air National Guard Base, located within SJU</td>
</tr>
<tr>
<td>USCG</td>
<td>Government</td>
<td>Operates Coast Guard Air Station Borinquen at Rafael Hernández International Airport</td>
</tr>
<tr>
<td>Lufthansa Technik</td>
<td>Private</td>
<td>Owns and operates large aircraft maintenance and repair center at Rafael Hernández International Airport</td>
</tr>
</tbody>
</table>

### Prestorm Conditions and Challenges

**Context and Recent Trends**

Puerto Rico previously supported a more varied air transportation profile than it currently does. The island’s first airports were built in the 1920s and 1930s, and by the 1940s more than 20 airlines were operating flights to Miami and New York City. From the 1960s through the 1990s, a number of commuter airlines and smaller cargo airlines operated in Puerto Rico. Many of these are now defunct, having either gone out of business or been acquired by larger carriers.

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Passenger Traffic

SJU serves the most air passengers in Puerto Rico. Figure 4.2 illustrates this point using counts of the passengers arriving at each airport each month for the period from July 2013 to March 2018, as provided by the PRPA.

Figure 4.2. Arriving Passengers by Airport, July 2013–March 2018

SOURCE: PRPA, unpublished data on passengers by airport, provided to HSOAC in 2018.

Figure 4.3 shows the same data as Figure 4.2 but excludes SJU. This figure shows that the order of the airports in terms of passengers served, from most to fewest, is Aguadilla, Ponce, Vieques, Ceiba, Culebra, Isla Grande, Mayagüez, Arecibo, and Humacao. The magnitudes of the passenger traffic served at each airport and the differences between them have varied by month, but the ordering has remained fairly consistent in recent years. There are no obvious trends or seasonal patterns for most of the airports, although it does appear that traffic at Aguadilla was increasing in recent years and was higher in winter months (December, January, and February) than in other months.
Figures 4.2 and 4.3 are based on counts of passengers arriving at different airports. Typically, the counts of passengers arriving at and departing from the same airport over a period any longer than a few days will be roughly the same. However, at SJU, more people have been departing from the airport than arriving in recent years. Figure 4.4 shows the cumulative count of passengers arriving at the airport minus the passengers departing from the airport for the period July 2013–March 2018. During this time, almost 500,000 more people departed from SJU than arrived there.

SOURCE: Data provided by the PRPA.
Number of Flights

Using data provided by the FAA allows us to study passenger traffic at SJU over a longer time frame. Figure 4.5 shows aircraft movements at SJU, including counts of both arriving and departing aircraft, from 1999 through 2017. The highest traffic level was observed in 2000, with over 200,000 aircraft movements per year. Traffic declined steadily between 2000 and 2011, with nearly 50 percent fewer aircraft movements in 2011 than in 2000. Traffic was rebounding in recent years; more than 125,000 aircraft movements were recorded in 2016.
Figure 4.5. Annual Aircraft Movements at SJU, 1998–2017

![Graph showing annual aircraft movements at SJU from 1998 to 2017.](image)

**SOURCE:** FAA, Aviation System Performance Metrics (online database), 2019.

Figure 4.6 shows counts of the number of flights arriving at each airport other than SJU by month from July 2013 through March 2018, again using data provided by the PRPA.\(^{27}\) Isla Grande is the busiest airport, followed by Aguadilla, Vieques, Ceiba, and Culebra. It seems clear that Isla Grande and, to a lesser degree Vieques, Ceiba, and Culebra, serve relatively large numbers of aircraft carrying relatively few passengers. This result can be explained by reexamining Table 4.1, which shows that the majority of the traffic at Vieques, Ceiba, and Culebra is “air taxi” service, while the largest share of the traffic at Isla Grande is devoted to “transient general aviation” traffic.

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\(^{27}\) Data provided by the PRPA to the HSOAC team included passenger arrivals and departures at all airports, but information on the number of flights and pounds of cargo was provided only for airports other than SJU in San Juan. PRPA staff do not maintain these data for SJU, as it is privately operated. Aerostar staff did not make these data available.
Figure 4.6. Monthly Flight Arrivals by Airport, Excluding SJU

Figure 4.7 shows the cargo arriving at each airport—again, other than SJU. This figure shows that Aguadilla is by far the busiest cargo airport of Puerto Rico’s nine airports. Ponce also handles some cargo, while the other airports receive quite small amounts of cargo. There is limited evidence of seasonality or trends in the data, although there is weak evidence of a slow decline in the weight of cargo arriving at Aguadilla.

Figure 4.8 shows the weight of cargo arriving at Rafael Hernández International Airport in Aguadilla minus the weight of cargo leaving each month. Substantially more cargo comes into Aguadilla than leaves Aguadilla. In October 2015, over 1,000,000 more pounds of cargo arrived than departed. A similar trend was not observed at the other airports; however, Aguadilla is the busiest of the airports studied by a significant margin in terms of weight of cargo arriving at or departing from the airport.
Figure 4.7. Cargo Arriving, by Airport, Excluding SJU

SOURCE: PRPA, unpublished data on cargo by airport, provided to HSOAC in 2018.

Figure 4.8. Cargo Arriving Minus Cargo Departing, Rafael Hernández International Airport

SOURCE: PRPA, unpublished data on cargo by airport, provided to HSOAC in 2018.
Funding, Functional, and Operational Challenges

A major challenge for airports is raising sufficient revenue to make needed repairs and upgrades.\(^{28}\) Revenue challenges prompted the PRPA to bring in the private firm Aerostar to operate SJU. According to the consulting firm LeighFisher Inc., an adviser on this P3 agreement, the PRPA had “increasing levels of debt, declines in passenger numbers, and many of its facilities in need of significant upgrades.”\(^{29}\) The agreement that the PRPA reached with Aerostar in 2013 to operate SJU resulted in the PRPA receiving “$615 million in an upfront leasehold fee, followed by $2.5 million each year for the first five years, 5 percent of revenue over the next 25 years, and then 10 percent of revenue for the final ten years.”\(^{30}\)

According to a 2016 audit, the PRPA promptly used $525 million of the initial $615 million to repay debt and to cover transaction costs; PRPA expenses outpaced revenues during the periods before and including the new arrangement, although the difference between the two has shrunk.\(^{31}\) Under the agreement, Aerostar was required to undertake airport improvement projects.\(^{32}\) Eighteen months after the agreement was put in place, Aerostar was reported to have begun these projects.\(^{33}\) The *Wall Street Journal* reports that the airport benefited from an investment of $400 million to modernize facilities.\(^{34}\) The Bipartisan Policy Center called the deal a “success story” based on its terminal renovations and job creation.\(^{35}\) LeighFisher notes that the deal yielded “the necessary private capital to fund improvements and upgrades at Luis Muñoz Marin International Airport.”\(^{36}\)

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\(^{28}\) Airports are required by the FAA to be self-sufficient to the extent possible, and most larger airports do not receive local or state tax revenues, but rather obtain revenues from airline landing fees, passenger facility charges, concessions, and so forth.


\(^{35}\) Bipartisan Policy Center, 2013.

\(^{36}\) LeighFisher Inc., undated.
Hurricane Damage

Emergency Response

SJU was closed for two days after Maria hit. Emergency and relief flights were given priority in the immediate aftermath of the storm. The airport operator used 21 emergency generators to power the airport when the power would otherwise have been out. There were initial reports of many passengers being stranded in the airport with limited access to food and water. Travelers without reservations were urged not to travel to the airport. JetBlue Airways reported that it was transporting relief supplies and allowing relief personnel to fly to the island at no cost. There were restrictions on flights after dark at Rafael Hernández International Airport in Aguadilla and at Mercedita International Airport in Ponce.

The Port Authority of New York and New Jersey sent volunteers to help remove debris and make repairs at SJU, in particular helping repair the damaged terminal roof. A new roof is needed for one of the terminals at SJU, which is expected to cost roughly $30 million. This can be categorized as a critical need given the importance of the airport to the island.

According to information provided by the PRPA, passenger and cargo flights have resumed at all of the airports covered in this report, though traffic is markedly down at many airports. For example, 1,182 passengers arrived at and 802 passengers departed from Benjamín Rivera Noriega Airport in Culebra in December 2017, down from 4,254 arrivals and 3,203 departures in December 2016.

Poststorm passenger and cargo movements were substantially lower through December 2017 as well. To the best of our knowledge, however, no airport suffered damage so severe that it was not able to resume flight operation at levels similar to those before the storms. The lower passenger counts may be due to a decline in demand as tourists and people traveling on business have changed their travel patterns.

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40 “100 Days, 35 Ways of Caring for Puerto Rico . . . and Beyond,” Out of the Blue (JetBlue Airways blog), 2017.
42 Kantrow-Vázquez, 2018.
Facility Damage

Damage for each airport is summarized in Table 4.4, and descriptions of damage at individual airports follow the table. Based on the full reports made available to the HSOAC team by the PRPA, the total cost of repairs needed is $108 million. The HSOAC team has not been provided with a detailed damage assessment of SJU; the figure in Table 4.4 was provided by the PRPA as part of a summary document. In addition, some privately held or managed assets such as the Lufthansa Technik facility at Rafael Hernández International Airport were only superficially assessed.

The Build Back Better request for federal assistance includes two projects focused on airports. It seeks $540 million for Rafael Hernández International Airport rehabilitation and an additional $24.5 million for “Regional Airports Optimization.” Note that both projects are considerably more expensive than the costs of repairs identified in the Gvelop damage assessments. The Rafael Hernández International Airport project in particular seems to be based on a long-standing desire to improve the airport and attract additional traffic to the area that was evident at least as far back a 2005 master plan for the airport.

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43 The HSOAC team reviewed damage assessment reports prepared by Gvelop for the PRPA. The figures in Table 4.4 are based on those reports, as they detail specific repairs needed—both emergency and permanent work as categorized by FEMA. However, the PRPA has also provided us with top-line estimates to repair damage at all airports, and they have differed from the original Gvelop reports. For example, the Gvelop report for Rafael Hernández International Airport indicates $2.1 million in emergency repairs and $4.7 million in permanent work, for a total of $6.8 million (Gvelop LLC, Rafael Hernández International Airport (BQN)—Aguadilla, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: Puerto Rico Ports Authority, September 27, 2017b). A PRPA Damage Inventory (Appendix B of the Strategic Plan for Recovery, Reconstruction, and Resiliency, Preliminary Draft), provided by the PRPA to the HSOAC team in June 2018, lists an “approximate cost” of $11.6 million. Finally, a PRPA Facilities Description, provided to the HSOAC team by Gvelop in August 2018, provides a cost estimate of $8.5 million. The Facilities Description cites Gvelop as the source of the estimate, while the Damage Inventory does not provide a source. The team has not been provided with updated Gvelop reports that might explain the cost revisions. Lacking more detail on the Damage Inventory and the Facilities Description, we have used the fall 2017 Gvelop report as the basis of the cost estimates for nine airports (except SJU). For this reason, the total of all airport damage in Table 4.4 differs from the total provided in the Recovery Plan.

44 Governor of Puerto Rico, 2017.

45 Team ERA, Enrique Ruiz and Associates, and Campbell and Paris, P.C., Rafael Hernandez Airport: Master Plan Update, prepared for Puerto Rico Ports Authority, San Juan, P.R., November 2005.
Table 4.4. Damage Summary for Puerto Rico Airports

<table>
<thead>
<tr>
<th>Airport</th>
<th>Company Conducting the Assessment</th>
<th>Date of Assessment</th>
<th>Major Areas of Damage</th>
<th>Estimated Repair Cost for All Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJU</td>
<td>Interlink-Hunt, LLC</td>
<td>Unknown</td>
<td>Roofing; terminal interior water damage; air traffic equipment; fencing</td>
<td>$85,861,660</td>
</tr>
<tr>
<td>Fernando Luis Ribas Dominicci Airport</td>
<td>Gvelop</td>
<td>September 2017</td>
<td>Exterior damage; mechanical infrastructure damage; buildings infiltrated by water</td>
<td>$4,859,151</td>
</tr>
<tr>
<td>Rafael Hernández International Airport</td>
<td>Gvelop</td>
<td>September 2017</td>
<td>One building collapsed; many others suffered “building envelope collapse”; damage to air-conditioning and fencing</td>
<td>$6,832,670</td>
</tr>
<tr>
<td>Benjamín Rivera Noriega Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>Roofing; terminal interior water damage; air traffic equipment; fencing</td>
<td>$285,150</td>
</tr>
<tr>
<td>Antonio Rivera Rodríguez Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>Mechanical equipment; air traffic equipment; fencing</td>
<td>$1,080,400</td>
</tr>
<tr>
<td>José Aponte de la Torre Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>Mechanical equipment; roofing; air traffic equipment; fencing</td>
<td>$1,025,100</td>
</tr>
<tr>
<td>Mercedita International Airport</td>
<td>Gvelop</td>
<td>September 2017</td>
<td>Roofing; mechanical equipment; fencing</td>
<td>$615,700</td>
</tr>
<tr>
<td>Eugenio María de Hostos Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>Building envelope damage led to structural damage; mechanical equipment</td>
<td>$644,644</td>
</tr>
<tr>
<td>Antonio (Nery) Juarbe Pol Regional Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>One hangar &quot;totally destroyed&quot;; mechanical equipment; building interior suffered water damage; air traffic equipment</td>
<td>$1,313,105</td>
</tr>
<tr>
<td>Dr. Hermenegildo Ortiz Quinones Airport</td>
<td>Gvelop</td>
<td>October 2017</td>
<td>Mechanical equipment; roofing; windows; doors; fencing</td>
<td>$384,300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$108,255,683</strong></td>
<td></td>
</tr>
</tbody>
</table>

**SOURCES:** SJU, PRPA Facilities Description; all others based on individual Gvelop reports.

**NOTE:** Estimated repair costs for all damage includes both emergency and permanent work, as classified by FEMA.

SJU appears to have suffered extensive and costly damage, but we were unable to obtain a detailed damage estimate. A brief summary from PRPA noted that the main areas of damage were “[r]oofing; terminal interior water damage; air traffic equipment; fencing.”\(^{46}\) According to press reports, some terminals at SJU “lost entire roofs.”\(^{47}\) While it was not on airport property, an FAA radar tower lost its power supply due to the storm and has been operating on generator

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\(^{46}\) Personal communication via comments on written draft COAs, provided to HSOAC June 10, 2018b.

\(^{47}\) Kantrow-Vázquez, 2018.
power. The road leading to the site, which is in El Yunque National Forest, is inaccessible to truck traffic due to storm damage. As of September 2018, fuel was being provided by all-terrain vehicles and helicopter.⁴⁸

Airport traffic in the fourth quarter of 2017 was down 26.9 percent, year over year, and international traffic was particularly depressed, declining 41.5 percent.⁴⁹ One reason for this decline was that the airport was unable to manage much traffic in the immediate aftermath of the hurricane. It was closed for the two days immediately after Maria hit and was only accepting ten flights a day roughly a week after the storm.⁵⁰ The latter restriction was attributed to “the limited signal range of the traffic control tower in San Juan.”⁵¹

The damage at Fernando Luis Ribas Dominicci Airport in Isla Grande was much more pronounced.⁵² Debris removal, perimeter fence stabilization, and temporary roof/wall coverings were among the largest line items, although they varied between locations within the airport. Some of the private hangars were completely destroyed. One taxiway was damaged and will require replacement in the long term. There was widespread exterior and mechanical infrastructure damage. Most buildings were infiltrated by water or lost their waterproofing capacity.

Damage was particularly extensive at Rafael Hernández International Airport in Aguadilla. One building suffered a structural collapse, while many others had “building envelope breakage and loss,” including the FedEx hangar, as can be seen in Figure 4.9.⁵³ Many infrastructure assets exposed to the elements including antennae, solar panels, air-conditioning units, and perimeter fencing have been lost. The most expensive items of emergency work identified include stabilization and installation of new perimeter fencing and building debris removal and disposal. Other emergency works include installation of tarps to cover damaged roofs and mitigate water infiltration issues, with the expectation of future permanent work to repair or rebuild the roofs.

⁵¹ Dávila Calero, 2017.
⁵² Gvelop, Fernando L. Ribas Dominicci Airport—Isla Grande (SIG), Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, September 26, 2017a.
⁵³ Gvelop, 2017b.
Less damage was reported at **Benjamín Rivera Noriega Airport** in Culebra. The largest line items again were vegetative and building material debris removal and mold remediation, although in this case the safety inspection was the second most costly line item. Water infiltrated the main terminal building as a result of damage to roof metal decks. A portion of perimeter cyclone fence collapsed on the runway, and some air traffic lights and signs were partially or totally destroyed.

On Vieques, **Antonio Rivera Rodríguez Airport** reported significant damage to one hangar and the main terminal building. Mold remediation was the largest expense, while vegetative and debris removal and disposal were also significant costs. Rainwater infiltration was prominent across the site, and some mechanical equipment was damaged. Some air traffic lights and signs were partially or completely destroyed, while approximately 30 percent of the perimeter fencing collapsed.

Damage was similar at **José Aponte de la Torre Airport** in Ceiba. The removal and disposal of vegetative and building materials is the largest cost alongside repairs to perimeter

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54 Gvelop, *Benjamin Rivera Noriega Airport (CPX)—Culebra, Hurricane Maria’s Site Observation Final Report*, San Juan, P.R.: PRPA, October 10, 2017g.

fencing. Mechanical equipment was damaged, as was roofing, which allowed for further water damage to the building interiors. Similar to other airports, perimeter fencing and navigational lighting were damaged, compromising airport security and operability. Some storage facilities were completely destroyed. Wood paneling, drain pipes, and roof-covering tarps are needed as emergency protective measures.

The damage at Mercedita International Airport in Ponce is less severe. Its most costly line item is mold remediation, followed by installation of a new airport wind sock and diesel generator service and maintenance. Water infiltrated some of the building interiors, and perimeter fencing was compromised.

The damage at Eugenio María de Hostos Airport in Mayagüez was quite sizable. Mold remediation was the largest expense, while removal of debris and the replacement of damaged runway lights were the other most substantial costs. Damage to the building envelope led to rain infiltration of some structures and may have also caused some structural damage. Mechanical equipment was damaged by strong winds, and portions of the border fences collapsed.

In Arecibo, the majority of costs at the Antonio (Nery) Juarbe Pol Regional Airport can be attributed to debris removal and disposal and mold remediation. One hangar was “totally destroyed,” while most of the others remain severely damaged. Radio antennae on the main building and other mechanical equipment were severely damaged, and the interior of the building suffered water damage. The electricity supply to the navigational lights system was damaged and requires repair in the immediate term while being evaluated for replacement in the long term.

Dr. Hermenegildo Ortiz Quinones Airport in Humacao lost one hangar, and the others suffered either structural damage, water infiltration, or both. The most substantial line items are vegetative and building material debris removal, mold remediation, and repairs to the runway lighting system. Mechanical equipment on the main terminal building was displaced and damaged, in addition to roofing components, windows, and doors. Some of the perimeter fence

56 Gvelop, José Aponte De La Torre Airport (RVR)—Ceiba, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, October 2, 2017d.
57 Gvelop, Mercedita International Airport (PSE)—Ponce, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, September 29, 2017c.
58 Gvelop, Eugenio María de Hostos Airport (MAZ)—Mayagüez, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, October 10, 2017h.
59 Gvelop, Antonio “Nery” Juarbe Regional Airport (ARE)—Arecibo, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, October 10, 2017i.
60 Gvelop, Humacao Regional Airport (HUC)—Humacao, Hurricane Maria’s Site Observation Final Report, San Juan, P.R.: PRPA, October 6, 2017e.
collapsed, and a power pole blocked the main airport road. As a result, the only access to the airport was through the runway.

**Impacts on Passenger Traffic**

To evaluate the extent to which Hurricanes Irma and Maria impacted Puerto Rico’s airports, we studied the performance of several usage indicators for those airports, comparing trends in those indicators before the hurricanes took place to trends after the storms. This analysis relies on time series regression analysis of unpublished monthly data provided by the PRPA from July 2013 through March 2018.61

Similar to Figure 3.26, Figure 4.10 depicts a time series graph of the number of passengers arriving at SJU, Puerto Rico’s largest and busiest airport. The black line in the figure shows the number of arriving passengers by month, and the red vertical line indicates September 2017, when Irma and Maria made landfall in Puerto Rico. The blue dashed lines represent the detrended, adjusted, monthly average number of arriving passengers before the hurricane (roughly 370,000), which falls to less than 230,000 in the September–December 2017 period. The difference between these two blue dashed lines gives us an impact estimate, which is a reduction of approximately 140,000 passengers per month, or a 38-percent reduction in passenger arrivals—a substantial effect.

Table 4.5 depicts the effect of Irma and Maria on all arriving and departing passengers in Puerto Rico’s airports. All airports experienced reductions in passenger traffic, although departures seem to be generally less impacted than arrivals.

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61 Details of how we conducted this analysis are provided in the “Impact of Damage” subsection of the present report’s “Seaports” section.
Figure 4.10. Number of Passengers Arriving at SJU, Monthly

SOURCE: PRPA, unpublished data on passengers by airport, provided to HSOAC in 2018.
NOTES: The red vertical line indicates September 2017, the month when Hurricanes Irma and Maria made landfall in Puerto Rico. The blue dashed lines correspond to pre-September 2017 and September–December 2017 adjusted means. The gray dashed line corresponds to the predicted series based on pre-September 2017 data.

Table 4.5. The Hurricanes’ Impact on Monthly Passenger Arrivals and Departures, by Airport

<table>
<thead>
<tr>
<th>Airport Name</th>
<th>Arrivals</th>
<th></th>
<th></th>
<th>Departures</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impact Estimate</td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td>Impact Estimate</td>
<td>Lower Bound</td>
<td>Upper Bound</td>
</tr>
<tr>
<td>SJU</td>
<td>–38.0%</td>
<td>–41.1%</td>
<td>–34.9%</td>
<td>–26.3%</td>
<td>–32.7%</td>
<td>–19.9%</td>
</tr>
<tr>
<td>Fernando Luis Ribas Dominicci</td>
<td>–46.2%</td>
<td>–65.2%</td>
<td>–27.2%</td>
<td>–61.4%</td>
<td>–92.8%</td>
<td>–30.0%</td>
</tr>
<tr>
<td>Rafael Hernández</td>
<td>–71.2%</td>
<td>–97.7%</td>
<td>–52.8%</td>
<td>–64.2%</td>
<td>–81.5%</td>
<td>–46.8%</td>
</tr>
<tr>
<td>Benjamín Rivera Noriega</td>
<td>–61.8%</td>
<td>–85.1%</td>
<td>–38.6%</td>
<td>–64.4%</td>
<td>–84.1%</td>
<td>–44.7%</td>
</tr>
<tr>
<td>Antonio Rivera Rodríguez</td>
<td>–50.4%</td>
<td>–65.0%</td>
<td>–35.8%</td>
<td>–39.8%</td>
<td>–53.2%</td>
<td>–26.5%</td>
</tr>
<tr>
<td>José Aponte de la Torre</td>
<td>–65.0%</td>
<td>–79.2%</td>
<td>–50.8%</td>
<td>–56.4%</td>
<td>–66.9%</td>
<td>–45.9%</td>
</tr>
<tr>
<td>Mercedita</td>
<td>–52.3%</td>
<td>–69.2%</td>
<td>–35.4%</td>
<td>–40.6%</td>
<td>–52.2%</td>
<td>–28.9%</td>
</tr>
<tr>
<td>Eugenio María de Hostos</td>
<td>–32.7%</td>
<td>–52.2%</td>
<td>–13.1%</td>
<td>–17.5%</td>
<td>–42.9%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Antonio (Nery) Juarbe Pol</td>
<td>–72.8%</td>
<td>–99.9%</td>
<td>–34.5%</td>
<td>–54.3%</td>
<td>–99.9%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Humacao</td>
<td>–53.4%</td>
<td>–99.9%</td>
<td>55.4%</td>
<td>–9.2%</td>
<td>–57.7%</td>
<td>39.3%</td>
</tr>
<tr>
<td>Total</td>
<td>–40.6%</td>
<td>–44.0%</td>
<td>–37.1%</td>
<td>–29.4%</td>
<td>–34.9%</td>
<td>–23.9%</td>
</tr>
</tbody>
</table>

SOURCE: PRPA.
NOTE: These percentage changes are estimated from a time series regression, in which the various outcome measures are regressed on a series of year and calendar-month indicators, and an indicator for September–March 2018. Gray cells denote that these estimated impacts are not statistically indistinguishable from 0 at the 95-percent confidence level. With 95-percent confidence, the true impact estimate lies within the reported lower and upper bounds (the 95-percent confidence interval).
Impacts on Daily Flight Operations, SJU and Rafael Hernández International Airports

Another data set on airport operations comes from the FAA’s Air Traffic Activity Data System (ATADS). Although the ATADS data do not provide passenger information, they instead provide higher-frequency daily information for the total number of flights arriving at and departing from two airports in Puerto Rico: SJU and Rafael Hernández International Airport. These data are collected from radar towers located at each of these airports.

Figure 4.11, Panel A, plots the total number of daily operations at SJU from January 1, 2017 to April 30, 2018. The black dotted line in Figure 4.11 represents the raw, daily data, while the solid black line was obtained by smoothing the data. Two vertical red lines mark the days that Hurricane Irma (September 7, 2017) and Hurricane Maria (September 20, 2017) made landfall in Puerto Rico. The substantial drop in operations during the hurricanes, and the limited recovery after the hurricanes, are both clearly evident. Panel B shows that most of this drop was due to nonmilitary operations, and that actually military operations increased immediately following the hurricanes, presumably because of relief efforts.

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62 We smoothed the data using the Holt-Winters method, one of many smoothing procedures used in time series analysis and forecasting. The procedure allows the current value of the series to depend on weighted lagged values of the series, with weights that decay exponentially over time. We use the additive version of the smoothing procedure, which assumes that seasonal effects and trends are additively separable from the overall unadjusted mean of the series. See Chris Chatfield, “The Holt-Winters Forecasting Procedure,” Applied Statistics, Vol. 27, No. 3, 1978, pp. 264–279 for a more detailed description.

63 Note that because these data were collected from radar towers, if a tower was damaged or not functioning during and immediately after the hurricane, planes could have taken off and landed at SJU, but they would not be recorded in the data. In discussions with officials at SJU, we ascertained that military flights were apparently using the airport within 24 hours, and commercial flights were using the airport within 48 hours. (Personal communication with former Environmental Manager at Luis Munoz Marin International Airport, April 2018.)
Figure 4.11. Total Operations, SJU, Daily

Panel A: Overall

Panel B: By Type

NOTES: In Panel A, the gray line represents the raw daily data, while the thick black line is a smoothed version of the data, obtained using the Holt-Winters method. In Panel B, raw and smoothed daily data are plotted for nonmilitary (black) and military operations (blue). Note that the two smoothed lines plotted in Panel B may not add up to the smoothed totals in Panel A. The two vertical red lines mark the days that Hurricane Irma (September 7, 2017) and Hurricane Maria (September 20, 2017) made landfall in Puerto Rico.

Following a similar regression analysis to adjust the daily data for seasonal and annual trends, we find that the post-Maria period is associated with 52 fewer flights per day, which is an 11.3-percent reduction in average daily flights, although the series appears to have stabilized by spring 2018. Given that the number of passengers has fallen 38 percent since Hurricane Maria, the total flights have fallen less than the number of passengers, suggesting that many flights may be operating below passenger capacity.

Figure 4.12 plots the total daily operations at Rafael Hernández International Airport from January 1, 2017 to April 30, 2018. Because this airport is a joint civilian-military airport, it is not surprising that the number of operations does not seem to be as sensitive to the hurricanes as those at SJU. In fact, a regression analysis finds that the impact of the hurricanes on operations at Rafael Hernández International Airport was only an average reduction of 34 flights, a 33.4-percent effect. Again, the flight operations effects are substantially smaller than the effects on passengers, suggesting that flights may be operating with smaller numbers of passengers.
Impacts on Air Cargo, All Airports Except SJU

We conducted a similar analysis on cargo tonnage loaded and deplaned at Puerto Rico’s airports. 64 In total, the hurricanes seem to have had somewhat smaller effects on cargo arrivals and departures, although certain airports seem to have been dramatically impacted, such as Fernando Ribas Dominicci Airport in Isla Grande.

Unfortunately, PRPA data on cargo coming through SJU only span 13 months, from January 2017 to January 2018. Because of this limited sample, we could not adjust the data to account for seasonality or annual trends, and this makes assessing the impact of the hurricanes difficult.

Despite these limitations, Figure 4.13 reports the pounds of cargo coming through each month at SJU. Panel A shows that from a pre-Maria average of 12 million pounds cargo loaded onto planes departing from SJU, cargo loaded falls to 7.4 million pounds in September 2009 and increases significantly, to an average of 14.7 million pounds from October 2017 to January 2018. Panel B shows that most of the activity in this overall series comes from domestic cargo.

64 This PRPA data series on cargo do not include SJU, since it is privately operated and ASUR maintains that information.
Table 4.6. The Hurricanes’ Impact on Monthly Cargo Tonnage Loaded and Deplaned, by Airport

<table>
<thead>
<tr>
<th>Airport Name</th>
<th>Loaded Impact Estimate</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Deplaned Impact Estimate</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Luis Ribas Dominicci</td>
<td>-92.9%</td>
<td>-99.9%</td>
<td>-83.7%</td>
<td>-92.2%</td>
<td>-99.9%</td>
<td>-80.9%</td>
</tr>
<tr>
<td>Rafael Hernández</td>
<td>-18.1%</td>
<td>-31.2%</td>
<td>-4.9%</td>
<td>-23.9%</td>
<td>-41.9%</td>
<td>-5.9%</td>
</tr>
<tr>
<td>Benjamín Rivera Noriega</td>
<td>-34.0%</td>
<td>-49.0%</td>
<td>-19.0%</td>
<td>-79.7%</td>
<td>-92.6%</td>
<td>-66.8%</td>
</tr>
<tr>
<td>Antonio Rivera Rodríguez</td>
<td>4.1%</td>
<td>-32.8%</td>
<td>40.5%</td>
<td>-56.2%</td>
<td>-78.4%</td>
<td>-34.0%</td>
</tr>
<tr>
<td>Mercedita</td>
<td>-34.8%</td>
<td>-47.1%</td>
<td>-22.5%</td>
<td>-33.2%</td>
<td>-44.1%</td>
<td>-22.2%</td>
</tr>
<tr>
<td>Eugenio María de Hostos</td>
<td>-68.7%</td>
<td>-73.6%</td>
<td>-63.8%</td>
<td>-51.5%</td>
<td>-75.9%</td>
<td>-27.0%</td>
</tr>
<tr>
<td>Antonio (Nery) Juarbe Pol</td>
<td>3.7%</td>
<td>-33.9%</td>
<td>41.4%</td>
<td>3.9%</td>
<td>-81.6%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Total</td>
<td>-19.9%</td>
<td>-31.7%</td>
<td>-8.2%</td>
<td>-24.9%</td>
<td>-41.5%</td>
<td>-8.3%</td>
</tr>
</tbody>
</table>

SOURCE: PRPA.

NOTES: These percentage changes are estimated from a time series Tobit regression, in which the various outcome measures are regressed on a series of year and calendar-month indicators, and an indicator for September 2017–March 2018. The model ensures that cargo tonnage cannot fall below 0. Gray cells denote that these estimated impacts are not statistically indistinguishable from 0 at the 95-percent confidence level. With 95-percent confidence, the true impact estimate lies within the reported lower and upper bounds (the 95-percent confidence interval). Data for SJU was not included in the data set. For Juarbe, the confidence interval is very large because the effect estimate is not precisely estimated. The time series for Juarbe has a handful of months with lots of activity, and no activity for the remainder of the year, making effect estimates extremely imprecise.
Panel C shows a massive spike in cargo deplaned at SJU of 48.3 million pounds in October 2017, the month following Hurricane Maria. Although this is mostly due to domestic cargo (Panel D), a significant increase in international cargo was also observed. Presumably these movements reflect the relief efforts of donors domestically and the international community to provide assistance to hurricane victims.
This chapter addresses the priority challenges that were identified during the course of the research, the barriers and facilitators to response, and information gaps.

Priority Challenges to Address During Recovery

The main challenges are summarized for each transportation mode below. They include geography and topography for creating a more resilient road network; better information on existing conditions; and addressing congestion, safety, and options for those who do not drive. For public transportation, they include staving off decline and ensuring service delivery. The port system needs sufficient redundant capacity to ensure that deliveries of critical imports continue during natural disasters or other severe interruptions in service. The airport system needs to be more resilient physically. Finally, within all modes it is important to balance the need for resilience improvements and possible increases in capacity and redundancy with limited resources and the need for ongoing maintenance.

Roads and Bridges

Given the extent of the road network in Puerto Rico, and the relative dearth of nonautomotive travel options, maintaining the roadway network in a state of good repair and in a way that makes it resilient to future storms is of great importance.

One important issue is the potential for sea level rise around the entire coastal area; this may increase flooding of roads near the coast. The island is served, as are many islands of similar size and topography, primarily by major perimeter roads. The mountainous interior presents challenges to road resilience in terms of landslides, steep terrain, and, in some places, environmentally sensitive lands. However, storm surge and sea level rise could make some of these perimeter roads vulnerable to flooding during both future storms and less extreme events (so-called nuisance flooding that occurs even in the absence of a major storm). It may be difficult to develop appropriate design solutions for specific major roads given the need to balance resilience to flooding and the need to protect sensitive lands.

The bridge network—over 2,300 bridges—is also an important component given that bridges can fail without warning and cause catastrophic damage. Bridges over water are vulnerable to scour, a type of damage caused by water that over time weakens bridge supports that are located in the waterway. Bridges in coastal areas are vulnerable to sea level rise and storm damage. Debris flows—caused by landslides, for example—can also damage bridges.

Another challenge is acquiring, maintaining, and using high-quality information about transportation assets in order to best manage their maintenance and repair in a cost-effective
manner. At the same time, resources are limited and tax revenues may fall in the near future, making management of transportation assets challenging. Information about ownership and condition is not always available in a systematic way or a consistent format. Setting up and using more sophisticated transportation asset management systems may require additional resources and new policies, plans, processes, and/or staff training. As of September 2018, the PRHTA was currently preparing a draft of a plan for asset management, and it has shared an internal draft with the HSOAC research team.¹

Congestion and safety are both major challenges. Congestion has typically been high in San Juan and some other cities, which may be due in part to recent development patterns that are not well served by transit and thus promote driving. While traffic safety has improved in recent years in terms of overall fatalities, driving in Puerto Rico remains more dangerous on a per-mile basis than anywhere else in the United States; crashes kill several hundred people per year.

A final challenge is the relative lack of options for people who do not drive, as discussed in the next section.

Surface Public Transportation

Public transportation systems on the island stopped operating in the days and weeks after Hurricane Maria made landfall. However, even during normal times the public transportation system is regarded as inadequate to meet demand. For example, the Tren Urbano suffers from high operating costs, low farebox recovery (the proportion of operating costs covered by passenger fares), declining ridership, and an unreliable power supply that could leave the system vulnerable to lengthy outages during future storms. The provision of bus and público service has also been declining, as has ridership. The bus system does not have many of the recent innovations of bus systems elsewhere in the country, such as real-time arrival information, that could boost ridership. The transit system may have already entered a downward spiral in which declining ridership leads to lower service, which in turn depresses ridership.

Puerto Ricans are generally dependent on driving for mobility needs, and some persons who do not drive have reported that they seldom leave their homes.² The island enjoys very few of the emerging mobility options that are enabled by widespread technology, such as bike sharing, that could ease the dependence on driving. Pedestrian and bicycle networks in many areas are often incomplete or nonexistent. A lack of options can contribute to congestion, as more residents have no choice except driving; to the social isolation of people who cannot easily access jobs, groceries, or other daily needs; and to air pollution if people drive instead of using less polluting modes. In

¹ PRHTA staff, interview with Liisa Ecola and Kenneth Kuhn, April 6, 2018c.
² PRHTA, 2018d.
addition, the island remains heavily reliant on fossil fuels, all of which are imported, for passenger and goods movement.

**Seaports**

Historical DHS resiliency assessments point out that the Port of San Juan functions as a major conduit for supplies to the island. At the time this report was written, there were no formal agreements or deliberate planning documents designating an alternate port, and there is insufficient information to determine the impact on the island’s economy, should the Port of San Juan be unavailable or experience severely decreased capacity.

Loss of the Port of San Juan’s capability to receive petroleum products and food supplies would have significant effects on the island’s energy supplies and ability to feed its population. As noted earlier, the port receives 84 percent of Puerto Rico’s fuel oil and 93 percent of its total food supply imports. Planning efforts do not fully address the effects of the loss of these shipments in the event of another major storm and subsequent port closure. Due to just-in-time inventory policy and limited emergency storage capacity, perishable food supplies would again be significantly impacted. Expanding on-island capacity and/or developing emergency reserve capacity within the region may alleviate this and should be considered in both future recovery and resiliency planning.

**Ferries**

One main challenge in the ferry system is the need to minimize disruption to service during hurricanes given that the populations of outlying islands were cut off from the rest of Puerto Rico for several days following the storms. Another challenge is to balance the needs of both residents and tourists with regard to how much ferry service is provided, and at what prices.

**Airports**

The priority with regard to airports will be to restore safe and efficient operations while improving resilience, repairing perimeter fences, reconstructing roofs, and ensuring that aviation facilities, including the radar system, have more reliable sources of power and access. Further investments in airports and aviation assets have been proposed and could drive future economic growth. However, such investments will be costly.

**Barriers and Facilitators to Response**

For all transportation modes, the prestorm financial challenges, discussed in Chapters 2, 3, and 4, continue to make response difficult. In addition, supplies on the ground are limited and must be brought in via ship; and many construction projects are competing for the same workers, materials, and equipment. While it is possible that a surge of funding (whether federal recovery
funds or private investment) may serve to facilitate a long-lasting recovery, barriers seem to outnumber facilitators.

**Roads and Bridges**

Barriers to response include difficult terrain (especially in the mountainous interior), which makes it more challenging to rebuild roads given the steep slopes. Such roads must be designed to be more resilient to landslides. A related barrier is the lack of alternative rights-of-way in some areas, meaning that many roads cannot be relocated to other areas where the terrain is less challenging. The lack of an existing asset management system means that standardized information on all roads and bridges that would be pertinent to rebuilding—construction type, past maintenance activities, age of asset—may not be available for all segments. Even six months after the storms, some roads continued to experience new stresses from rainfall or other incidents. Many road segments and bridges may have been past their useful life even before the storms, making it difficult to prioritize reconstruction activities when the needs are so widespread.

**Surface Public Transportation**

One barrier is an apparent lack of coordination among multiple private operators in the transit system: the Tren Urbano is operated by a consortium of two private firms, and a third firm operates some bus service. In addition, *público* operators are independent. This number of discrete entities may make coordination more difficult, introducing inefficiencies. And private taxi operators and ride hailing firms may pull riders away from transit, leading to a downward spiral of lower revenues and demand.

**Seaports**

As with public transportation, the sheer number of owners, operators, and other stakeholders may complicate recovery. Additionally, because Puerto Rico is an island, there is primary reliance on maritime shipping and supporting functions to maintain economic activity and government services, yet much of the port cargo-handling capacity information is unknown or not available for consideration in recovery planning efforts. Elements of the MTS include terminals and piers, many of which are privately owned and operated; this adds a level of complexity to any planning efforts to enhance response to port incidents. The *Area Maritime Security Plan* is missing some essential elements of information that detail the role of the USCG’s Marine Transportation System Recovery Unit and steps to facilitate port recovery or move operations to a secondary port, which makes the Port of San Juan facilities particularly vulnerable if critical operations are impacted and there is no viable plan to rapidly reconstitute delivery of life-sustaining commodities to neighboring ports.
Ferries

One immediate barrier to response is that, as of September 2018, inspections of ports and ferry terminals were still ongoing, meaning that not all damage assessments had been finalized. A possible facilitator is that ferry service to Culebra and Vieques was under consideration to be moved from its longtime location at Fajardo to the Roosevelt Roads redevelopment site in Ceiba. To the extent this is considered an important potential economic development project, this may raise its priority. At the time of this writing, the decision on the final ferry location had been made to relocate the terminal, and plans were moving ahead. At the time of this writing, a study was underway to consider whether the ferry service could be run by a private operator.4

Airports

One potential barrier at SJU is that its operator, Aerostar, is a private firm and thus may not be eligible to apply for assistance through FEMA. The facility owner, the PRPA, would probably need to formally request assistance.

The damage assessment for Rafael Hernández International Airport in Aguadilla cited earlier in this report included only a superficial look at the damage caused to the Lufthansa Technik facility on the airport grounds. The authors noted in their report that “access to [the] building was restricted, so only exterior evaluations [were] performed.” A similar issue prohibited evaluation of FedEx facilities on-site.5

Key Information Gaps

Complete information on the pre- and posthurricane statuses of the transportation infrastructure is not available. Many of the data sets we have obtained ended prior to the storms, so it is difficult to ascertain the storms’ impact overall with regard to specific indicators in this report.

Roads and Bridges

It would be useful to have better data on the condition of all roads given that the vast majority are owned by municipalities, but to the best of our knowledge, municipalities do not track this information, and at this time of this writing there were no island-wide asset

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3 FEMA, staff, email to Jeffrey Kendall, August 23, 2018c.
4 A copy of the draft study (Puerto Rico Public-Private Partnerships Authority, Desirability and Convenience Study for the Puerto Rico Maritime Transportation Services Project [working draft], February 2018), was provided to HSOAC in March 2018.
5 Gvelop, 2017b.
management systems. Besides current conditions, useful information would include the volume of traffic (some local roads are sampled for traffic volumes, but not regularly), the grade (to determine how many roads might in the future require designs suited to mountainous roads), and the destinations it serves (given that some local roads serve very few households and businesses). Finally, updated floodplain maps will provide valuable information about which road segments are vulnerable to increased flooding, whether due to storms or simply to nuisance flooding that occurs even in the absence of a large storm.

**Surface Public Transportation**

It is difficult to know whether the causes of the prestorm decline in transit ridership are due primarily to population loss, increases in unemployment, cutbacks in service (especially reduced bus service and less frequent público service), or other factors. Without information on travel demand preferences and transit options (which may have been covered in recent travel demand surveys, although we were unable to obtain these data), good planning for travel options for people who do not drive will be limited. It would also be helpful to understand why operating costs for the Tren Urbano are so high.

**Seaports**

The lack of a coherent baseline and prestorm port conditions of Puerto Rican seaports (regarding capacity and capability) make it difficult to identify the most advantageous measures needed for both recovery and resiliency. A baseline economic assessment of the health of the ports prestorm and a determination of the desired path forward for port recovery should set the parameters to inform fiscally feasible resiliency planning options. Current and future port capacity and capability is linked to the island’s overall demand on the MTS, which includes imports of petroleum products, food, and supplies, as well as tourism, recreational activity, and commodity exports. These maritime import and export, supply and demand, and commercial and recreational activities are key drivers of MTS capacity and capability needs, as well as future requirements. For example, any decrease in island population and tourism may indicate that capital investments within the MTS may not yield the needed return on investment, but developing additional temporary emergency capacity and capability in another port or ports may provide the needed resiliency in the aftermath of another storm.

While it would be helpful to have more specifically defined metrics of port capacity, the amount of cargo that can be moved efficiently through a port depends on a number of factors: the depth of the channels, the number of berths, the number and size of cranes, the amount of warehousing space, the capacity of the road network, the degree of automation, and the availability of a qualified labor pool, among others. We anticipate that one important element of the long-term recovery plan will be identifying the appropriate amount of port capability and capacity to serve the island in the future during both normal and emergency periods, as well as
ports’ roles as regional hub or transshipment locations. These requirements and roles will be influenced by all of the aforementioned elements.

**Ferries**

For ferry service, it would be useful to know the composition of travelers—that is, whether they are predominantly local residents or tourists—as this might influence recommendations about frequency and cost of service. During the course of writing this report, a decision was made to move the ferry service terminal for Culebra and Vieques from Fajardo to Roosevelt Roads, as well as to relocate the Vieques ferry terminal from its present location to Mosquito Pier.⁶

**Airports**

We were unable to obtain a complete damage assessment from SJU, the largest and busiest airport in Puerto Rico. The airport is privately operated, and FEMA staff confirmed that the operators did not provide a damage assessment to FEMA. The lack of a damage assessment from SJU and the superficial nature of the inspections of facilities run by private firms such as FedEx and Lufthansa Technik make it difficult to fully assess airport damage. We also do not have official information on the types of repairs and improvements planned at SJU.

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⁶ FEMA, 2018c.
6. The Strategy for Recovery in Puerto Rico’s Transportation Sector

This chapter builds on the damage assessments and assessments of recovery and economic development needs. It discusses how the HSOAC team developed COAs to address the needs identified, and how it shaped them into differing portfolios for decisionmakers. Ultimately, the plan contains 22 such transportation COAs; Appendix A provides detailed write-ups of each. The team focused its efforts on developing recommended activities that rebuild and strengthen surface, maritime, and air transportation to ensure a flexible and reliable transportation system that moves people and goods, ensures economic continuity, and facilitates disaster response. The COAs presented in Appendix A reflect a collection of potential activities, policies, and other actions that could contribute to recovery, along with estimates of the associated costs.

Rough order-of-magnitude cost estimates were established to support high-level planning and inform decisionmaking. More detailed cost estimates will require more specificity regarding implementation choices, as well as the completion of ongoing damage assessments. As more detailed policy choices are made in support of these COAs, more detailed cost-benefit analyses will help inform policymakers about various investments’ impacts on long-term fiscal sustainability. This will, in turn, support consideration of different levels of implementation for some COAs to constrain costs and maximize benefits. Costs are associated with correcting prehurricane deficiencies, as well as addressing hurricane damage.

The overarching goal for the transportation sector is to modernize road and transportation systems and establish a culture of preventative maintenance. The collection of 22 COAs can be categorized into four broad actions, to include:

1. upgrading ports and consolidating ownership to improve emergency response and attract new maritime business (TXN 10, TXN 12, TXN 13, TXN 14, TXN 15, TXN 22)
2. prioritizing repairs to roads and bridges, and extending three key highways (TXN 1, TXN 2, TXN 5, TXN 9, TXN 11, TXN 16, TXN 19, TXN 20, TXN 21)
3. developing new mobility options to supplement improvements to bus service (TXN 7, TXN 8, TXN 17, TXN 18)
4. upgrading SJU and Rafael Hernández International Airport to boost resilience and Porta del Sol tourism (TXN 3, TXN 4, TXN 6).

The Process for Developing Courses of Action

To address the damage and needs identified as part of the research, we developed a set of recovery actions—that is, COAs—to address the needs for recovery and economic development. While a COA can have different meanings in different contexts, our working definition is that a
COA is a policy or project that could be implemented to facilitate recovery or economic development.

An important component of these COAs is that they are at a reasonable level of specificity. A repair of a single municipally owned road is too granular to be an effective COA, since hundreds of such repairs are required. On the other hand, a goal of making the transportation system more resilient is too broad to be a meaningful COA, because it does not provide sufficient guidance to act on. COAs should guide decisionmaking at a policy level.

The team has developed a list of 22 COAs with ideas from internal discussions, background reading, and interviews and meetings. These interviews and meetings were held with a very wide group of stakeholders across 40 entities, including the San Juan–based FEMA-led Transportation Sector Solutions Team; the Recovery Support Function staff from USACE; modal administrations of DTOP, the PRPA, and the U.S. Department of Transportation (USDOT); and subject-matter experts from other organizations. A full list of entities with whom the team engaged is provided in Appendix B.

This process was iterative, and over the course of several months we developed draft lists, shared and discussed them with the Transportation Sector Solutions Team and the government of Puerto Rico’s Central Office of Recovery, Reconstruction, and Resiliency (COR3). In many cases we modified COAs in response to feedback, removed from the list COAs that were deemed unworkable for Puerto Rico, and added COAs proposed by COR3. The principles that guided our work were that, collectively, the COAs should

- be at a usable level of specificity
- have been demonstrated to be effective based on implementation in other contexts
- incorporate all needs for repairs to storm damage
- balance innovation with basic needs
- reflect best practices, as gleaned from examples in the continental United States and around the world
- address both recovery and economic development
- include both policies and specific projects
- collectively be a manageable number (between 20 and 30)
- represent all modes of transportation, as well as both passenger and goods movement
- address Puerto Rico’s specific needs, as identified in the first part of our research.

Table 6.1 provides some examples of how COAs address specific needs as identified in Chapters 2–5 of this report.

For each COA we decided to include in our draft list, the team collected information in a format developed within HSOAC to ensure that all the important information was captured. This format forms the basis of the write-up of each COA, as found in Appendix A. Items include the issue that the COA addresses, a description of the COA and how it might be implemented, potential benefits and positive spillover impacts, potential costs and funding mechanisms, potential pitfalls, and whether other COAs would be necessary precursors.
Table 6.1. Examples of Links Between Critical Transportation Needs and Courses of Action

<table>
<thead>
<tr>
<th>Transportation Needs</th>
<th>Courses of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of maintenance; infrastructure in poor condition</td>
<td>Support infrastructure asset management and harden</td>
</tr>
<tr>
<td>before the storms</td>
<td>vulnerable transportation infrastructure</td>
</tr>
<tr>
<td>Many port assets remain in substandard condition</td>
<td>Increase port facility resilience</td>
</tr>
<tr>
<td>Myriad port owners, leading to inefficiencies in</td>
<td>Consolidate port ownership</td>
</tr>
<tr>
<td>operations</td>
<td></td>
</tr>
<tr>
<td>Heavy reliance on Port of San Juan</td>
<td>Develop redundant seaport capacity</td>
</tr>
<tr>
<td>Bus service declining in ridership and frequency</td>
<td>Improve bus service</td>
</tr>
<tr>
<td>Dearth of options for nondrivers</td>
<td>Incentivize a variety of mobility options</td>
</tr>
</tbody>
</table>

Decisionmaking for Courses of Action and Portfolios

The COAs represent a bottom-up approach to addressing specific challenges. We also engaged in a strategic top-down approach to ensure that the transportation sector recovery approach was aligned with the vision of the then-governor of Puerto Rico. Once specific COAs were identified, the team then developed multiple portfolios of COAs, each of which represented different approaches to recovery. While our focus was transportation, portfolios could also include COAs from other sectors that would support transportation needs (e.g., a COA from the Natural and Cultural Resources [NCR] Sector team to reduce flooding might be helpful in minimizing the damage that could occur to roads due to standing water following a storm). The goal of developing portfolios was to provide examples to senior officials in the government of Puerto Rico of ways that they could combine COAs to achieve specific goals. For each portfolio, we also developed a cost to implement that portfolio. Individual COAs could be implemented at various levels (i.e., a COA with a range of implementation options could be implemented at 25, 50, or 100 percent of the estimated costs).

In alignment with the vision for the future of Puerto Rico, our COAs address roadway and port restoration efforts that could promote sustainable economic growth and contribute to a more vibrant and competitive economy that can provide opportunities for job growth within the transportation sector; contribute to enhancing Puerto Rico’s ability to withstand and recover from future disasters through redundant systems, improved codes, and standards; and strengthen Puerto Rico’s critical port and roadway infrastructure and transportation network through reconstruction that will be more modern, sustainable, and resilient for infrastructure than was the case before the hurricanes.¹

¹ COR3, 2018.
We presented five draft transportation portfolios to senior officials in DTOP and PRPA over the course of three meetings in San Juan between June 1 and June 8, 2018. Following these discussions, we dropped some portfolios and revised others. Ultimately, we developed three portfolios for a final round of decisionmaking with the governor’s authorized representative (the head of COR3) on June 15. The focus of each portfolio and the differences between them are illustrated in Figure 6.1. The portfolios are not mutually exclusive; some COAs were included in all portfolios, albeit in some cases at different levels of implementation depending on the focus of the COA. The final selection was Portfolio 3: Support Tourism, Industry, and Goods Movement.

The selected approach to recovery is the most future-focused and expansive of the three portfolios. It includes investments in transportation that will help the economy as a whole, with the end goal being to enhance Puerto Rico’s economic recovery and financial situation. The COR3 vision for transportation reads, “Transform maritime, surface, and air transportation into flexible and reliable systems that move people and goods to ensure economic continuity and facilitate disaster response.” Themes that support this goal include the following:

- **Upgrading ports and consolidating ownership to improve emergency response and attract new maritime business.** Ports authorities, in collaboration with private operators, will repair damage to ports and ferry terminals so they are at their full prehurricane capacity (TXN 12) and make upgrades that enhance their resilience to storms and sea level rise (TXN 22). To ensure that backup capacity exists if the Port of San Juan is damaged, the PRPA and other port operators will further develop an existing seaport (e.g., Ponce) to provide redundant capacity through the use of P3s (TXN 10). Reevaluating the Marine Transportation System Recovery Plan will help the ports take advantage of lessons learned during hurricane response, such as pre-positioning reserve capacities and assets to better respond to an emergency, establishing an integrated operations center, developing a communications protocol for first responders during a disaster, and implementing prehurricane protection measures in an integrated fashion to protect critical resources (TXN 13). To better manage the MTS as a whole and to make ports more attractive to maritime businesses and investors, input from industry experts indicates the need for consolidating ownership and oversight of the nine main ports (TXN 15). In addition to being a multipurpose port, the Port of Ponce will be a future regional transshipment hub for cargo traveling between North and South America, with shipping agencies incentivized to use it through reduced taxes or a government subsidy (TXN 14).

- **Prioritizing repairs to roads and bridges and extending three key highways.** The PRHTA will repair damaged roads and bridges and restore them to prehurricane functionality to ensure the mobility of people, goods, and service providers. Within four years, this initiative will replace missing road signs and inoperable traffic signals and repair or replace collapsed or weakened bridges (TXN 16). The PRHTA will harden, reengineer, or relocate infrastructure in high-risk areas to make it more resilient in future disasters, with a focus on the most cost-effective projects (TXN 2). Under a new “fix it first” approach, the PRHTA will prioritize road maintenance and repair projects over new or expanded infrastructure. This approach will improve roadway conditions and make safety or operational improvements, and it will prioritize projects based on their cost-
effectiveness (TXN 5). Projects to extend PR-5 and PR-22, and to complete PR-10, potentially through the use of P3s, are included as surface transportation projects to improve mobility, safety, access, resilience, and emergency response and to complete Puerto Rico’s strategic highway network (TXN 19, TXN 20, TXN 21). To better manage transportation infrastructure, public agencies will develop infrastructure asset management programs to inventory their assets and track their condition to improve maintenance, repair, and rehabilitation (TXN 11). In support of this effort, the PRHTA has submitted an initial asset management plan to the FHWA that focuses on improved infrastructure conditions and cost-effective asset management.² Related to this effort, the PRHTA will review its standards on road and bridge design. This will involve updates to include more innovative standards on roadway marking, lighting, drainage, and signs and signals (including the use of solar power) and better enforcement of both new and existing standards (TXN 1). In addition, the PRHTA will develop an intelligent transportation system so that transportation operations across Puerto Rico can provide real-time traveler information, divert traffic away from crashes, clear crashes more quickly, and reduce the possibility of secondary crashes after an initial incident (TXN 9).

- **Developing new mobility options to supplement improvements to bus service.** The AMA will make bus service more reliable through transit signal priority (which gives buses additional time to cross a signalized intersection) and dedicated bus lanes, as well as bus stops that provide real-time arrival information and use smart card fare media (TXN 8). Developing additional options—such as ride hailing, ride sharing, expanded público service, intercity bus service, bike or scooter sharing, and peer-to-peer car sharing—will address the dearth of other mobility services, particularly outside of San Juan (TXN 7). In addition, the PRHTA proposes two new high-capacity transit services, likely bus rapid transit (BRT), to give travelers another way to reach SJU (TXN 17), which is currently served by just three bus routes, and to give the 130,000 residents of Caguas a public transit option to reach nearby San Juan (TXN 18).

- **Upgrading the San Juan and Aguadilla airports to boost resilience and Porta del Sol tourism.** To ensure that SJU can operate at full capacity during both normal operations and in an emergency, the PRPA and airport operator Aerostar will repair remaining damage to the facilities (TXN 4), update Airport Emergency Plans to take advantage of lessons learned from the hurricanes, and further develop a coordinated disaster recovery strategy for the various airports across Puerto Rico (TXN 6). In addition, the PRPA proposes to expand and upgrade Rafael Hernández International Airport in Aguadilla, including upgrading the runway, taxiways, and terminals. These actions would increase Puerto Rico’s overall capacity for air traffic and boost tourism in Porta del Sol, a region with beautiful beaches that are currently difficult to reach (TXN 3).

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² PRHTA, “PRHTA Initial Asset Management Plan,” San Juan, P.R.: Puerto Rico Highway and Transportation Authority, draft version provided to HSOAC, April 2018b.
Portfolio 1: Focus on Future Maintenance

After making needed repairs, Puerto Rico develops strategies to emphasize continued maintenance and cost-effective management practices

17 COAs including:
- Develop islandwide ITS infrastructure asset management
- Encourage joint trenching (communications COA)
- Improve road design standards and enforcement

Total Costs: $2.8 billion

Portfolio 2: Focus on Resilience

Focuses on investments in existing infrastructure rather than new capacity. The primary benefit is upgrading vulnerable assets to be more storm resilient.

24 COAs including:
- Harden vulnerable transportation infrastructure
- Backup power system for Tren Urbano
- Reduce urban nuisance flooding (water COA)
- Reduce landslide risk (NCR COA)

Total Costs: $8.2 billion

Portfolio 3: Support Tourism, Industry, and Goods Movement

New projects to improve goods movement and commuting. The goal is to spur domestic production and consumption, as well as support tourism.

38 COAs including:
- 3 road extension projects
- 2 transit projects
- Improve bus service
- Innovative mobility options
- Redundant port capacity
- Redevelop Aguadilla airport

Total Costs: $8.9 billion
Transportation Courses of Action

This section presents brief versions of all COAs. Table 6.2 shows the breakdown of all 22 COAs by transportation mode and type of COA. The selected portfolio includes COAs that address repairs and maintenance, upgrades to resilience or service provisions, new capacity in terms of additional major projects, and COAs around policy, planning, and management. Six COAs address upgrades to ports and consolidated ownership to improve emergency response and attract new maritime business (TXN 10, TXN 12, TXN 13, TXN 14, TXN 15, TXN 22); nine COAs prioritize repairs to roads and bridges, and extend three key highways (TXN 1, TXN 2, TXN 5, TXN 9, TXN 11, TXN 16, TXN 19, TXN 20, TXN 21); four COAs develop new mobility options to supplement improvements to bus service (TXN 7, TXN 8, TXN 17, TXN 18); and three COAs upgrade the San Juan and Aguadilla airports to boost resilience and Porta del Sol tourism (TXN 3, TXN 4, TXN 6).

Table 6.2. Final Transportation Courses of Action by Mode and Type

<table>
<thead>
<tr>
<th>Mode</th>
<th>Repairs and Maintenance</th>
<th>Upgrades</th>
<th>New Capacity</th>
<th>Policy, Planning, and Management</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads/bridges</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Surface public</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ports and ferries</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Airports</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>22</td>
</tr>
</tbody>
</table>

Brief descriptions of the individual COAs are provided below.

The Courses of Action

TXN 1: Refine and Enforce Design Standards for Roads and Bridges

Collect and refine guidance on road design (e.g., “complete streets” policies that address the needs of all road users, including pedestrians and bicyclists), develop a set of engineering standards that promote innovative and resilient features, and ensure that roads meet these standards.

Potential benefits: Improves road safety through better roadway markings, signs, and lighting; reduces maintenance costs, increases roadway life, and prevents damage from future disasters through improved roadway drainage systems and bridge design; encourages people to walk and bicycle instead of driving by promoting sidewalks and bicycle lanes, which provides public health benefits and reduces traffic congestion.
TXN 2: Harden Vulnerable Transportation Infrastructure

Analyze transportation infrastructure vulnerability to natural hazards, beginning with floodplain mapping and landslide risk analysis, and then undertake cost-effective engineering projects to mitigate risk, including road relocation; traffic rerouting; and bridge, pavement, and culvert reconstruction.

_Potential benefits:_ Reduces the likelihood of infrastructure failure due to either age or natural causes.

TXN 3: Redevelop Rafael Hernández Airport

Improve infrastructure at Rafael Hernández International Airport in Aguadilla. Specifically, upgrade the runway, taxiways, apron area, and terminals.

_Potential benefits:_ Preserves airport capacity, improves service to airport passengers, and boosts local economic activity by attracting more visitors.

TXN 4: Repair Airport Damage

Make repairs to other airport facilities that were damaged during Hurricanes Irma and Maria, including runways, roofs, fences, commercial backup power, fuel-operated generators and electrical systems, heating and cooling, and fire suppression.

_Potential benefits:_ Ensures that airports can operate at full capacity and receive relief and recovery supplies, improves airport safety, and boosts local economic activity.

TXN 5: Road Maintenance and Repair Program

Adopt a “fix it first” policy: Give priority to cost-effective road maintenance and repair projects over new construction or expanding existing roadways. Select projects on the advice of traffic engineers to improve the condition, safety, and operation of roadways.

_Potential benefits:_ Reduces vehicle operating costs, travel times, crash rates, severity of crashes, pollutant emissions, and future road maintenance costs while increasing resilience.

TXN 6: Update Airport Emergency Plans

Update the _Airport Emergency Plans_ at three major airports and disaster preparedness plans at general aviation airports to identify reserve capacity, test and evaluate for continuity of operations, ensure the readiness and pre-positioning of items needed for response efforts before an emergency, develop a communications protocol for first responders, and integrate disaster protection measures to ensure the safety of the airport staff, passengers, and the community in which the airport is located.

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3 In the _Recovery Plan_, this COA was titled “Update the All-Airport Emergency Plan.” See footnote in Appendix A, TXN 6, for an explanation.
Potential benefits: Supports quicker recovery in the event of a future disaster; and promotes the health, safety, and security of communities near airports.

TXN 7: Incentivize a Variety of Mobility Options

Provide additional travel options for people who do not drive or prefer to use other modes of transportation. Examples include ride hailing, ride sharing, expanded público service, intercity bus service, bike or scooter sharing, and peer-to-peer car sharing.

Potential benefits: Increases mobility and quality of life for people who do not drive, reduces traffic congestion, reduces costs for people who give up driving, and promotes public health and decreases air pollution through the use of nonmotorized transportation.

TXN 8: Improve Bus Service

Improve existing bus service by giving priority to buses at intersections, providing real-time arrival information, upgrading bus stops, updating the payment system to use smart cards, adding dedicated bus lanes to some roads, and expanding the bus fleet.

Potential benefits: Increases the reliability and comfort of bus travel and expands transportation options for people who do not drive.

TXN 9: Develop an Intelligent Transportation System

Support transportation agencies in providing real-time travel information to highway users, optimize traffic signals on key roadways, and develop a plan to ensure that crashes and roadway obstructions are cleared from travel lanes as quickly as possible.

Potential benefits: Diverts traffic away from incidents, decreases incident response time, reduces probability of crashes after an initial incident, and provides data to inform transportation planning decisions.

TXN 10: Develop Redundant Seaport Capacity

Expand an existing seaport (possibly Ceiba, Mayagüez, or Ponce) to mitigate the effects of major disruptions to the Port of San Juan that could prevent goods from being delivered in a timely manner.

Potential benefits: Helps ensure that residents receive food and fuel in case of an emergency that disrupts operations at Port of San Juan.

TXN 11: Support Infrastructure Asset Management

Help public agencies inventory their transportation infrastructure, including roads, bridges, culverts, and signs. Improve systems for tracking the condition of that infrastructure and for scheduling maintenance, repair, and rehabilitation.

Potential benefits: Reduces infrastructure maintenance costs, vehicle operating costs, travel times, pollutant emissions, and the rate and severity of vehicle crashes. Ensures compliance with Transportation Performance Management regulations issued by USDOT.
TXN 12: Repair Damage to Ports and Ferry Terminals

Repair damage to ports, ferry terminals, and vessels that limits their use or poses long-term safety or operational concerns. Repairs would take environmental impacts into account.

*Potential benefits:* Ensures that ports can operate at full capacity and provides some redundancy in the event of a disaster that disrupts operations at a major port.

TXN 13: Reassess the Marine Transportation System Recovery Plan

Reassess the *Marine Transportation System Recovery Plan* to ensure preparation for future disasters, including coordination among various partners and measures to protect critical resources. Establish an integrated operations center and a communications protocol for first responders during a disaster.

*Potential benefits:* Uses lessons learned from Hurricanes Irma and Maria to ensure that disaster response plans are in place at ports and that ports can recover quickly.

TXN 14: Long-Term Planning to Develop Port of Ponce as a Regional Transshipment Hub

Begin long-term strategic planning for the Port of Ponce to serve as a transshipment hub. Provide economic incentives (through reduced taxes or government subsidies) for shipping agencies to use Ponce as an intermediate destination for goods heading to North and South America, Europe, and (potentially) other foreign locations.

*Potential benefits:* Encourages economic growth of Puerto Rico’s MTS and makes the island’s ports more attractive to investors and shipping companies.

TXN 15: Consolidate Port Ownership

Consolidate ownership and oversight of Puerto Rico’s nine main ports to better manage maritime transportation.

*Potential benefits:* Increases the efficiency and profitability of Puerto Rico’s ports, improves coordination among port owners, increases port response and recovery operations, and makes Puerto Rico’s ports more attractive to investors and shipping companies.

TXN 16: Repair Damage to Surface Transportation Network

Repair roads that remain damaged, and replace bridges that failed or were severely damaged during the hurricanes. Repair transit systems to meet codes.

*Potential benefits:* Restores Puerto Rico’s surface transportation network to its prehurricane state and ensures efficient transportation of people, goods, and services.

TXN 17: Provide High-Capacity Transit Service to San Juan Airport

Establish high-capacity BRT service to SJU.

*Potential benefits:* Provides an alternative means of transportation to Puerto Rico’s busiest airport and reduces pollutant emissions and traffic congestion.
TXN 18: Provide High-Capacity Transit Service Between San Juan and Caguas

Establish high-capacity BRT service between San Juan and Caguas, probably along the route of PR-52.

_Potential benefits:_ Provides an alternative means of transportation between San Juan and Caguas and reduces pollutant emissions and traffic congestion.

TXN 19: Extend PR-5

Extend privately operated PR-5 in Bayamón between PR-167 and PR-199, and ensure that environmental risks are mitigated and a resilient design is used.

_Potential benefits:_ Provides upgraded connections between the San Juan metropolitan area and mountain municipalities.

TXN 20: Extend PR-22

Extend privately operated PR-22 for roughly 25 mi to the area currently served by PR-2, and ensure that environmental risks are mitigated and a resilient design is used.

_Potential benefits:_ Improves connections between San Juan and western Puerto Rico and serves Rafael Hernández International Airport in Aguadilla.

TXN 21: Complete PR-10

Fill gaps in Puerto Rico’s highway network by completing work on PR-10, one of the few north-south routes, and ensure that environmental risks are mitigated and a resilient design is used.

_Potential benefits:_ Improves mobility between Puerto Rico’s interior and the north and south coasts, spurs local economic activity, and improves infrastructure resilience and road safety.

TXN 22: Increase Port Facility Resilience

Improve and rehabilitate hurricane-damaged and deteriorated piers and associated buildings at ports to increase their resilience to disasters, storm surge, damaging winds, and sea level rise. Upgrades would take environmental impacts into account.

_Potential benefits:_ Helps ensure continuity of operations at ports and increases the structural integrity and reliability of port infrastructure, preventing potential premature or catastrophic failure.

Cost Estimates

Table 6.3 provides three cost categories for each COA: the potential up-front cost, the potential recurring cost, and the potential total costs. The HSOAC team drew on several sources for the cost estimates: estimates previously developed by the government of Puerto Rico (e.g., DTOP estimates for road extensions), estimates of damage repair and resilience enhancements provided by contractors who assessed the infrastructure, and estimates based on previous
experience in other locations. Costs in the “Potential Up-Front Costs” column were estimated to occur over some number of years, based on the team’s judgment of how long the initial investment would take to complete. Annual costs were then assumed to be incurred in the following years, up through a time period of 11 years, or 2018 through 2028; this is the “Potential Recurring Costs” column. The “Potential Total Costs” column sums these two columns, which provides a range; these ranges are included in the Recovery Plan. All cost estimates are at a rough order of magnitude; these should be considered very high-level estimates.

The ranges are in some cases quite large because various COAs could be implemented in a number of ways. For example, TXN 7 discusses six potential mobility options, each with its own costs. The low estimate assumes that one low-cost option would be implemented in one city, while the high estimate assumes all six options would be implemented in four cities.

Details on the sources of these estimated costs are provided in Appendix A. The write-ups also include brief notations regarding potential funding sources and implementing agencies. However, given that this is a long-term recovery plan and not an implementation plan, this information should be considered preliminary.

Given the nature of these estimates as being at a very high level, most costs are provided to only one or two significant digits. This explains why for several COAs the up-front and recurring costs sum to a slightly different amount than shown in the potential total costs column (TXN 16 and TXN 21).

One COA, TXN 15, is shown at zero cost. This reflects a decision by our team not to include costs unless they represent spending on infrastructure, personnel, or other tangible costs. While this COA would likely incur some type of “cost,” we determined that it would be very difficult to assign a dollar value to it. The same is true of several COA costs in other sectors as well.

For several COAs, recurring costs are listed as $0. This is because the up-front cost is estimated to take the full 11 years’ time frame, so no recurring costs would be incurred during this period.

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4 See the Recovery Plan for an explanation of the selection of an 11-year time frame.
<table>
<thead>
<tr>
<th>COA Number</th>
<th>COA Name</th>
<th>Potential Up-Front Costs</th>
<th>Potential Recurring Costs</th>
<th>Potential Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXN 1</td>
<td>Refine and Enforce Design Standards for Roads and Bridges</td>
<td>$2 million--$100 million</td>
<td>$3 million--$4 million</td>
<td>$6 million--$100 million</td>
</tr>
<tr>
<td>TXN 2</td>
<td>Harden Vulnerable Transportation Infrastructure</td>
<td>$1.3 million--$380 million</td>
<td>$0</td>
<td>$1.3 million--$380 million</td>
</tr>
<tr>
<td>TXN 3</td>
<td>Redevelop Rafael Hernández Airport</td>
<td>$400 million--$500 million</td>
<td>$0</td>
<td>$400 million--$500 million</td>
</tr>
<tr>
<td>TXN 4</td>
<td>Repair Airport Damage</td>
<td>$250 million--$12 million</td>
<td>$270 million</td>
<td></td>
</tr>
<tr>
<td>TXN 5</td>
<td>Road Maintenance and Repair Program</td>
<td>$100 million--$900 million</td>
<td>$1.0 billion--$6.4 billion</td>
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</tr>
<tr>
<td>TXN 6</td>
<td>Update Airport Emergency Plans</td>
<td>$4 million--$1 million</td>
<td>$5 million</td>
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<tr>
<td>TXN 7</td>
<td>Incentivize a Variety of Mobility Options</td>
<td>$450,000--$17 million</td>
<td>$4.9 million--$190 million</td>
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<tr>
<td>TXN 8</td>
<td>Improve Bus Service</td>
<td>$200,000--$79 million</td>
<td>$8 million--$730 million</td>
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<tr>
<td>TXN 9</td>
<td>Develop an Intelligent Transportation System</td>
<td>$30 million--$48 million</td>
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<td>TXN 10</td>
<td>Develop Redundant Seaport Capacity</td>
<td>$87 million--$160 million</td>
<td>$14 million--$180 million</td>
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</tr>
<tr>
<td>TXN 11</td>
<td>Support Infrastructure Asset Management</td>
<td>$5 million--$1 million</td>
<td>$6 million</td>
<td></td>
</tr>
<tr>
<td>TXN 12</td>
<td>Repair Damage to Ports and Ferry Terminals</td>
<td>$940 million--$46 million</td>
<td>$990 million</td>
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<td>TXN 13</td>
<td>Reassess the Marine Transportation System Recovery Plan</td>
<td>$100,000--$300,000</td>
<td>$300,000--$500,000</td>
<td></td>
</tr>
<tr>
<td>TXN 14</td>
<td>Long-Term Planning to Develop Port of Ponce as a Regional Transshipment Hub</td>
<td>$50 million--$300 million</td>
<td>$100 million--$500 million</td>
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<tr>
<td>TXN 15</td>
<td>Consolidate Port Ownership</td>
<td>$0</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>TXN 16</td>
<td>Repair Damage to Surface Transportation Network</td>
<td>$800 million--$16 million</td>
<td>$820 million</td>
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<tr>
<td>TXN 17</td>
<td>Provide High-Capacity Transit Service to San Juan Airport</td>
<td>$400 million--$170 million</td>
<td>$570 million</td>
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<td>TXN 18</td>
<td>Provide High-Capacity Transit Service Between San Juan and Caguas</td>
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<td>$370 million</td>
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<tr>
<td>TXN 19</td>
<td>Extend PR-5</td>
<td>$220 million--$1 billion</td>
<td>$220 million</td>
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<tr>
<td>TXN 20</td>
<td>Extend PR-22</td>
<td>$1 billion--$0</td>
<td>$1 billion</td>
<td></td>
</tr>
<tr>
<td>TXN 21</td>
<td>Complete PR-10</td>
<td>$370 million--$510,000</td>
<td>$370 million</td>
<td></td>
</tr>
<tr>
<td>TXN 22</td>
<td>Increase Port Facility Resilience</td>
<td>$360 million--$540 million</td>
<td>$360 million--$540 million</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$3.9 billion--$13.3 billion</td>
<td>$1.1 billion--$16 billion</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:** Some figures are rounded to the nearest $10 million. Figures in this table match the estimates provided in the *Recovery Plan*, but in the course of writing this sector-specific report some estimates have changed. The total for TXN 4 differs from the detailed estimate in Table 4.4 (summarized in Tables S.1 and 1.2) because the team changed its estimate of the total cost to repair airport damage after the *Recovery Plan* was submitted; see the explanation in Chapter 4, in the Hurricane Damage section, Facility Damage subsection. The estimate for TXN 12 changed based on more recently updated information, but by a much smaller amount. TXN 7 and TXN 8 differ due to errors.
7. Conclusions and Policy Implications

Transformation and Innovation in the Wake of Devastation: An Economic and Disaster Recovery Plan for Puerto Rico was presented to the U.S. Congress on August 8, 2018. This is only one of many milestones on the long road to recovery and greater resilience to future storms or other disasters. While this report focused exclusively on damage and needs in transportation, all infrastructure sectors were heavily damaged by Hurricanes Irma and Maria, as were other elements such as the education, health and social services, housing, and public building sectors.

Based on the HSOAC team’s research into published and unpublished sources, information gleaned from our meetings, interviews, on-the-ground experience in FEMA’s Joint Recovery Office, and professional judgment, we offer the following closing thoughts on transportation and recovery.

Transportation infrastructure is more critical for Puerto Rico than in most parts of the United States. While every location where people live requires transportation, islands are unusually dependent on maritime and air transportation. Crossing land borders to neighboring states is not an option, creating an overwhelming dependence on the seaborne supply chain and MTS for the majority of life-sustaining commodities. As a small island, Puerto Rico also produces relatively little of some of its most important needs: food and fuel. Even with the goals set out in the Recovery Plan to produce more locally, achieving full self-sufficiency in food and fuel is probably impossible. Therefore, investments in maintenance of the maritime and air infrastructure are crucial to both economic health and disaster preparedness.

For many important decisions, all options present challenges. The mountainous topography, threat of sea level rise, and increasing storm surge risks mean that decisions about where to build or relocate key pieces of transportation infrastructure will require difficult trade-offs. Moving perimeter roads to avoid frequent nuisance flooding may mean building in other environmentally sensitive areas. All airports are currently on the perimeter of the island. Decisions may need to be made about which ports and airports to retain if the challenge of sea level rise makes it impossible to keep all of them functioning. These decisions will produce winners and losers, and will be politically challenging.

Like all of the building environment and infrastructure, transportation infrastructure needs to be commensurate with population. Given the recent outmigration following the hurricanes, on top of a long-term trend, it may be necessary to plan for a future with a lower population. A gradually declining population is not unique to Puerto Rico; a number of high-income countries face similar challenges. Population decline may require hard decisions about where to invest. On the other hand, if population increases in the future, that requires a different set of decisions about planning transportation investments in conjunction with land use and where to build.
Maintenance should be a top priority. One of the reasons why damage was so widespread and severe after the hurricanes was the lack of previous maintenance, as well as preexisting poor conditions. In many cases, keeping infrastructure in a state of good repair would have prevented some of the severity of the damage. The effects would probably still have been very serious, but not to the extent they were. Many state departments of transportation (DOTs) are moving toward more systematic asset management, which could likely save money in the long term by deploying preventive maintenance at recommended intervals.

Transportation in Puerto Rico is an essential component of both recovery and economic development. The COAs provided in this report should help this aspect of the island’s recovery and continued growth.
Appendix A. Courses of Action

This appendix presents the full descriptions of all 22 COAs.

With regard to cost calculations: Recurring costs represent ongoing, annual costs for activities, such as operations and maintenance, meant to sustain initial investments. Some initial investments may take several years to complete. If recurring costs that are incurred when the initial investment is complete are $R$ per year, and if it takes $N$ years to complete the investment, we estimate that $1/N \times R$ is incurred in the first year, $2/N \times R$ is incurred in the second year (and so forth), and $R$ is incurred in each year after the up-front cost has been fully incurred through the end of the time period, or 11 years. That is, the investment cost is spread equally over the years, and the recurring costs grow with the cumulative investment. There may be alternate patterns for both investment and operations and maintenance cost streams; we use this estimate for consistency across courses of action.
Refine and Enforce Design Standards for Roads and Bridges

**Issue/Problem Being Solved**

Existing design standards may not be adequate to address Puerto Rico’s specific needs, and roads do not always meet standards.

**Description**

This COA will collect available guidance and research on road design, refining the set of engineering standards for roads and bridges currently used in Puerto Rico, and ensuring that roads meet the new standards. The standards will cover geometric design, intersection design, signage, roadway marking and lighting, drainage, and signals. The standards will cover innovative treatments such as the use of solar-powered signs and signals. Ensuring that roads meet the standards will require enforcement efforts—including the enforcement of appropriate truck weight limits—and the application of numerous engineering treatments.

The FHWA and PRHTA have established roadway design and construction standards.¹ The standards currently used in Puerto Rico comply with guidance offered by the American Association of State Highway and Transportation Officials, the American Society for Testing and Materials, and the FHWA’s *Manual on Uniform Traffic Control Devices*.² This, however, is an opportunity for Puerto Rico to undertake an effort that will lead to new and refined standards for road design. These standards could be applied elsewhere in the future.

Certain revisions of codes and standards could address known recurrent causes of damage to roads and bridges, such as high wind pressure loads, with the objective of rebuilding more resilient transport infrastructure. Many bridges in Puerto Rico have been repeatedly damaged by flooding and sedimentation, and design standards could move away from box culverts into bridge designs with a higher clearance to reduce these recurring problems. Other revisions could be undertaken to improve safety based on analysis of crash data from the government of Puerto Rico. Particular attention will be paid to innovative treatments that could improve the serviceability offered by roads—particularly after natural disasters or extreme weather events, when electric power may not be available.

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Standards could also address “complete streets” policies, which create streets that encourage use by all modes (that is, pedestrians and bicyclists are considered just as important as drivers). According to a recent survey of municipalities in Puerto Rico, 40% said they had few or no sidewalks, and all said they had few or no bike lanes.\(^3\)

With regard to enforcement, stronger efforts could be made to enforce truck weight limits on specific roads, depending on their design capacity. Trucks, especially heavy trucks with high axle weights, damage roads far more than do passenger vehicles. According to the Fourth Power Law, the damage caused to pavement is roughly proportional to the weight of a vehicle raised to the power of 4.\(^4\)

### Potential Benefits

Increased use of roadway marking, signage, and lighting will improve safety. Improved roadway drainage systems will lead to reductions in maintenance cost, longer roadway life, and reductions in the possibility of major damage during future hurricanes. Better bridge standards should reduce risks from flooding and sedimentation. Better sidewalks and bicycle infrastructure should encourage more people to walk and bicycle, thus reducing congestion.

The links between roadway marking, signage, and lighting and traffic safety are well established. One meta-analysis found that for urban roads, “a reduction in accidents involving injuries of approximately 30% can be expected at night following an improvement in the lighting from very bad to good.”\(^5\) Stricter standards and the use of additional techniques and tools can yield more impressive benefits. For example, meta-analysis shows that the installation of speed bumps and speed tables reduces collision rates on a road section by roughly 14% and 47%, respectively.\(^6\)

As the brief description above notes, this COA will also involve developing standards for the use of solar-powered signs and signals. In the aftermath of the recent hurricanes, many traffic lights and signals in Puerto Rico were nonoperational. This led to large traffic delays and unsafe

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driving conditions, particularly at night. Increased use of solar-powered signs and signals would increase resilience.

**Potential Spillover Impacts to Other Sectors**

This COA would provide near-term employment opportunities on engineering and construction projects. It would also lead to better health for people who can use active transportation (walking and bicycling).

**Potential Costs**

Potential up-front costs: $2 million–$100 million in estimated up-front costs (3 years). Potential recurring costs: $3 million–$4 million in estimated recurring costs (11 years). Potential total costs: $6 million–$100 million in total estimated costs.

The up-front cost estimate ranges from $2 million to $100 million, depending on the number of small-scale projects that are undertaken. These could include adding street lighting and lane markings to ensure that existing roads meet these new standards.

This project includes at least 2 distinct components. The first of these will involve developing new standards for road design. This is a onetime research task for a relatively small group of traffic engineers. The Transportation Research Board spent just over $500,000 on a research project that produced guidance on the process for the geometric design of low-volume roads. The scope of the standards development effort in this COA is larger in the sense that all types of roads and issues other than geometric design will be considered. The task will likely involve more review of existing practice and less research than the Transportation Research Board effort. The task will likely cost on the order of $2 million, which is the low-end estimate.

The second component will involve enforcing the new standards: ensuring that newly constructed roads meet the standards and implementing a portfolio of relatively small projects to bring existing roads up to code. The cost of this task will depend on the standards developed and on the scale of the portfolio of projects undertaken. As a point of reference, consider “complete streets” projects. The complete streets movement aims to change how roads are designed and, in particular, to ensure that roads serve pedestrians, bicyclists, and transit riders better than they do now. Complete streets projects involve redesigning intersections or road sections. Literature from Smart Growth America reveals that such projects generally cost between $1 million and

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$10 million and are highly site specific.\(^9\) Somewhat similar efforts involving many projects, such as the New York City DOT’s effort to redesign and reconstruct several streets, allocate hundreds of millions of dollars to projects to improve local roads.\(^10\) Here we assume a relatively limited scope of dozens of projects that, for example, add street lighting and lane markings, for an upper-end cost of $100 million.

There would also be ongoing costs, most notably to cover the time taken up by a small group of trained engineers to periodically evaluate roads and to enforce new road design standards. Here we assume an office of 3 such engineers at a cost of roughly $375,000 per year. This cost estimate is based on our project standard that a local engineer costs approximately $125,000 yearly in salary and overhead costs. The estimate of $3 million–$4 million depends on how quickly the office is established.

**Potential Funding Mechanisms**

USDOT, other grants.

Specific programs that are potential funding mechanisms include the NHWA’s Highway Safety Improvement Program (HSIP), National Highway Performance Program (NHPP), and Surface Transportation Block Grant Program (STBGP), as well as local Traffic Safety Commission funds.\(^11\) The Road to Zero Coalition also provides competitive grant funding to traffic safety projects.\(^12\)

**Implementation**

PRHTA.

**Potential Pitfalls**

This COA requires a trained and motivated workforce. Staff turnover could be an issue. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

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\(^11\) FHWA, “Highway Safety Improvement Program (HSIP),” webpage, revised April 14, 2017a; FHWA, “National Highway Performance Program (NHPP),” webpage, revised September 21, 2017b; FHWA, “Surface Transportation Block Grant Program (STBG),” webpage, revised September 21, 2017c.

Likely Precursors

No precursors have been identified. The relevant agency, DTOP, is currently responding to a memorandum of understanding with the FHWA that includes a requirement to study its internal organizational structure and processes to comply with federal requirements for highway funding. This potential reorganization may need to be undertaken before this COA can be realized.
**Issue/Problem Being Solved**

Much infrastructure remains vulnerable to natural disasters.

**Description**

This COA will analyze transportation infrastructure to identify exposure to natural hazards and then undertake engineering projects to mitigate risk. This effort will begin with hydrological and geotechnical evaluations, including floodplain and landslide risk mapping. This COA will identify the most vulnerable infrastructure assets and propose beneficial engineering works, including the relocation of roads; bridge, pavement, and culvert reconstruction; and projects to increase the structural strength of certain roads or to reroute traffic toward more resilient infrastructure. This COA will also undertake a portfolio of particularly cost-effective projects to harden transportation infrastructure.

Previously developed geotechnical and floodplain maps may prove useful. The results of new evaluations should be compared with any previously available data. The PHRTA has a vast library of geotechnical studies that have been prepared for their projects throughout the years.

Two potential projects have been identified as requiring this type of analysis and site-specific design solution. PR-25R, on the northern shoreline of Old San Juan, faces the risk of erosion, which may in turn endanger historical sites in that area. PR-187, in Loiza, requires restoration of the sand dunes to provide protection against roadway damage.

**Potential Benefits**

This COA increases the chances that the transportation system functions well after future natural disasters and extreme weather events, and will improve the resilience of the transportation system. “Functions well” means that the system supports the safe and efficient transport of goods and people. This COA could lead to reduced travel times and crash risk if, for example, a particular section of road is less likely to flood. Reductions in future maintenance, repair, and reconstruction costs are also likely depending on the specifics of engineering works undertaken.

**Potential Spillover Impacts to Other Sectors**

This COA would offer employment opportunities in the short term and reduce the chances of transportation infrastructure failure in the long term, benefiting the economic sector in particular.

In the process of hardening the transportation infrastructure, the relocation of water, power, and communication lines has to be thoroughly coordinated. All future utility plans should be shared with DTOP as the lead agency in coordinating excavation for utilities on the island, since
it is the agency most affected by uncoordinated trenching. At the time of this writing, coordination was done by the Puerto Rico Commission on Public Service.¹

**Potential Costs**

Potential up-front costs: $1.3 million–$380 million in estimated up-front costs (10 years).  
Potential recurring costs: $0.  
Potential total costs: $1.3 million–$380 million in total estimated costs.

The estimated range of $1.3 million–$380 million is fairly large, as it ultimately depends on the projects undertaken. It is based on 4 similar infrastructure hardening projects proposed, and favorably reviewed, in California. The cost of implementing this COA will vary with the scope of the analysis and, in particular, the selection of the engineering works undertaken to harden infrastructure assets. It is anticipated that expenditures for the COA would require 10 years.

Options available to mitigate risk on 1 road in 1 area can vary from $1 million to $1 billion. The California DOT, District 1, published a Vulnerability Assessment and Pilot Studies document in December 2014. In response to environmental risk in Del Norte County, California, DOT commissioned a study on “prototype location adaptation options” that included a “relocate infrastructure (horizontally)” plan with an “assumed total capital investment” that was between $300 million and $1 billion. In contrast, a plan to reroute traffic when roads are flooded in nearby Humboldt Bay had a capital cost of roughly $1 million.² Both of these were preferred plans identified by the California DOT as ideal ways to increase resilience. The Minnesota DOT has published a report describing its Flash Flood Vulnerability and Adaptation Assessment Pilot Project. This report includes details on 2 case studies and associated flood risk mitigation options. The options are generally smaller in scale than those studied by the California DOT and cost roughly between $1 million and $7 million.³ An Oregon DOT report described projects to improve resilience that cost between $2.8 million and $41 million.⁴

Based on this variety of sources, and assuming a variety of project types, we developed a rough low-end estimate of $5 million and a high estimate of $1.5 billion. The portfolio selected

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¹ According to written comments on COAs received from JRO staff, received June 13, 2018.  
included this COA at 25% implementation. Rounding these numbers provides a range of $1.3 million–$380 million.

Maintenance costs on these new projects would be covered under TXN 5, on road maintenance, so no recurring costs are included for this COA.

**Potential Funding Mechanisms**

FEMA Hazard Mitigation Grant Program, U.S. Department of Housing and Urban Development Community Development Block Grant—Disaster Recovery (CDBG-DR), USDOT, U.S. Department of Energy.

Specific programs that are potential funding mechanisms include Chapter 1 of Title 23 funds, the HSIP, the NHPP, the STBGP, the U.S. Department of Energy Clean Cities Program, or the USDOT Transportation Investment Generating Economic Recovery program.

**Implementation**

PRHTA.

**Potential Pitfalls**

This COA involves analysis and engineering work that requires specialized expertise. It will be important to recruit and retain a skilled workforce for project management. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

This COA will involve analyzing the vulnerability of roads and bridges to landslide, flood, and other extreme weather events and developing plans to increase resilience. This will likely require collaboration among pavement, geotechnical, and environmental engineers. While similar studies have been carried out before in Puerto Rico and elsewhere, they are still somewhat unusual. For example, the PRHTA is currently conducting a type of vulnerability analysis, but results are not yet publicly available.\(^5\) The Colorado DOT undertook a similar study for a major corridor, I-70, and engaged on outside firm on the grounds that it did not have sufficient in-house expertise.\(^6\)

This COA involves implementing plans to increase resilience that may be quite innovative—for example, requiring the use of new materials or methods to solidify the base of a road. There is some risk of poor analysis, design, or construction leading to suboptimal results.

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\(^5\) PRHTA, 2018d.

It will be important to develop clear criteria to identify and select architectural and engineering firms. It may make sense to consider firms based outside of Puerto Rico for design or construction efforts. Allowing for this may require modifications to existing regulations or even new legislation.

Academia could be inserted in this process. At least 3 schools of engineering on the island have graduate programs that could provide students for these studies. A joint task force of academia and the transportation industry is a possible tool to be considered.

**Likely Precursors**

No precursors have been identified.
**TXN 3**

**Redevelop Rafael Hernández Airport**

**Issue/Problem Being Solved**

Despite being a desirable tourist destination and home to some of the nicest beaches in Puerto Rico, the Porta del Sol region, located in the western part of the island, is not easily accessible to the public. The closest major airport, Rafael Hernández International Airport in Aguadilla, has only limited passenger service and mainly focuses on cargo transport. This airport is the site of a former U.S. Air Force base, and the surrounding transportation infrastructure has not been updated to maximize commercial airport operations.

**Description**

Formerly Ramey Air Force Base, Rafael Hernández International Airport is located on a 1,600-acre site and has an 11,702-ft runway. This is the largest runway in the region, making it capable of handling significant traffic from large aircrafts.\(^1\) However, air passenger traffic has been declining. In the early 1990s, the airport received 290,000 passengers per year on average, but this has fallen to 75,000–85,000 passengers in recent years.\(^2\) Converting the existing taxiway into a second runway would increase the ability of the airport to handle a larger volume of air traffic, as would expanded taxiways, apron areas, upgrades to terminals, and a new control tower.

This COA will upgrade and expand Rafael Hernández International Airport with a new runway, taxiway, apron areas, terminals, and control tower, all of which would increase flight capacity and better position the airport to serve passengers. These investments have been planned at least as far back as 2005, but to date they have yet to be undertaken. The FAA Reauthorization Act of 2018 also includes a provision specifically calling for a study of the potential for a Puerto Rico airport, presumably Rafael Hernández International Airport, to serve as an air cargo transshipment hub.\(^3\)

**Potential Benefits**

An expanded Rafael Hernández International Airport could increase passenger travel to Aguadilla—a municipality in the Porta del Sol region—and it could boost local economic


activity, both for the municipality itself and for the entire region. This could generate local employment opportunities, expand tourist revenues, and generally stimulate economic growth in the region. An expanded Rafael Hernández International Airport could also potentially reduce air traffic and airport congestion at SJU.

Using data from the United States from 1978 to 2012, McGraw finds that hub airports increase personal income by 2.3% and increase the number of new firms by 1.6% within their respective commuting zones.\(^4\) He also finds evidence suggesting that when airport hubs close, employment in tourism falls.

An expanded Rafael Hernández International Airport could create the potential for airlines to create more nonstop routes from the continental United States and international origins to Aguadilla. These nonstop air routes could benefit manufacturing firms, with existing research showing that new nonstop air routes tend to increase plant-level investment by 8% and productivity by 1.3%, on average.\(^5\) Similarly, prior research has found that that airline hubs have facilitated the consolidation of corporate headquarters and, additionally, job growth.\(^6\)

A large body of literature also finds a causal relationship between airport investments and tourism growth. For example, in the Dominican Republic, tourism in Punta Cana was initially confined to small enclaves. However, it took off after investments in Club Med resorts were made, and these were tied to the construction of a new local international airport.\(^7\)

### Potential Spillover Impacts to Other Sectors

A larger airport with more regular passenger service could increase the demand for tourism and lead to growth in maritime and other ocean economy activities. However, the expansion and associated economic benefits would need to be weighed against potential environmental costs.

Environmental degradation caused by aircraft emissions is likely to increase in severity with the growth in the number of flights.\(^8\) As greater passenger traffic increases the demand for

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4 Marquise McGraw, “Hub Airports and Local Economic Outcomes,” paper presented at the 2015 Meeting of the North American Regional Science Council, Portland, Ore., November 11–14, 2015. “Hub” is defined here as an airport with a large number of connecting flights (as opposed to FAA’s designation of airports as large hubs, medium hubs, etc. that are based on the number of enplanements).


tourism in the area, this could increase the growth of hotels and resorts, which could also adversely affect the environment.

**Potential Costs**

Potential up-front costs: $400 million–$500 million in estimated up-front costs (10 years).
Potential recurring costs: $0.
Potential total costs: $400 million–$500 million in total estimated costs.

The primary cost estimate of $800 million–$1 billion is from the *Economic Development and Government Transformation Plan for Puerto Rico.* The selected portfolio assumed that this COA would be implemented at 50%, hence the estimate of $400 million–$500 million.

According to an initial assessment of damage done to the airports by Gvelop for the PRPA (which owns the airports), repairing Rafael Hernández International Airport after the hurricane would cost $2.1 million in emergency repairs, and an additional $4.7 million in permanent works, for a total of $6.8 million. However, this includes only repair work, not any improvements.

Since the investments in redeveloping Rafael Hernández International Airport are likely to take place over a decade, we are not considering maintenance costs for the time frame of this plan.

**Potential Funding Mechanisms**

FEMA Public Assistance Grants, CDBG-DR, USDOT (FAA), PRPA, municipal governments, P3s, private insurance.

**Implementation**

PRPA.

**Potential Pitfalls**

The benefits of expanding the capacity of Rafael Hernández International Airport hinge on the extent to which it stimulates greater local economic activity and increases tourism. Environmental damage is also possible.

Although infrequent, airport spending is sometimes wasteful, particularly if projects are not well planned. For example, Montreal-Mirabel International Airport is currently 397 square km in

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10 Gvelop, 2017b. See also the discussion of inconsistencies in airport damage assessment costs in Chapter 4.
size, larger than the city of Montreal. It was built to provide capacity for passenger traffic during the 1976 Olympics, but it currently has far more capacity than demand.\(^{11}\)

**Likely Precursors**

No precursors have been identified. Investments in Rafael Hernández International Airport will need to be made after demographic and economic trends have stabilized and Puerto Rico is out of disaster response mode. However, no specific COAs are required to be implemented before this COA could take place.

Roads leading to the airport will need to be improved in tandem with the airport improvements. Access to Rafael Hernández International Airport is now provided by two 2-lane roads (PR-107 and PR-110), both of which have significant right-of-way constraints and will need to be improved.\(^{12}\) The airport will also need more direct access to the planned PR-22 toll road when it is extended westward from its present terminus near Hatillo.

Another precursor may be to consult with the airline industry to identify companies that may be interested in expanding service in Puerto Rico, and particularly serving Rafael Hernández International Airport. Such companies may be willing to invest in the airport under a P3 agreement (similar to SJU), and such a discussion could be a valuable precursor in judging the viability of the airport.


\(^{12}\) DTOP, 2012.
Issue/Problem Being Solved

Repairs are needed to allow for the safe and efficient operation of the airports in Puerto Rico at roughly the same capacities and capabilities as they had before Hurricanes Irma and Maria.

Description

This COA will make repairs to airport facilities that were damaged during the storms. This includes replacing signage and repairing perimeter fences, pipes, and storage tanks; repairing heating, ventilating, and air-conditioning equipment; and rebuilding infrastructure—particularly roofs. Repair needs are based on available damage assessments.

Our understanding of the work needed to repair airport damage is based on assessments conducted by Gvelop in the immediate aftermath of Hurricane Maria. See the subsection “Potential Costs,” below, and the “Hurricane Damage” section in Chapter 4 for further information.

Potential Benefits

Allowing for continued operation of the airports in Puerto Rico will, in turn, allow for the delivery of recovery supplies. This COA is essential for the local economy. Some of the repairs—for example, those related to perimeter fencing and lighting—will improve safety.

Potential Spillover Impacts to Other Sectors

Repairing the airports will allow for continued air travel to Puerto Rico, improving the outlook for tourism and the economy more generally.

Potential Costs

Potential up-front costs: $250 million in estimated up-front costs (3 years).
Potential recurring costs: $12 million in estimated recurring costs (11 years).
Potential total costs: $270 million in total estimated costs.

The estimate in the Recovery Plan, $250 million, was based on information provided by the PRPA in June 2018. This was the most current information at the time the plan was written.

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After the plan was released, we received subsequent information in the *PRPA Facilities Description*, revising the repair costs downward to $108 million. We have been unable to determine the basis for this change in the PRPA’s estimate. The damage assessments described in Chapter 4, Table 4.4, are based on Gvelop estimates and the *PRPA Facilities Description* for SJU. The damage at SJU was costlier than the damage at other airports, according to the available assessments. Presumably this is because there were more assets, and more expensive assets, at SJU, since it is the largest airport in Puerto Rico by any measure. Cost details are provided in Chapter 4, Table 4.4.

Ongoing maintenance and repair activities will be required to keep Puerto Rico’s airports operational. In addition, investments in maintenance can reduce the need for more expensive and otherwise disruptive repair activities in the future. Aerostar, the private firm operating SJU, is responsible for maintenance of facilities at that airport, but at all other airports the public sector must fund any needed maintenance. Airports Council International estimates that the operating expenses at small and medium-size airports in the United States for 2008–2013 work out to roughly $15–$20 per enplanement. Roughly 20% of airport operating expenses went to repair and maintenance work. Maintenance costs are likely to lower for new or recently repaired facilities. We assume an ongoing maintenance cost of $2 per enplanement at airports in Puerto Rico other than SJU, arriving at a figure of roughly $1.2 million per year in ongoing costs for this COA.

**Potential Funding Mechanisms**

FEMA Public Assistance Grants, FEMA Hazard Mitigation Grant Program, CDBG-DR, USDOT, and private insurance (in the case of SJU).

SJU is operated by Aerostar, which may receive payments from insurance to cover some damage repair work it undertakes at the airport, but we have no information on the amount.

**Implementation**

PRPA, Aerostar (San Juan Airport operator), private sector.

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3 Enplanements are half of the passenger movements in Table 4.4. Total enplanements other than SJU are approximately 592,000.
**Potential Pitfalls**

Temporary minor repairs are not a substitute for major repairs or reconstruction. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

There is a risk that airport operators will rely on temporary minor repairs and fail to adequately assess the conditions of the assets that they manage or to undertake needed major repairs or reconstruction projects. Providing additional funding for maintenance would mitigate this concern.

**Likely Precursors**

No precursors have been identified.
**TXN 5**  
**Road Maintenance and Repair Program**  

**Issue/Problem Being Solved**

Many roadways in Puerto Rico have suffered from a lack of basic maintenance.

**Description**

This COA requires that road maintenance and repair projects be given priority over the construction of new, or expansion of existing, facilities through adopting a “fix it first” policy. It also includes selecting and implementing a portfolio of such projects. Projects will improve the condition of roadways and could include safety or operational improvements. This COA will select projects based on their cost-effectiveness, drawing on the judgment of pavement engineers. Relevant similar projects include Michigan’s pioneering Preserve First Program, portions of the more recent State Highway Operation and Protection Program (SHOPP) in California, and “Let’s Go CT!” in Connecticut. Relevant stakeholders include the PRHTA and municipalities.

Maintenance may include that of bridges, streambeds, and embankments to prevent scouring and debris damage. It may also include widening storm drainage trenches to quickly move rain runoff away from roadways, and increasing underground storm drain openings to capture greater volumes of water during heavy rain events.

It will be important to select and apply specific standards, rules, and regulations for road maintenance and repair work. Completed work should be checked, and conditions verified.

**Potential Benefits**

Improved road conditions will lower vehicle operating costs, travel times, travel time variance, crash rates, the severity of crashes, pollutant emissions, and future road maintenance expenditures, all while increasing resilience.

Reducing the roughness of a road surface will allow vehicles to drive on the road using less fuel and oil, and will reduce the chances of damage to the vehicle that would require costly repair. Roughness is commonly measured using the IRI, tracking the movement of a vehicle’s suspension system divided by the movement of the vehicle itself in meters per kilometer. Research shows that an increase of 1 in the IRI “increases fuel consumption of passenger cars by

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2% to 3% irrespective of speed.” The micro- and macrotexture of the road surface determine wear and tear on tires, as well as skid resistance, a key factor in determining crash risk. Travel times and travel time variance are higher on roads in poor condition. Finally, cars that drive on smoother roads will emit fewer pollutants, partially due to the fact that they are burning less fuel. These relationships are well understood by pavement engineers and are modeled in systems like the World Bank’s Highway Development and Management Model. In that model, the user costs incurred by a heavy truck per vehicle-kilometer are over $1.20 when the road’s roughness expressed using IRI is above 17, but less than 80 cents when the roughness is less than 4. Finally, investments in maintenance and repair will increase resilience and make it less likely that facilities will fail in the aftermath of another natural disaster.

**Potential Spillover Impacts to Other Sectors**

Reductions in vehicle operating costs, travel times, and travel time variance should benefit the economy.

**Potential Costs**

Potential up-front costs: $100 million–$5.5 billion in estimated up-front costs (5 years). Potential recurring costs: $900 million in estimated recurring costs (9 years). Potential total costs: $1.0 billion–$6.4 billion in total estimated costs.

The low estimate for up-front costs is $100 million, assuming 200 lane-miles of pavement are repaired, 200 are rehabilitated, and 200 are reconstructed (there are over 16,500 centerline miles of paved roads in Puerto Rico). The $100 million is rounded down from the per-lane-mile numbers in Figure A.1 to reflect a very minimal level of upgrade. Successful implementation will produce some cost savings in out-years, but in order to ensure that maintenance remains a priority we would nonetheless recommend increasing annual maintenance spending.

The cost of implementing this COA will vary directly with the scope and scale of the road maintenance, repair, and reconstruction projects undertaken, and there is no single correct scope and scale. Simply mandating a “fix it first” policy would cost nothing, but using similar past projects such as SHOPP and Let’s Go CT! as a baseline, this COA could cost billions of dollars.

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Let’s Go CT! was originally planned to be a $100 billion investment in Connecticut’s roads.\(^5\) The $5.5 billion high estimate is based on California’s SHOPP estimate of $18 billion, for a road network 3.3 times larger than Puerto Rico’s.\(^6\)

Here the COA is assumed to include repairing 1,000 lane-miles of pavement, rehabilitating an additional 1,000 lane-miles of pavement, and reconstructing an additional 1,000 lane-miles of pavement. This represents a relatively modest investment in roadwork in comparison to the other projects mentioned here, but keeps the cost of the COA in line with the costs of other COAs. Figure A.1, from a fact sheet for the Let’s Go CT! project,\(^7\) shows how pavement deterioration proceeds over time and reasonable estimates for the costs of maintenance activities.

![Figure A.1. Model of Pavement Deterioration and Maintenance Costs](#)

**Figure A.1. Model of Pavement Deterioration and Maintenance Costs**


The rough estimate for the increase in ongoing cost is $100 million per year, over 9 years. Available studies indicate that road maintenance, repair, and reconstruction projects produce cost savings in out-years, although these savings are difficult to quantify and will again depend on the specifics of how this COA is scoped. Looking again at Figure A.1, note that $200,000 spent on

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\(^6\) California DOT, 2018.

road preservation in year 13 or 14 will ensure that it is not necessary to spend $750,000 on rehabilitation in year 17 or 18 or $3,000,000 on reconstruction in year 20 or 25. Cost savings in out-years due to maintenance activities are difficult to quantify because they will depend on decisions made in those out-years. Engineers generally talk of maintenance activities extending the service life of roads and bridges rather than saving future agency costs.

The states of Florida, North Carolina, and Virginia have at various times developed budgets that set aside $1 billion, $1.37 billion, and $2.13 billion, respectively, for road maintenance and operations for 1 year on their roads. It is important to note that maintenance costs will be incurred by both state and local governments. (Of the budget numbers quoted above, only the figure from Virginia includes both costs.) As a rough rule of thumb, costs accruing to local government equal costs accruing to state government. In reality, maintenance needs and costs will vary with the types of roads and bridges being managed, local environmental and traffic conditions, and the existing conditions of the managed assets, among other things. The PRHTA has estimated that it needs $262 million in annual funding to “keep the highway system in a state of good repair.” This COA proposes increasing existing maintenance budgets by $100 million per year to ensure that maintenance is a priority in the future.

**Potential Funding Mechanisms**

USDOT, DTOP.

Partial funding for this COA could come from USDOT grant programs, such as Chapter 1 of Title 23 funds, the HSIP, the NHPP, and the STBGP, as well as government of Puerto Rico funds (through DTOP).

**Implementation**

PRHTA.

**Potential Pitfalls**

Failure to train, attract, and retain a skilled workforce could limit benefits. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

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**Likely Precursors**

No precursors have been identified. Site surveys and sophisticated transportation infrastructure asset management systems, of the type that would be funded through TXN 11, would help ensure that this COA delivers maximum benefits. However, these are not necessarily a prerequisite for this COA.
Update Airport Emergency Plans

**Issue/Problem Being Solved**

There is a lack of both coordination and documentation of multijurisdictional activities that have been identified as significant for effective emergency management.

Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended, the elected officials of the communities that own and operate airports are legally responsible for ensuring that necessary and appropriate actions are taken to protect people and property from the consequences of emergencies and disasters. These communities must also develop emergency preparedness programs to assist state and local emergency management officials in complying with emergency preparedness responsibilities. FEMA has published the *National Response Framework*, the *Guide for All-Hazard Emergency Operations Planning*, and provided guidance on the National Incident Management System.\(^1\) The *Framework* and the *Guide* provide emergency managers and other emergency services providers with information regarding the FEMA concept for developing risk-based, all-hazards emergency operations plans.

Concerns have been raised regarding airport emergency management. For example, a 2015 USDOT Office of the Inspector General memorandum noted that air rescue and firefighting equipment at SJU had not been properly maintained and this might “directly impact the airport’s ability to fight fires and respond to other emergencies on runways and taxiways.”\(^2\)

**Description**

Reevaluate and update the Airport Emergency Plans (AEP)\(^3\) to assign key roles to partners to identify reserve capacities and pre-positioned response assets, develop a communications protocol for first responders during a disaster, and implement prestorm protection measures in an integrated

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3. This discussion focuses on the AEP for SJU, which is the largest airport in Puerto Rico. The *Recovery Plan* refers to an “All-Airports Emergency Plan,” which is not a specific document. Three of the 10 airports in Puerto Rico should have their own AEPs, as they are certificated (SJU, Ponce, and Aguadilla). The title of the COA has been changed in this document to reflect this. However, the general intent was to encourage emergency planning across airports and ensure that plans are updated based on the experience of the recent hurricanes.
fashion to ensure the safety of and emergency services for airport staff, passengers, and the community in which the airport is located.

The AEP for certificated airports must meet the requirements set forth in the Code of Federal Regulations, Title 14, Section 139.325, Airport Emergency Plan. For all other airports, the FAA recommends the use of the guidelines and standards contained in the relevant advisory circular for the development of AEPs. Although the advisory circular is not mandatory for noncertificated airports, the AEP for such airports must follow the general guidelines prescribed by Homeland Security Presidential Directive 5, Management of Domestic Incidents and Presidential Policy Directive 8, National Preparedness. In development of new AEPs, the FAA also recommends that all airports (certificated and noncertificated) use as guidance certain provisions in the National Fire Protection Agency Standards (i.e., only 424, 1500, 1561, and 1600—the latest editions).

In addition to reassessing the plan, stakeholders should identify communications protocols and physical resources including, but not limited to, equipment to repair critical infrastructure in the airport, pre-positioned response assets, and identification of pre-storm protection measures to protect these resources.

Common issues with AEPs include failures to communicate and coordinate with emergency response units when developing plans, incompleteness of planning leading to difficulties training staff, and a lack of participation when developing the plans leading to unintentional over- or underrepresentation of specific emergencies, issues, or concerns. Multijurisdictional planning is particularly important and problematic as an area where many of these issues become especially tricky.

In addition, there are likely lessons learned during the 2017 hurricane season. For example, after fielding numerous, repetitive inquiries from the public, staff at SJU used Facebook to publish airport status updates and flight schedules each day in the immediate aftermath of Hurricane Maria. Figure A.2 shows 1 such post. Airport staff also had to respond to numerous

uncommon issues such as condensation on the floors caused by the lack of air-conditioning. Multiple airports had extensive damage to roofs and perimeter fences. Lessons learned could be used to improve airport contingency planning.

Figure A.2. Luis Muñoz Marín International Airport Flight Schedule Facebook Post

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El Aeropuerto Luis Muñoz Marín continúa operando de 7:00 am a 5:00 pm y con plantas de emergencia por lo que no hay aire acondicionado y algunos servicios están limitados. Para el día de mañana se tienen programados 24 vuelos los cuales compartimos en la parte inferior, si usted cuenta con un vuelo confirmado deberá presentarse al aeropuerto mínimo con 4 horas de anticipación debido a que hay largas filas para la documentación con la aerolínea así como en los puntos de seguridad.

Si su vuelo no aparece en el listado deberá contactar a su aerolínea para conocer el estatus de su vuelo, los itinerarios se trabajan día a día por lo que no contamos con la información de los vuelos para los días subsiguientes.

The Luis Muñoz Marín Airport continues to operate from 7:00 am to 5:00 pm and with emergency generators so there is no air conditioning and some services are limited. For tomorrow we have scheduled 24 flights which we share at the bellow, if you have a confirmed flight must be present to the airport minimum 4 hours in advance because there are long lines for check in with the airline as well as in the check points.

If your flight does not appear in the list you should contact your airline to know the status of your flight, the schedules are worked day by day so we do not have the flight information for subsequent days.

See Translation

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8 Personal communication with former Environmental Manager at Luis Munoz Marin International Airport, April 2018.
Potential Benefits

Comprehensive AEPs will take advantage of lessons learned during Hurricane Maria to further develop precoordinated disaster recovery plans for the various airports in Puerto Rico. Updated plans will ensure that Puerto Rico can recover quickly in the event that a future disaster disables or disrupts airport activity, causing cascading effects to the health, safety, and security of the population.

A comprehensive approach improves the effectiveness of emergency management and response personnel across the full spectrum of potential incidents and hazard scenarios (including but not limited to natural hazards, terrorist activities, and man-made disasters). Such an approach improves coordination and cooperation between public and private agencies and organizations in a variety of emergency management and incident response activities. The National Incident Management System describes the comprehensive approach.

Potential Spillover Impacts to Other Sectors

Some elements of emergency planning should be integrated with the communications/information technology and energy sectors, as ensuring that adequate backup electricity generation and communication channels will likely be an important component. Successful plans should also minimize postdisaster economic disruption.

Potential Costs

Potential up-front costs: $4 million in estimated up-front costs.
Potential recurring costs: $1 million in estimated recurring costs (11 years).
Potential total costs: $5 million in total estimated costs.

Reassessing and updating the AEPs is estimated at $500,000. Implementing portions of the plan, including pre-positioning assets and establishing an integrated operations center, may cost $2 million–$5 million, from which we extrapolated an estimate of $4 million for all up-front costs ($500,000 for the update and $3.5 million for the center). These figures were provided to us by the PRPA.9

This estimate is associated with capital investments, administrative expenses, and operational expenses to be incurred by the PRPA, as the plans are required to be reviewed regularly by the FAA. Estimates for implementation may vary depending on required technology investment and/or new regulations that could be imposed.

Ongoing costs (e.g., conducting exercises) are estimated at $100,000 annually.

9 PRPA, memorandum to the HSOAC team, June 10, 2018a.
Potential Funding Mechanisms

FEMA Hazard Mitigation Grant Program, CDBG-BR, USDOT, FAA, PRPA.

Implementation

Aerostar, PRPA.

Potential Pitfalls

Establishing consensus among partners on final approval of the plan.

 Likely Precursors

No precursors have been identified.
TXN 7
Incentivize a Variety of Mobility Options

Issue/Problem Being Solved

Puerto Rico has fairly limited public transportation service, especially outside of San Juan, no scheduled intercity transportation, and few other transportation options, making travel difficult for persons who do not drive.

Description

This COA will provide additional travel options for people who do not drive or who prefer to use other options. Puerto Rico has fairly limited public transportation service, especially outside of San Juan, no scheduled intercity transportation, and ride hailing (e.g., Uber) is not available in all areas, or may be cost-prohibitive. Mobility options would include ride hailing, ride sharing, expanded público service, intercity bus service, bike or scooter sharing, and peer-to-peer car sharing.

Implementation of this COA would be accomplished by both public and private entities. The public sector could provide either financial or regulatory incentives to allow private operators to offer a greater variety of services to the transportation market. Provision of (or enhanced provision of) private or public-private services (such as ride sharing and públicos) could begin fairly quickly.

This COA increases travel options beyond driving one’s own car. There has been a virtual explosion of innovative mobility options in cities around the world, and Puerto Rico could be adopting many of these for local use to reduce reliance on driving and to provide more options for persons who do not drive or prefer not to.

In addition, more than 20% of Puerto Rico’s population has a disability.¹ Not only are there limited transportation options in general, but transportation in Puerto Rico lacks special accommodations for people with disabilities. For example, públicos and ride hailing services are not generally accessible to persons who use wheelchairs. However, legal issues around access to ride hailing for disabled persons remain somewhat in limbo.²

¹ DTOP, 2013b.
² Americans with Disabilities Act (ADA) regulations prevent discrimination against persons with disabilities. In transportation, they apply broadly to both public and private entities and to almost all types of transportation services, including fixed bus service, rail (e.g., commuter, rapid, and light rail), complementary paratransit, demand-responsive service, and ferry service. However, while the country’s largest ride hailing services, Lyft and Uber, have policies that comply with ADA, in practice both have been sued by persons with disabilities over a lack of access. These issues were still in court at the time this report as written. For a more detailed discussion of ADA and ride hailing, see Bryan Casey, “Uber’s Dilemma: How the ADA May End the On-Demand Economy,” University of Massachusetts Law Review, Vol. 12, No. 124, 2017, pp. 124–164.
While improving transit service is covered in other COAs, this COA considers a wide variety of services that are facilitated by the popularity of smartphones and other information technology (IT) innovations:

- **Ride hailing:** These are services that allow residents to request door-to-door rides via smartphones. While most closely associated with the introduction of Uber, which was the main commercial service available in Puerto Rico at the time of this writing, ride hailing could be expanded to include other commercial providers, especially local ones such as ProCar and PinkCar, or upgrading the existing taxi fleet to provide this service (e.g., many U.S. taxi fleets are now served by an app called Curb, which also provides smartphone hailing and credit card payment).

- **Nonprofit ride hailing or ride sharing:** These are similar to ride hailing but are provided by nonprofits in areas where demand may be too low for commercial services. For example, a nonprofit in California, Green Raiteros, uses low-emissions hybrid vehicles to provide rides in a rural low-income community. Services could also provide ride matching for recurring or longer-distance trips, to promote carpooling.

- **Expanded público service:** Puerto Rico has a long-standing network of jitney services called públicos, which are generally 10- to 15-passenger vehicles that service longer intercity trips and operate based on demand rather than being scheduled. According to the most recent Islandwide Long Range Transportation Plan, these services are declining. This decline could potentially be reversed through improved technology (e.g., giving riders the option to book in advance) and more cooperation with municipalities (e.g., possible subsidies or other partnership), as has occurred in Caguas. Restructuring of routes and changes in the price structure could also be considered.

- **Scheduled intercity bus service:** Some cities in the United States have seen a major recent uptick in the number of commercial intercity bus providers, especially between cities that are a few hundred miles apart (a distance more easily covered by surface transportation than by air). These providers generally have low fares, online ticket purchases, reserved seats, and amenities such as Wi-Fi. Regulations and enforcement would be needed to ensure that vehicles meet safety standards and drivers have appropriate commercial licenses. While this is a market that could be served by commercial providers, it could also get a jump start from a partnership between municipalities (by providing space in existing parking lots or terminals) or could require some initial subsidies.

- **Bike or scooter sharing:** An emerging trend in U.S. cities is bike sharing. The first iteration, in which bicycles are parked in fixed locations in locked racks, is now established in more than 100 programs around the United States, according to a 2016 list of programs. A new type of program called dockless bike sharing, in which bikes can be parked anywhere, has recently cropped up in a smaller number of cities. Scooter sharing

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4 The project is funded by the FHWA and the National Highway Traffic Safety Administration. See, for example, Pedestrian and Bicycle Information Center, University of North Carolina Highway Safety Research Center, “Programs Promote Bike Share Programs,” webpage, undated.
programs are even more recent. All such programs allow residents to rent bikes or electric scooters for short periods of time for low prices (or for free, for members), and per-trip prices go up with the length of time. Other recent innovations in bike sharing include electric bikes and bike sharing for children.\textsuperscript{5}

- **Peer-to-peer car sharing:** This is a service that allows individuals to rent their personal vehicles to other individuals. Rentals are facilitated by technology that allows the renter to access the vehicle without a key. The vehicle owners can generally set the hourly rate for the rental, allowing them to realize income from vehicles that they may not drive regularly, and the service company takes a percentage.

- **Combined mobility and payment platform:** This is the only option on this list that would represent a leapfrog effort over existing technologies and programs, as no city had a service like this at the time this report was written. The goal would be to create a unified mobility platform that would allow users to access and pay for all forms of mobility—vehicle tolls, parking fees, ride hailing services, transit fares, bike sharing, and car sharing—through a single portal. This would require a high degree of cooperation and coordination between existing public and private operators, new technology development, and careful attention to equity and privacy issues.

Because walking and bicycling are important, sidewalk and bicycle infrastructure are discussed in a separate COA on road standards, TXN 1. Given the paucity of appropriate sidewalks and bicycle lanes around the island, improvements in those areas would likely be the best way to encourage the use of such modes.

Implementation of this COA would be accomplished by both public and private entities. The public sector could provide either financial or regulatory incentives to allow private operators to offer a greater variety of services to the transportation market, as well as developing regulations or initiatives that would make it easier for private companies to offer these options. Provision of (or enhanced provision of) private or public-private services (such as ride sharing, bike sharing, and públicos) could begin fairly quickly, within a year or less. These modes should be developed and implemented in compliance with applicable ADA regulations.

As part of this COA, DTOP could also develop a transportation technology strategy to plan for emerging technology services and integration into the overall transportation network. This could be incorporated into the *Islandwide Long Range Transportation Plan* and the *Statewide Transportation Improvement Program*. Such a strategy could support Puerto Rico in establishing a platform for transportation innovation while ensuring that the island can meet its safety, environmental, mobility, and equity goals and objectives.

Potential Benefits

Benefits to individuals and households would vary. Persons who do not drive would enjoy increased mobility options, which could lead to a variety of improvements in their quality of life: increased ability to visit friends and family, seek health care, and so forth. Increased use of nonmotorized modes would also improve health for some persons, as active transportation provides exercise. Use of nonmotorized modes could also reduce air pollution if pedestrians and bicyclists switch from driving.

If programs reduce vehicle ownership, this should have a positive impact on reducing congestion, as persons who do not own cars tend to drive less. While vehicle ownership is high in Puerto Rico (as of 2008, 1.7 vehicles per household, similar to the U.S. average), the rates of people with disabilities is also high (over 20%), and some of those persons may be limited in their ability to drive. While we were unable to locate specific estimates of the cost of transportation in Puerto Rico, for the average U.S. household transportation costs are second only to housing costs, and most of these costs are related to vehicle ownership. Reducing the need to own a car may benefit lower-income households if they can meet their travel demands through lower-cost options. Allowing car owners to drive for hire (e.g., with a ride hailing service such as Lyft or Uber) or rent out cars to others (e.g., through a peer-to-peer car sharing network such as Getaround or Turo) could also be a source of income for some households.

Potential Spillover Impacts to Other Sectors

Mobility options focused on active transportation could contribute to improved health outcomes in 2 ways: first, nonmotorized transportation can contribute to better health, as active transportation provides an opportunity for exercise; second, better access to transportation allows people to access health care. The natural environment can also be positively affected by reductions to air pollution if people drive less, but this depends on the magnitude of the shift.

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7 According to data in the *Islandwide Long Range Transportation Plan* (DTOP 2018b), in 2008, 2.4 million vehicles were registered in Puerto Rico, or 1.7 per household and 0.6 per capita, which is very high considering the poverty rate in Puerto Rico. The overall U.S. rate was 1.86 per household in 2009, according to the National Household Travel Survey (see Nancy McGuckin and Anthony Fucci, *Summary of Travel Trends: 2017 National Household Travel Survey*, Washington, DC: Federal Highway Administration, FHWA-PL-18-019, July 2018.

8 In 2016, the average household spent $18,886 on housing and $9,049 on transportation, which was more than was spent on food ($7,203) or health care ($4,612). Bureau of Labor Statistics, “Consumer Expenditures in 2016,” webpage, April 2018.

Potential Costs

Potential up-front costs: $450,000–$17 million in estimated up-front costs.
Potential recurring costs: $4.4 million–$170 million in estimated recurring costs (11 years).
Potential total costs: $4.9 million–$190 million in total estimated costs.\(^{10}\)

Most of these strategies have start-up and annual operating costs between $50,000 and $2 million. In terms of up-front costs, the low-cost estimate is peer-to-peer car sharing in 1 city, at $50,000, and our high-cost estimate includes intercity buses and other services in 4 cities, each at $17 million. See Table A.1 for details of individual costs. The recurring costs over 11 years are $4.4 million on the low end and $170 million on the high end (for the same sets of projects).

Rough order-of-magnitude costs are provided for both start-up and operational costs. These include our best estimate of all costs to start up and provide the service, regardless of whether they are borne by the public sector or private firms. Sources and assumptions are provided following Table A.1.

Table A.1. Summary of Estimated Costs for Elements of TXN 7

<table>
<thead>
<tr>
<th>Service</th>
<th>Start-up Cost (for 1 system)</th>
<th>Annual Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonprofit ride hailing or ride sharing</td>
<td>Under $1 million</td>
<td>Under $500,000 (estimated)</td>
</tr>
<tr>
<td>Expanded público service</td>
<td>$700,000</td>
<td>$2 million</td>
</tr>
<tr>
<td>Scheduled intercity bus service</td>
<td>$5 million</td>
<td>$1.5 million</td>
</tr>
<tr>
<td>Bike or scooter sharing</td>
<td>$1.3 million</td>
<td>$600,000</td>
</tr>
<tr>
<td>Peer-to-peer car sharing</td>
<td>$50,000</td>
<td>$400,000</td>
</tr>
<tr>
<td>Combined mobility and payment platform</td>
<td>Unknown, but similar efforts are $100 million and up for technology development and implementation</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Some of these services could be provided exclusively by the private sector. The main requirement would authorize them to operate and, where needed, coordinate for access to public space (e.g., where intercity buses would pick up and drop off passengers). However, the main prerequisite for these companies to operate is sufficient passenger demand to generate revenues. This may not be true for all areas of the island. The following list provides costs and examples of

\(^{10}\) These are the ranges shown in the Recovery Plan. Due to a spreadsheet error, the $50,000 annual operating cost for real-time arrival information was entered as $450,000, thus leading to the estimate of $450,000 for low-end start-up costs. The numbers in the following paragraph and in Table A.1 have been updated to address this error.
services that could be provided either only with public or other noncustomer support, or that could be set up as some type of partnership between public and private or nonprofit operators.

- **Nonprofit ride hailing or ride sharing:** In some areas, demand—either in terms of the number of passengers, or their ability to pay—may not be sufficient to support commercial ride hailing services. The public or nonprofit sector could fill these gaps with a variety of service types. The Green Raiteros program is largely for commuting in rural areas. Start-up costs for a network of electric vehicle charging stations were over $500,000.\(^{11}\) Another rural nonprofit received a grant in the low hundreds of thousands of dollars to purchase an electric van to provide rides between 2 small communities.\(^{12}\) Operating costs would vary depending on the type of system and the number of vehicles required.

- **Expanded público service:** Caguas has worked with neighboring municipalities to expand público service, providing incentives to drivers for driving a certain number of hours and routes, and equipping vehicles with Global Positioning System technology for verification.\(^{13}\) In 2013, operating costs were about $2 million annually.\(^{14}\) In 2014 Caguas also purchased 12 additional vehicles for $700,000.\(^{15}\)

- **Scheduled intercity bus service:** Scheduled bus service could be provided by commercial providers at essentially no public cost, or it could be incentivized through a P3. (Some intercity travel is already subsidized; for example, Mayagüez has regular air service to SJU that is subsidized by the federal government’s Essential Air Service program at $1.5 million per year.)\(^{16}\) While we could not locate estimated operating costs, the new group of curbside bus operators in the United States is thought to have lower operating costs than previous bus services, for 2 reasons: fewer and lower-paid staff, and no terminal fees because they operate on city streets.\(^{17}\) Colorado subsidizes intercity bus service between Colorado Springs and Denver that started in 2015 with a fleet of 13 buses. It required $10.9 million in up-front costs and a $3 million annual operating subsidy.\(^{18}\) Service runs between 2 and 7 times daily, depending on the route, and

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\(^{13}\) “Listos para poner los rieles” [“Ready to Lay the Rails”], *El Nuevo Día*, March 20, 2013.


\(^{15}\) Carmen Arroyo Colón and Lydia Santiago, “Alcalde de Caguas entrega nuevas guaguas a Transcriollo y al Departamento de Servicios al Ciudadano” [“Caguas Mayor Delivers New Público Vehicles to Transcriollo and the Department of City Services”], *Foro Noticioso*, April 6, 2014.

\(^{16}\) USDOT, 2017a.

\(^{17}\) Nicholas J. Klein, “Emergent Curbside Intercity Bus Industry: Chinatown and Beyond,” *Transportation Research Record: Journal of the Transportation Research Board*, No. 2111, 2009, pp. 83–89.

generally twice daily on weekends. Presuming service would run half that amount, we assume half of these costs.

- **Bike or scooter sharing:** Costs depend on the size of the system, measured in the number of stations and bikes. According to a report prepared for the FHWA, “As of March 2012, the capital costs for implementing a jurisdiction-wide bike sharing system ranged from an average of $4,200–$5,400 per bicycle, including all system components, staff and administrative support. Operating costs ranged from an average of $150–$200 monthly per bicycle.”\(^{19}\) For a system of 250 bikes, costs would be approximately $1.05 million–$1.35 million, with annual operating costs of $450,000–$600,000.\(^{20}\)

- **Peer-to-peer car sharing:** The only current models in the United States are for-profit companies, but peer-to-peer car sharing could in theory be set up as a nonprofit or quasi-public enterprise. The main start-up costs are equipping participating vehicles with insurance, customer service, and technology that allows them to be accessed by other drivers.\(^{21}\) If we assume that the technology is $250–$500 per vehicle,\(^{22}\) start-up costs would be $25,000–$50,000 for a fleet of 100 vehicles. If we assume the insurance per vehicle is about $1,500 per year, and customer service costs are the same for bike sharing services ($200 per vehicle per month), operating a fleet of 100 vehicles would cost about $400,000.

- **Combined mobility and payment platform:** This new idea would probably be the most expensive on this list. No metropolitan area has developed a platform like this, so we cannot estimate costs based on past experience. Efforts to provide integrated fare media across multiple transit agencies have cost $100 million or more, but these also served larger metropolitan areas.\(^{23}\)

These are meant to be rough order-of-magnitude cost estimates. More specific cost estimates would require detailed estimates of demand, which would influence the number of vehicles in a system and the price that users would pay for the system, as well as operating assumptions. For example, bike-sharing costs would depend on the number of vehicles; whether the system operates with docks or is dockless; the pricing system (whether there are daily ride options or only an annual subscription, what the cost would be of a ride of a specific length, and whether

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\(^{20}\) Cities with bike-share programs in this range include Charlotte, N.C.; Chattanooga, Tenn.; Houston, Tex.; and Tampa, Fla. See, for example, Pedestrian and Bicycle Information Center, University of North Carolina Highway Safety Research Center, “Programs Promote Bike Share Programs,” webpage, undated.

\(^{21}\) Staff of the Shared Use Mobility Center, telephone communication with Liisa Ecola, April 30, 2018.


there are provisions for lower-income users); how many riders would use it, and at what prices; how many rides are taken; the usage pattern (rebalancing the bicycles in a system with docks incurs costs); and the level of equipment losses and repair needs (the rate at which bicycles are damaged).

**Potential Funding Mechanisms**

USDOT, private sector, users.

Innovative mobility options could be supported through a variety of means:

- **Federal funds:** If the applicant were an approved grantee, USDOT FTA funds could support purchases of vehicles for intercity bus service.\(^{24}\)
- **User fees:** Many of these systems—ride hailing, bus service, bike sharing, and car sharing—charge fees to users. In some cities, ride hailing has become so popular that it is now seen as a potential revenue generator for other transportation modes.\(^{25}\) Given that these models promote the use of modes other than driving alone, parking fees could also be used.
- **Advertising:** Private companies could pay to promote their logos on vehicles or stations. For example, the Denver B-Cycle program, with over 700 bikes, covers its $2 million budget with fees (around 50%), corporate sponsorships (30%), and grants (20%).\(^{26}\)
- **Grants:** Grants from private nonprofit organizations could be used for start-up costs for some of these systems. The Better Bike Share Partnership offers grants to build “equitable and replicable” bike sharing systems.\(^{27}\)

**Implementation**

AMA, PRHTA, private companies.

**Potential Pitfalls**

Lack of demand, technological unreliability, technological change, and lack of popular support could all hinder implementation of this COA.

**Lack of demand:** These services assume there will be sufficient demand to support them. While some of these services are not expected to be self-sufficient financially, it would be

\(^{24}\) Per personal communications with FTA staff, público owners are not eligible to apply for FTA funding, unless they can meet federal standards such as ADA and alcohol/drug testing. FTA staff, telephone conversation with Liisa Ecola and Jeff Kendall, June 7, 2018.


\(^{27}\) Better Bike Share Partnership, “Grants,” webpage, undated.
unproductive to support services with very low demand when resources are limited. It is also possible that demand may exist, but primarily among potential users without the means to pay user fees. Developing these services requires attention to demand patterns, prices that would be attractive to potential users, and starting small with the intent to grow rather than rolling out a major system all at once. It is also important to consider and plan for operating and maintenance issues.

**Technology unreliability:** All of these services assume some level of technology to support them—in particular, internet and smartphone access. While smartphone penetration is generally high in Puerto Rico, some demographic groups may require assistance or other means of access (e.g., the ability to book rides via telephone). These services also require stable communications networks; without them, they could be considered unreliable by users.

**The pace of change:** Most of these services did not exist a decade ago. With rapidly evolving technologies, there is always a danger of investing in something that becomes obsolete quickly. In addition, given that in many cases these will require private-sector involvement, there is danger that firms will go out of business while a project is ongoing, leading to potential operational or financial challenges.

**Lack of political or popular support:** While many of these systems have been embraced by users, they may also experience conflicts with established interests (e.g., taxi drivers opposing ride hailing) as well as competition for scarce road space (e.g., a surge in bicycling could provoke a backlash from drivers who view bicycles as a nuisance). While these conflicts may resolve themselves over time as certain systems gain popularity and drivers adjust to change, planners must be prepared to withstand criticism and develop strategies to explain the benefits of these systems.

**Likely Precursors**

To promote walking and bicycling, it would be helpful to implement the “complete streets” standards component in TXN 1. It would also be helpful to conduct a study regarding how new mobility options, expanded bus service, and the Tren Urbano can be better integrated. Most of these services are enabled by access to smartphones and wireless communications. If reliable communications services are not available, these mobility options will be unreliable or unavailable to certain people at certain times.
TXN 8
Improve Bus Service

Issue/Problem Being Solved

Bus service is often slow and unreliable, and many persons who do not drive have severely limited mobility options.

Description

This COA includes 6 ways to improve existing bus service: transit signal priority, provision of real-time arrival information, upgrading of bus stops, smart card fare media, dedicated lanes, and additional buses.

- **Transit signal priority**: This would give buses additional time to cross a signalized intersection, either by extending an existing green light or truncating a red light.
- **Real-time arrival information**: This would provide riders with information on web-enabled devices or smartphones about arrival time based on where buses are currently located, instead of scheduled times that may not be accurate given traffic conditions.
- **Upgraded bus stops that include signage**: This would provide a comfortable waiting experience for riders.
- **Smart card fare media**: This would allow riders to store value on a card and avoid needing exact change.
- **Dedicated lanes**: This would give buses their own travel lane to avoid being stuck in congested lanes with other traffic.
- **Additional buses**: These would allow service to operate more frequently.

Some of these improvements could be made within 1 or 2 years; others would require longer periods of time to implement. The main agency would be the AMA, but the PRHTA also operates some bus service. Most bus service is provided in San Juan. All improvements would comply with ADA requirements.¹

¹ USDOT issues regulations implementing the transportation and related provisions of ADA and Section 504 of the Rehabilitation Act of 1973, as amended. These regulations apply broadly to both public and private entities and to almost all types of transportation services, including fixed-route bus and rail (e.g., commuter, rapid, and light rail), complementary paratransit, demand-responsive service, and ferry service. Title II of ADA applies to public transportation provided by state and local governments. Section 504 applies to all organizations and agencies that receive federal funding. Both laws require that policies, practice, and procedures be modified so that the transportation services are accessible to individuals with disabilities.
Potential Benefits

Direct outcomes should include more reliable and comfortable bus service. Improving bus service would provide a useful alternate mode of transportation to people who cannot or choose not to drive.

Transit signal priority has been shown to have positive impacts on bus delay, rider travel time, travel time reliability (better on-time performance), rider satisfaction, and even ridership. A few systems have even found that they could avoid an additional bus purchase since they had more efficiency from existing buses.\(^2\) Real-time arrival information can reduce both actual and perceived waiting time and even increase ridership by a few percentage points.\(^3\) (Before the Tren Urbano opened in 2005, buses carried over 100,000 riders per day.)\(^4\) Smart card fare media can save 1 or 2 seconds per passenger boarding, which means buses can spend less time at each bus stop.\(^5\)

Potential Spillover Impacts to Other Sectors

Increased use of transit could reduce air pollution produced by single-occupant vehicles. Transit signal priority could be developed alongside other traffic management systems (such as proposed in TXN 9) and preemption for emergency response vehicles.

The natural environment can also be positively affected by reductions in air pollution if people drive less, but this depends on the magnitude of the shift.

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\(^4\) DTOP, 2013b, Figure 5.11.

Potential Costs

Potential up-front costs: $200,000–$79 million in estimated up-front costs (2 years).
Potential recurring costs: $7.9 million–$650 million in estimated recurring costs (11 years).
Potential total costs: $8 million–$730 million in total estimated costs.6

Given that any of these costs could change depending on assumptions about how widely they are implemented, for the lowest cost we assume only the cheapest of the 6 options, real-time transit information, is implemented, for a cost of $200,000. (See Table A.2 for all cost estimates.) For the high cost we assume $79 million (including transit signal priority at 80 intersections and 5 mi of dedicated bus lanes). Implementing all 6 proposed improvements based on a reasonable set of assumptions would cost approximately $79 million. Operating costs could range from $790,000 to $650 million annually, with almost all of that for operating a larger bus fleet.

Table A.2. Estimated Highest Cost of Six Bus Service Improvements

<table>
<thead>
<tr>
<th>Enhancement</th>
<th>Initial Cost</th>
<th>Annual Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit signal priority</td>
<td>$2,000,000</td>
<td>No additional cost</td>
</tr>
<tr>
<td>Provision of real-time arrival information</td>
<td>$200,000</td>
<td>$75,000</td>
</tr>
<tr>
<td>Bus stop upgrades</td>
<td>$1,200,000</td>
<td>No additional cost</td>
</tr>
<tr>
<td>Smart card fare media</td>
<td>$6,500,000</td>
<td>$5,000,000</td>
</tr>
<tr>
<td>Dedicated lanes</td>
<td>$30,000,000</td>
<td>$110,000</td>
</tr>
<tr>
<td>Additional buses</td>
<td>$39,000,000</td>
<td>$58,500,000</td>
</tr>
<tr>
<td>Total</td>
<td>$78,900,000</td>
<td>$64,675,000</td>
</tr>
</tbody>
</table>

Rough order-of-magnitude costs are provided for both start-up and operational costs. These include our best estimate of all costs to start up and provide the enhancement, regardless of whether they are borne by the public sector or private firms.

- **Transit signal priority:** While this can be implemented with various types of software and configurations, system costs vary primarily based on the number of intersections and buses. In a 2005 study, 3 smaller implementations (each with fewer than 150 buses and fewer than 65 intersections) reported implementation costs ranging from $325,000 to $860,000. (The largest bus fleet in Puerto Rico, the AMA, had 157 vehicles in 2016.)7 Annual maintenance costs were $20,000 or less.8 Figures are adjusted upward to account

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6 These are the ranges shown in the *Recovery Plan*. Due to a spreadsheet error, the $75,000 annual operating cost for real-time arrival information was entered as $750,000, thus leading to the low end estimate of $7,900,000. The numbers in the following paragraph have been updated to address this error.

7 FTA, 2016 Annual Database Agency Mode Service, undated c.

8 Smith, Hemily, and Ivanovic, 2005, Table 9.
for inflation given that the study is over 10 years old. For the high estimate in Table A.2, we assumed $25,000 each for 80 intersections, or $2 million.

- **Provision of real-time arrival information:** Many transit agencies work with private firms to provide real-time bus arrival information via web-enabled devices and smartphones (in addition to, or instead of, providing real-time displays at bus stops). Unfortunately, the costs of these systems to the transit agencies are not well understood. A survey revealed that most agencies could not quantify their costs. Those that could quantify costs did so based on the costs of delivering text messages, while the current market seems to be moving away from such services.\(^9\) Third-party services, such as OneBusAway, Moovit, and Transit App, rely on vehicle location information supplied by the transit agency and made available in usable formats. One major transit agency reported a cost of $715,000 for a 5-year contact to implement and maintain a branded application based on OneBusAway.\(^10\) Given the smaller size of the San Juan fleet, we assume these costs to be somewhat lower; we also assume that implementation costs more than maintenance.

- **Bus stop upgrades:** Bus stop upgrades could include a number of items to improve rider comfort and convenience, such as shelters, lights, benches, signage information, trash cans, and ensuring accessibility in accordance with ADA. A review of bus stop upgrades in Maryland found that basic improvements (minor fixes to sidewalks and a sign) cost about $7,000 per stop, while more extensive upgrades (“lighted shelters, a bench, trash can and branded pylons, the corresponding trenching to provide electricity, permits, replacing and fixing portions of sidewalks and installing signs and posts”) cost $58,000 per stop.\(^11\) Our high estimate assumes these enhanced upgrades at 20 stops.

- **Smart card fare media:** Implementing a smart card system requires producing and distributing the smart cards, as well as equipping buses with readers. A 2008 study found capital costs of $35.5 million and $47.8 million per 1,000 vehicles.\(^12\) Assuming this would be implemented on all AMA buses, this suggests a rough cost of between $5.3 million and $7.2 million. We use $6.5 million as our “best” estimate. Based on the same study, we estimate annual operating costs as $1 million–$5 million per year, and assume a best estimate of $3 million.\(^13\)

- **Dedicated bus lanes:** Dedicated bus lanes can speed travel times by giving buses their own lane without other traffic. According to 1 study, converting an existing lane on an arterial is estimated to cost $3 million per mile (in 2009 dollars). Assuming a 5-mi route

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10 Transit agency staff, email to Liisa Ecola, May 3, 2018.


12 Iseki, Demisch, Taylor, and Yoh, 2008.

13 Iseki, Demisch, Taylor, and Yoh, 2008. System costs are reported as “lifetime,” and 1 transit agency assumes a lifetime of 15 years. We divide the operating costs per 1,000 peak buses ($99.4 million and $492 million, as reported in Iseki, Demisch, Taylor, and Yoh, 2008, Table 3) by 15 years, and adjust for the MBA’s fleet of 157 vehicles.
is converted, this is estimated at $30 million. The same study suggests operating costs (for road maintenance, not vehicle operating cost) of $11,000 per mile, or $55,000 for a 5-mi route.\footnote{Jeffrey Ang-Olson and Anjali Mahendra, \textit{Cost/Benefit Analysis of Converting Lane for Bus Rapid Transit—Phase II Evaluation and Methodology}, Washington, D.C.: National Academies Press, National Cooperative Highway Research Program Research Results Digest 352, August 2011.}

- **Additional buses:** According to information received from DTOP, a current proposal to improve bus service would require the purchase of 130 new vehicles.\footnote{DTOP, Combined COAs General Review, unpublished (written comments received from FEMA and DTOP), received June 13, 2018.} The per-vehicle cost was estimated at $300,000, for a total capital costs of $39 million. U.S. systems with similar numbers of buses had average operating costs of $45 million per year.\footnote{California Air Resources Board, “Literature Review on Transit Bus Maintenance Cost,” discussion draft, Sacramento, Calif.: California Air Resources Board, August 2016.} For a low estimate of operating cost, we use $42 million, the average of 11 smaller but still comparably sized systems. For a high estimate, we increase the cost by 30%, to $58.5 million, to account for the fact that the AMA has hourly operating costs of 30% above comparably sized systems.

These are meant to be rough order-of-magnitude cost estimates. More specific cost estimates would require detailed estimates of improvements, such as the number of intersections and buses that would be part of a transit signal priority system (in many cities, this system is first rolled out on 1 or 2 corridors, rather than systemwide), or the number of bus stops to be improved. These could also constitute the first steps toward providing BRT on additional corridors with mixed traffic. (BRT is currently provided only on PR-22, a limited access highway.)

### Potential Funding Mechanisms

USDOT, users, advertising, P3s.

Bus services could be supported through a variety of means:

- **Federal funds:** USDOT FTA funds can support most transit projects.
- **User fees:** Bus fares could support improvements, although it would be important to balance these with riders’ ability to pay.
- **Advertising:** Private companies could pay to promote their logos on buses or at bus stations. For example, the Washington Metropolitan Area Transit Authority generates $20 million annually from bus and rail station advertising.\footnote{Washington Metropolitan Area Transit Authority, “Metro Adds 28 New Digital Ad Displays to Increase Revenue,” press release, Washington D.C., September 13, 2016.}
• **Public-private partnerships**: Some bus service in San Juan is already provided by private operators. Expansion of these concessions could provide capital funding for improvements, which could boost ridership and thus fare revenues.

**Implementation**

AMA.

**Potential Pitfalls**

Potential pitfalls include lack of demand leading to reduced bus service revenue and benefits, technological unreliability limiting benefits, and technological change causing improvements to be outdated.

**Lack of demand**: We assume that improvements will boost ridership, as they have in other cities, but if bus ridership has been declining for reasons unrelated to the quality of service (such as outmigration), these improvements may not be successful. Transit ridership has generally been declining throughout the United States in the past few years.\(^{18}\)

**Technology unreliability**: Transit signal priority and real-time information provision both rely on wireless technology that locates buses along a route. As such, they require stable communications networks or they could be considered unreliable by users. Technologies that utilize radio can encounter dead zones that produce inaccurate information.\(^{19}\)

**The pace of change**: With rapidly evolving technologies, such as the ability to provide real-time information to riders, there is always a danger of investing in something that becomes obsolete quickly. In addition, given that in many cases these will require private-sector involvement, there is danger that firms will go out of business while a project is ongoing, leading to operational or potentially financial challenges.

**Likely Precursors**

No precursors have been identified. However, real-time location information is enabled by access to smartphones and wireless communications. If reliable communications services are not available, some of these components will be unreliable or unavailable to certain people at certain times.

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\(^{19}\) Jenna Fortunati, “Transit Agencies Have a Path Forward in Modernizing Real-Time Arrival Information,” Mobility Lab, February 22, 2018.
TXN 9
Develop an Intelligent Transportation System

Issue/Problem Being Solved

Congestion; this COA would improve capacities for detection, response, and clearing of traffic incidents to restore the flow of traffic.

Collecting, managing, and utilizing traffic information will allow for greater coordination between transportation agencies and improved analytic capabilities in the transportation sector. Congestion management projects have been laid out in the New Fiscal Plan for Puerto Rico drafted in April 2018. Puerto Rico has had traffic data collection practices in place since January 2016 in its traffic management center. A traffic management center for PR-52 was anticipated to be completed in December 2018.¹

Description

This COA will develop the capabilities of transportation agencies to provide real-time traveler information to highways and to manage traffic through optimized traffic signalization. In addition to developing the informational capacity, this COA includes incident management, which is designed to clear incidents (e.g., crashes, roadway obstructions) on roadways and safely restore traffic capacity as quickly as possible.

System components include the following:

- dynamic message signs
- closed-circuit television (CCTV) cameras and detectors
- road service patrol
- integration of regional network initiatives
- regional data management initiatives
- operations support initiatives.

The relevant agencies include DTOP, the AMA, the PRHTA, and the Puerto Rico Commission for Traffic Safety. Support would include dedicated funding for a large-scale ITS infrastructure project, as well as several more targeted incident management projects.

Initial implementation of this COA will involve coordinating the relevant transportation agencies to both share data with and receive data from the traffic management center, as well as to assess the ideal placement of CCTV systems and dynamic message signs for communication with travelers. The next step would be the installation of the signs and development of incident

management programs. The benefits would likely be realized as soon as the signs are in operation, and would continue as the ITS is developed. While dynamic message signs would be implemented on major roadways, the system would support other forms of traveler information (such as cell phone alerts and real-time arrival information for buses) across the island. Traffic light timing could be optimized to manage traffic flow under both normal conditions, or with changes to signal timing in the events of heavy congestion or other incidents.

**Potential Benefits**

Intelligent transportation systems, coupled with incident management systems, promise to divert traffic away from incidents, decrease incident response time, as well as mitigate increased probabilities of crashes after an initial incident.\(^2\)

An ITS would provide enhanced traffic analytical capacity that can better inform future decisionmaking for traffic-related planning. Reductions in traffic crashes can reduce emergency services costs, travel times, and travel time variance. In a 2006 study, dynamic message signs and CCTV camera systems were indicated by transportation and emergency services professionals to be some of the ITS technologies with the highest potential benefits.\(^3\) A road service patrol program providing a dedicated service to road incidents, combined with the use of severe incident response vehicles, would monitor the highways on a daily basis to enhance responses to road incidents.

Available cost-benefit analyses indicate that these kinds of projects are both cost-effective and produce savings in the form of reduced crashes and crash-related incidents, but these savings are difficult to quantify and will depend on the specifics of how this COA is scoped.\(^4\)

**Potential Spillover Impacts to Other Sectors**

An ITS could benefit the economic sector by decreasing the costs associated with roadway incidents and potentially increasing productivity previously impacted by congestion and incident related delays.

The communications and IT sector is likely to benefit from increased structural capacities within agencies and any interagency communication gains. In particular, both the CCTV systems and dynamic message signs will require that a large amount of fiber optic communications cable


be laid. Increased information collection capability for roadways and integration of data from transportation and emergency services sectors will increase analytic capabilities across participating agencies and likely contribute to the move toward a data-driven culture.

**Potential Costs**

Potential up-front costs: $30 million in estimated up-front costs (2 years).
Potential recurring costs: $48 million in estimated recurring costs (11 years).
Potential total costs: $78 million in total estimated costs.

The up-front cost estimate is between $20 million and $40 million, depending on the level of coverage the project aims to achieve. We assume an up-front cost of $30 million.

The cost of implementing this COA will vary with the scope of the system(s) being developed and, in particular, the scale of the investment made in developing ITS infrastructure. Program-specific cost estimates are based on 2 sources with similar programs: Broward County, Florida, where a large traffic incident management program took effect in 2005, and the Los Angeles County Regional Integration of Intelligent Transportation Systems (RIITS), which developed its *RIITS Ten-Year Strategic Plan* in 2010. This plan includes regional data management, operations support services, and integration of regional network services.

The capital cost estimate of $30.1 million consists of dynamic message signs ($11 million) and CCTV and detection systems ($18.3 million), which would need to be installed for the system to be operational. The capital cost also includes $800,000 in investments in regional data management, operations support services, and integration of regional network services. The annual cost estimate is $4.6 million and consists of DMS maintenance and operating costs ($818,000), CCTV system maintenance costs ($167,000), road service patrol and severe incident response vehicles ($2.8 million), and annual strategic initiative costs ($800,000). The low and higher estimates assume a 30% reduction or increase in costs based on the “best” estimate.

Detailed estimates based on Los Angeles County’s *RIITS Ten-Year Strategic Plan* are provided in Table A.3. It is worth noting that these are estimates for a 10-year plan and as such are subject to inflationary changes or other unforeseen economic factors. Additionally, to scale

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5 FHWA, 2007.
6 Los Angeles County Metropolitan Transportation Authority, *RIITS Ten-Year Strategic Plan*, Los Angeles: Los Angeles County Metropolitan Transportation Authority, 2010.
7 FHWA, 2007.
8 These are based on the first-year costs to implement similar items in the *RIITS Ten-Year Strategic Plan*.
9 FHWA, 2007. Annual strategic initiatives costs are based on ongoing costs to implement the *RIITS Ten-Year Strategic Plan* past the first year.
this project from Los Angeles County to Puerto Rico, we scaled costs downward based on population. This simple scaling is not perfect, but is used to get a more accurate cost representation of creating ITS infrastructure to serve 3.3 million residents rather than over 13 million.  

With this scaling, regional data management is estimated to cost $1.8 million, operations support services are expected to cost $5.2 million, and integration of regional network services is estimated to cost $1 million. These costs are divided among the 10 years over which the plan is designed to take place, yielding $180,000, $520,000, and $100,000 as the annual cost estimates for regional data management, operation support services, and regional network services, respectively.

### Table A.3. Cost Estimates Based on the RIITS Ten-Year Strategic Plan

<table>
<thead>
<tr>
<th>Action/Initiative</th>
<th>Cost</th>
<th>Cost Scaled for Puerto Rico Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Data Management</td>
<td>$7,063,000</td>
<td>$1,765,063</td>
</tr>
<tr>
<td>Regional data archive enhanced</td>
<td>$2,556,000</td>
<td>$638,751</td>
</tr>
<tr>
<td>Filtered data and custom queries</td>
<td>$1,550,000</td>
<td>$387,349</td>
</tr>
<tr>
<td>Performance measurement</td>
<td>$2,015,000</td>
<td>$503,554</td>
</tr>
<tr>
<td>Travel forecasting and modeling</td>
<td>$942,000</td>
<td>$235,408</td>
</tr>
<tr>
<td>Operations Support Services</td>
<td>$20,799,000</td>
<td>$5,197,726</td>
</tr>
<tr>
<td>Regional event reporting</td>
<td>$3,569,000</td>
<td>$891,903</td>
</tr>
<tr>
<td>Regional video sharing</td>
<td>$8,371,000</td>
<td>$2,091,935</td>
</tr>
<tr>
<td>Enhanced situational awareness</td>
<td>$8,859,000</td>
<td>$2,213,888</td>
</tr>
<tr>
<td>Integration of Regional Network Services</td>
<td>$4,188,000</td>
<td>$1,046,592</td>
</tr>
<tr>
<td>Regional portal for internet service providers / developers</td>
<td>$1,454,000</td>
<td>$363,358</td>
</tr>
<tr>
<td>Common ITS field device broker</td>
<td>$900,000</td>
<td>$224,912</td>
</tr>
<tr>
<td>Data consolidator for Southern California 511</td>
<td>$1,064,000</td>
<td>$265,896</td>
</tr>
<tr>
<td>Data consolidator for Los Angeles Congestion Reduction Demonstration Program</td>
<td>$770,000</td>
<td>$192,425</td>
</tr>
</tbody>
</table>

**SOURCE:** Los Angeles County Metropolitan Transportation Authority, 2010, p. 71.

### Potential Funding Mechanisms

CDBG-BR, USDOT.

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The DHS also offers grant programs that could be utilized for funding: the Emergency Operations Center Grant Program and the Interoperable Emergency Communications Grant Program.\textsuperscript{11}

**Implementation**

PRHTA.

**Potential Pitfalls**

Lack of skilled workers, interagency communication, and interagency cooperation could limit benefits. ITS infrastructure will require analysts and programmers able to set up and manage relevant software and databases, as well as workers trained in transportation management to use the systems. Benefits could be impeded if these skills are lacking in the Puerto Rican labor force. The coordination of multiple agencies is also key to this COA’s success. If there are issues in the communication and cooperation of relevant agencies, benefits may be limited.

**Likely Precursors**

It is possible that fiber optic cable may need to be upgraded. Further technical analysis would be required to understand precursor needs in terms of available telecommunications infrastructure.

\textsuperscript{11} Los Angeles County Metropolitan Transportation Authority, 2010.
Issue/Problem Being Solved

Puerto Rico lacks adequate redundant seaport capacity. Because of the island’s dependence on arrival of goods by sea, a major disruption (natural disaster, vessel sinking, or other similar shock) that affects the Port of San Juan could lead to cascading impacts for food security, energy distribution, and community sustainability.

Current emergency plans fail to identify the loss of the Port of San Juan as a significant hazard or designate alternative transportation routes for critical commodities; as of 2010, 84% of fuel oil, 70% of gasoline, 93% of food products, and 97% of manufactured equipment and machinery imported into Puerto Rico enter through the Port of San Juan, making it a sole source and key transshipment node. Moreover, no formal agreements exist designating an alternate port, and without advance planning, there is a risk of ill-informed decisionmaking and inability to recover in a timely manner. There will likely be cascading and significant impacts to food inventories, fuel supplies, and electrical power after 3 weeks of disruption in the port. Due to just-in-time inventory policy and very limited emergency storage capacity, perishable food supplies would be significantly impacted.

Loss of the Port of San Juan’s capability to receive petroleum products would have significant effects on the island’s energy supplies. The 3 fuel docks in San Juan harbor receive 70% of all inbound petroleum product shipments. While other ports on the island also import petroleum products, planning efforts do not fully address the effects of a port closure in San Juan or alternate methods of transportation, including logistic elements such as upstream, midstream, and downstream components.

Description

This COA recommends additional development at an existing seaport to create a sustainable redundant capacity for the arrival of maritime goods in the event of the loss of the Port of San Juan due to a natural or man-made disaster. The ports of Ceiba (Roosevelt Roads), Mayagüez, and Ponce are prime candidates based on their strategic locations and available capacity.

The government of Puerto Rico would initiate and maintain oversight of a new project to develop a seaport in Puerto Rico to create redundancy in the case of a natural or man-made

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disaster. The project would be funded through a P3 using federal grants, government of Puerto Rico funds, and private industry investment to achieve success and spread risk across multiple entities. The development of a redundant port would require the establishment of a large project management team to create a sustainable approach that leverages private business development and federal grants for resiliency. The development of a redundant seaport would create opportunities for disaster relief and economic growth on the island, as well as humanitarian assistance in surrounding Caribbean nations.

As a first step, emergency management authorities should initiate an exercise simulating the loss of the Port of San Juan and the surrounding infrastructure to better identify the gaps and challenges to shift the import of food and petroleum resources to a separate port. This exercise should identify required alternate port capacity, including offloading, storage, and follow-on transportation to end users along potentially damaged road systems.

**Potential Benefits**

This COA could help prevent devastating losses to the economy and population in the event of another disaster that cripples the capability of the Port of San Juan to receive food and fuel supplies. As demonstrated during the 2017 hurricanes, Puerto Rico’s food and fuel supplies depend on the ability for these goods to arrive via the maritime domain. Currently, the island receives 100% of its fuel and approximately 80% of its food through maritime transportation. Only 1 seaport on the island of Puerto Rico is prepared today to receive a high percentage of those arrivals. In the event another disaster cripples the capability of the Port of San Juan to receive these goods, the island economy and population risks devastating losses without implementation of this COA.

Ports connect island communities to the outside world; as 1 article notes, “contemporary seaports are key strategic and functional service nodes, constituting a range of value-adding business activities” that are vital to the health of an island.² As such, seaports need to be particularly resilient for island communities. The following strategies can be used to create resiliency in the event of a shutdown of a port: ship rerouting, export diversion (i.e., keeping items on the island instead of exporting them), use of inventories (i.e., those already existing on the island), conservation of resources (i.e., using fewer imported goods), unused capacity (i.e., manufacturing or food production), input substitution (i.e., use of LNG and/or coal instead of

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diesel), import substitution (i.e., prioritizing imports), and production recapture (i.e., overtime shifts).  

In the case of Puerto Rico (due to lack of exports, just-in-time inventory, lack of resources, and lack of production), the only options are ship rerouting to another port on the island or restructuring on-island capacities to increase inventory of food and petroleum supplies. The only option for a long-term shutdown is rerouting to another port, which requires port redundancy. The short-term benefits of developing an additional port include job creation, infrastructure improvements, and capacity growth. Long-term benefits include potential ability to compete for a portion of the world shipping market share as a transshipment location, humanitarian aid and disaster recovery during future events, and (if designed properly) resiliency against climate change, rising sea levels, and stronger storms.

**Potential Spillover Impacts to Other Sectors**

This COA positively impacts the CPCB, economic, and energy sectors. Development of a redundant port will provide job opportunities, competition, diversification, community development, and redundancy and resiliency in supply of oil for the energy sector.

A relevant news article claims that the employment impacts of ports are positive and are usually higher for the service sector than for the industrial sector. Empirical evidence underlines that port infrastructure investment projects do foster economic development and are important when a port is nearing its operational capacity.

**Potential Costs**


This action was costed at 50% implementation in the *Recovery Plan*.

The estimate for the ports of Ceiba and Mayagüez are $174 million and $315 million, respectively, based on detailed estimates from MARAD for structural improvements; dredging; cargo, ferry, and fueling operations; acquisition of additional land; and pier structures to support humanitarian assistance and disaster relief operations. Feasibility assessments for this type of increase in port capacity were not conducted for the Port of Ponce. Per personal communication

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with officials at the Port of Ponce, additional improvements could include realignment of Berths 2 and 3 to handle 2,500-ft berthing and providing a bulkhead for Pier 8, to provide increased resilience.

The estimate for annual operating costs (for any selected port) is $3 million–$5 million, based on recent budgets of $3.3 million and $4.3 million for comparably sized ports. Table A.4 shows cost estimates for creating redundant seaport capacity.

### Table A.4. Cost Estimates for Creating Redundant Seaport Capacity

<table>
<thead>
<tr>
<th>Port/Element</th>
<th>Cost (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roosevelt Roads</strong></td>
<td></td>
</tr>
<tr>
<td>Restore fuel pier operations</td>
<td>$45</td>
</tr>
<tr>
<td>Establish cargo and ferry operations</td>
<td>$37.8</td>
</tr>
<tr>
<td>Humanitarian assistance and disaster relief forward-staging base (including pavement, fencing, utilities, demolition, building renovation/new buildings, and soft costs)</td>
<td>$91</td>
</tr>
<tr>
<td><strong>Mayagüez</strong></td>
<td>$314.6</td>
</tr>
<tr>
<td>Increase depth of channel to 35 ft, with 2 ft advance maintenance</td>
<td>$100.7</td>
</tr>
<tr>
<td>Expand dock berth</td>
<td>$139</td>
</tr>
<tr>
<td>Connect PRIDCO and municipal docks</td>
<td>$29.8</td>
</tr>
<tr>
<td>Develop ferry service and Customs and Border Patrol pier</td>
<td>$44.9</td>
</tr>
<tr>
<td>Restore PRIDCO and GABSCO docks with resilient design</td>
<td>$65.8</td>
</tr>
<tr>
<td>Contingency/soft costs</td>
<td>$84.9</td>
</tr>
</tbody>
</table>

**SOURCES:** Roosevelt Roads: DCM Architecture & Engineering, “Naval Station Roosevelt Roads, Puerto Rico, Feasibility Assessment for Ferry and Cargo Operations, Task 002,” Camden, N.J.: DCM Architecture & Engineering, March 28, 2018b, unpublished manuscript; DCM Architecture & Engineering, 2018a; Mayagüez: MNW, 2018a, Table 6. **NOTES:** The Mayagüez project includes pier expansion and rehabilitation for the East Pier, Municipal Bulkhead, PRIDCO Bulkhead, and West Pier, as well as dredging, cargo operations, and ferry facilities. For both projects, it assumes that repairs noted elsewhere would also be undertaken.

There is substantial variability in costs depending on the port that is chosen for additional investment. The primary ports with appropriate infrastructure and channel depth to serve as a redundant port include Ceiba, Ponce, and Mayagüez. Each port has distinct advantages and challenges.

The Port of Ceiba was once Naval Station Roosevelt Roads, but it has deteriorated over the decade since it was decommissioned by the Navy and requires significant investment to bring it to bare minimum capability to offload cargo. It would not possess as much capacity and capability as currently exists at the Port of San Juan and would not have as much depth as the

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Port of Ponce. With additional resources, the Port of Ceiba could match the Port of San Juan in capability and capacity for cargo operations, but would still have the challenge of distance to transport goods to the population center located in San Juan, requiring road infrastructure investment (e.g., expansion of Route 66). Ceiba could also possibly serve as a tourist destination for cruise ships, as it is closer to the smaller resort islands of Culebra and Vieques. Roosevelt Roads is also being considered for additional redevelopment by Puerto Rico, including moving the ferry system supporting outlying islands to the port, which would further stimulate tourism.

The Port of Ponce is the only deepwater port on the island (with a depth greater than 50 ft), and it has adequate pier and holding space to support cargo operations, but it requires reconstruction, repair costs, and infrastructure development for cranes. It would also have the challenge of distance to transport goods to the population center in San Juan, but would possess the additional advantage of competing for global shipping as a transshipment port among all Caribbean islands if economic incentives (lower cost for ship arrivals) were created. Ponce is strategically located on the south coast of Puerto Rico, shielded from the North Atlantic storm approaches. An approach to develop the Port of Ponce as a multipurpose port could possibly add to its redundancy value if supported by accompanying transportation infrastructure investments.

The Port of Mayagüez has many disadvantages but remains an important major strategic port despite its limitations. The port routinely receives critically needed food, fuel, and other supplies to support a major city and surrounding populous via barge and smaller coastal freighters. The port is also strategically located, on the western end of the island, exposed only to the Mona Passage and in the lee of Rincón to the north and Cabo Rojo to the south, thus providing a safe haven for maritime traffic to avoid adverse weather conditions from the North Atlantic and Caribbean. Additionally, the majority of hurricane paths originate from the east. The Port of Mayagüez does not have the deepwater capability of Ponce, is farther from San Juan than the other ports, and has not had investment to support expanded cargo operations comparable to Ponce or San Juan. It too would require a significant investment modernization, and it would not have the land storage capacity of either of the other locations.

Based on operating costs from comparably sized ports in the United States, all 3 options would likely require at least $4 million in annual operating costs to maintain their ability to function as a redundant port.6 These costs for the government would depend on the P3 arrangement.

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6 Port of Olympia Income Statement—Management Format 2017 Budget, 2017, Olympia, Wash.: Port of Olympia, October 27, 2016 ($4.3 million); Port of Port Angeles, Port of Port Angeles 2018 Budget, Port Angeles, Wash.: Port of Port Angeles, undated ($3.7 million); City of Pensacola, Fiscal Year 2013 Approved Annual Budget for the Year Ending September 30, 2013, Pensacola, Fla.: City of Pensacola, 2013 ($4.6 million).
Potential Funding Mechanisms


The USDOT provides Better Utilizing Investments to Leverage Development (BUILD) grants ($1.5 billion in 2018), which are awarded on a competitive basis for projects that have a significant local or regional impact. BUILD funding can support roads, bridges, transit, rail, ports, or intermodal transportation.7

The Port Security Grant program ($100 million in 2017), administered by the USCG, provides annual funding to support security measures across U.S. ports.

FEMA’s Pre-Disaster Mitigation Grant Program assists states, U.S. territories, federally recognized tribes, and local communities with a goal of reducing overall risk to the population and structures from future hazard events while also reducing reliance on federal funding in future disasters.8

Additionally, P3s can be used to develop redundant port capacity.9

Implementation

PRPA, port authorities, port operators.

Potential Pitfalls

There is high potential for a redundant port to fall into disrepair and become unable to perform as a redundant port if not used regularly for private commerce or government use.

The Rafael Cordero Santiago Port of the Americas in Ponce demonstrates the potential pitfalls of creating increased capability in a port without the follow-on economic activity to sustain the business model. Beginning in 2011, the government of Puerto Rico invested $285 million into the Port of the Americas to develop it as a transshipment port on completion of the expansion of the Panama Canal.10 However, global shipping companies were not attracted to the port despite it being the deepest port in the Caribbean. In 2018 it was reported that all of the newly purchased cranes, including 2 new Super Post-Panamax cranes, were inoperable due to lack of maintenance; the port would not be able to offload containers today if required to.

8 FEMA, “Pre-Disaster Mitigation Grant Program,” webpage, updated August 8, 2018.
10 American Shipper staff, 2014.
Likely Precursors

Creation of a P3 and associated project management plans.
Issue/Problem Being Solved

Much of Puerto Rico’s transportation infrastructure has suffered from lack of regular maintenance, and centralized information on conditions, age, and other pertinent information is not readily available to facilitate long-term management of these assets.

Description

This COA will support public agency efforts to inventory the transportation infrastructure assets that they manage and to develop or improve systems for tracking the conditions of these assets and for selecting and scheduling maintenance and repair activities. Assets may include pavements, bridges, and ancillary assets such as culverts and signage. Support includes dedicated funding for, and the arranging of, inventory surveys, asset condition testing, infrastructure management software development, and staff training. This is particularly important given the widespread damage to assets in the aftermath of the hurricanes. Relevant systems can include systems for managing government of Puerto Rico or local roads, public transportation assets, or assets at ports or airports.

Transportation infrastructure asset management refers to the plans, policies, and processes used to keep physical facilities in a condition that enables the safe and efficient movement of people and goods. Asset management is of particular concern for state and local government agencies in the United States that oversee networks of assets but have limited resources to use for maintenance, repair, and rehabilitation activities. Sophisticated asset management systems are software suites that include databases that store data collected by agencies on the condition, use, and functionality of assets they manage in order to help asset managers allocate resources. Not all agencies have such sophisticated systems or the data, trained staff, and other resources needed to make use of such systems.

The PRHTA has a pavement management system and uses the American Association of State Highway and Transportation Officials’ BrM bridge management software. However, “the agency’s constrained finances have not allowed the Authority to adequately invest in data collection, data analysis, and training to fully use the pavement management system.” The agency also notes that, when it comes to BrM, it “lacks the staff to fully develop the model’s ability to forecast and analyze investment scenarios.”¹ The cited document includes a high-level plan for improving asset management practice at the PRHTA that includes staff training and

¹ PRHTA, April 2018a.
software evaluation, among other things. Municipalities in charge of smaller-scale public works such as sidewalk repair could benefit from infrastructure asset management systems as well.

The World Bank has a long history of supporting efforts to develop and use asset management systems in developing countries where fewer resources are available. For example, the World Bank and the Global Facility for Disaster Reduction and Recovery are supporting the development of a “sustainable risk-based asset management system” in Dominica in response to devastation on the island’s transportation infrastructure wreaked by Tropical Storm Erika.¹ As part of this effort, the two organizations have sponsored workshops and training sessions involving a senior asset management consultant, engineers from Dominica’s Ministry of Public Works and Ports, and other officials.³ Other recent relevant World Bank projects include the Second Road Asset Management Project for Cambodia, the Results-Based Operation for Local Bridge Construction and Road Asset Management Project for Vietnam, the Transport Connectivity and Asset Management Project for Sri Lanka, and the Secondary Road Asset Management Project for Georgia.⁴ This list only includes World Bank projects approved between March 18, 2016 and May 19, 2016.

The public sector would be primarily responsible for enacting this COA, although the private sector could help with software provision and staff training. Relevant agencies include the PRHTA and municipalities.

Initial implementation involving the development of asset inventories and the setup and refinement of an asset management system could be accomplished in 1 or 2 years. There would, however, be reasons to dedicate some funding to activities that occur further into the future and on a recurring basis.

**Potential Benefits**

Infrastructure asset management systems have, historically, led to reductions in asset maintenance costs and improvements in the serviceability offered by transportation assets.

A 1982 paper on 1 of the first infrastructure asset management systems, the Arizona Pavement Management System, claimed that the state saved $14 million in its first year of using the system and was forecast to save over $100 million over the next 4 years without sacrificing

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serviceability.\textsuperscript{5} It is important to note that the authors of the cited study were the developers of the system in question; it is generally difficult to obtain data on the benefits of such systems from analysts who do not develop or promote such systems. A more recent study found that implementing a system for managing the State of Vermont’s highway network “improves pavement condition at 10.1 points on a 0–100 point scale” and that the federal government’s effort to develop the national HERS-ST tool for highway management produced “agency, user, and external benefits [that] may reach to $359 million over 10 years and $2.0 billion over 25 years.”\textsuperscript{6} Figure A.3, from the cited study, provides a schematic diagram of the relationship between asset management, cost, and performance.

\textbf{Figure A.3. Benefits of Asset Management}

![Figure A.3. Benefits of Asset Management](image)


\textsuperscript{6} McNeil and Mizusawa, 2008.
followed by bridge management, and later water pipeline and energy infrastructure management. It would seem logical to develop and utilize management systems in the communications and IT sector. The literature on this point is scarce, likely because private organizations are responsible for much of the relevant infrastructure. The systems used to manage buildings, sometimes called building information management systems, are subtly different from those considered in this COA. For this reason, there is cause to think that this COA could lead to change in the energy and water sectors. It could also—although this is less likely—impact the housing and public building sectors.

In addition, successful implementation of this COA could benefit capacity building and municipalities. Municipalities may obtain tools for infrastructure asset management that enable them to save money or improve the condition of the assets that they manage. Staff training will build capacity at public agencies.

**Potential Costs**

Potential up-front costs: $5 million in estimated up-front costs (2 years).
Potential recurring costs: $1 million in estimated recurring costs (11 years).
Potential total costs: $6 million in total estimated costs.

The estimate for this COA is $6 million, split evenly between efforts to inventory assets and improve asset management systems and system use. The cost of implementing this COA will vary with the scope of the system(s) being developed and, in particular, the scale of the investment made in obtaining an inventory of the infrastructure being managed.

Recent estimates of the cost of infrastructure asset management systems are largely unavailable. The capital and operating costs for the Alberta Pavement Management System were reported to be Can$495,000 in 1980, with annual operating costs of just under Can$1 million in 1989, including “all staff and equipment time (including outside contractors) and equipment operating costs for field and office data collection and entry.”7 More recently, the Executive Budget: Fiscal Years 2018 and 2019 for the State of Michigan includes a request for $2 million “to implement a pilot for a statewide asset management database to better align and coordinate infrastructure needs.”8 The government of the District of Columbia has provided just under $3 million in “total budget authority” to its development of the Capital Asset Replacement

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Scheduling System, an effort that has drawn praise.\textsuperscript{9} It is not clear what portion of these funds will go toward software acquisition versus labor.

Outside of the United States, the Global Facility for Disaster Reduction and Recovery is managing a project in Dominica entitled “Improving the Resilience and Affordability of Roads and Bridges.” This focuses on developing an asset management system to “systematically track infrastructure conditions, perform comprehensive and detailed vulnerability disaster assessments of the road network, and prepare an investment mitigation action plan.” The total project is valued at just over US$1 million.\textsuperscript{10}

There would also be ongoing costs, most notably to cover the time taken up by a trained IT professional or engineer responsible for the asset management system. Here, we assume 1 such professional at a cost of roughly $125,000 per year. This cost estimate is based on doubling the average, fully burdened cost of government labor in Puerto Rico.\textsuperscript{11}

**Potential Funding Mechanisms**

USDOT.

Specific programs that are potential funding mechanisms include Chapter 1 of Title 23 funds, the HSIP, the NHPP, and the STBGP.

**Implementation**

PRHTA.

**Potential Pitfalls**

Failure to train, attract, and retain a skilled workforce could limit benefits, as could failure to integrate asset management into decisionmaking.

The use of sophisticated transportation infrastructure asset management tools requires analysts and programmers who are able to set up and manage relevant software and databases, as well as engineers trained to conduct the asset assessments and utilize the tools. This COA could fail to deliver benefits if agencies lack the necessary skilled workforce or if staff training is


\textsuperscript{10} Global Facility for Disaster Reduction and Recovery, “Dominica,” webpage, undated.

\textsuperscript{11} For further detail on the cost methodology used in the *Recovery Plan*, please see the cost and funding methodology report available at RAND Corporation, *Supporting Puerto Rico’s Disaster-Recovery Planning*, spring 2019.
insufficient. Staff turnover among analysts and programmers is particularly relevant; the needed tools are typically managed by a relatively small number of staff. The need to integrate the use of infrastructure asset management systems into budget planning and the benefits of regularly collecting condition data to support such systems are also relevant.

**Likely Precursors**

No precursors have been identified.
TXN 12
Repair Damage to Ports and Ferry Terminals

Issue/Problem Being Solved

Puerto Rico’s ports and ferry terminals sustained substantial damage during Hurricanes Irma and Maria. In many cases there was damage from before the hurricanes, or conditions that were worsened by the hurricanes.

Damage at ports includes damage to ramps and wharves, electrical damage from flooding, building damage to roofs and windows, and damage to water distribution and fire suppression systems. While no ports are entirely nonoperational due to damage, all ports suffered some degree of damage.

Description

This COA will repair damage to Puerto Rico’s ports and ferry terminals that constrains their current use, and specifically in the import of key goods, such as food and fuel.

FEMA requested that assessments of ports, including both landside facilities and underwater infrastructure, be conducted by MARAD. (While the PRPA also conducted assessments of ports under its jurisdiction, these assessments did not include underwater damage and thus are generally superseded by the MARAD assessments.) The FTA conducted assessments of ferry terminals and vessels.

Potential Benefits

Repairing Puerto Rico’s ports and ferry terminals should keep them in good repair so that they can be available at their full capacity in the future. In addition, it provides some redundant capacity in the event that a major port is unavailable in a natural disaster or after some other major disruption.

For example, 1 important repair is to the 2 Post-Panamax cranes at the Port of Ponce. These cranes were installed in 2010 and were nonoperational before the storms due to lack of maintenance. The Port of Ponce is the second largest port in Puerto Rico and the only port besides the Port of San Juan capable of handling container ships. Without repair to these cranes, there is no alternative for container ships to berth if there is insufficient capacity at the Port of San Juan.

Potential Spillover Impacts to Other Sectors

Ensuring that the ports are fully functional would be beneficial to Puerto Rico’s economic well-being given its reliance on imports. Engineering and construction can also provide short-term employment opportunities.
Potential Costs

Potential up-front costs: $940 million in estimated up-front costs (9 years).
Potential recurring costs: $46 million in estimated recurring costs (11 years).
Potential total costs: $990 million in total estimated costs.

Up-Front Cost Assessments: The up-front cost estimates are based on assessments conducted by MARAD and the PRPA (for cruise ship and cargo ports), as shown in Chapter 3, Table 3.5, and the FTA (ferry terminals), as shown in Chapter 3, Table 3.7 (in both cases, costs are shown in the column “Cost to Repair to Functionality”). Based on this information, the current cost estimate is $946 million: $908 million for cargo and cruise ship ports, and $38.4 million for ferry terminals. In some cases, the repair costs are the costs of complete replacement, since the existing facilities have been judged too damaged to be repaired. (Costs rounded to two significant digits.)

Port Operations and Maintenance Estimates: Cost estimates for maintaining the critical infrastructure and operating the most important ports to sustain recovery operations and provide greater resiliency are based on a 2016 PRPA audit. This audit shows that for FY2016, “rent, repair, and maintenance” operating expenses were $2.7 million. As the PRPA administers the Port of San Juan and smaller ports, we assume this figure would cover maintenance at those ports. Given inflation, we adjust this upward to $3 million. Based on relative port size, we adjust downward to include annual maintenance costs at 3 other ports: Ponce, at $1.5 million; Mayagüez, at $1.0 million; and at Roosevelt Roads, $1.0 million. This brings ongoing costs to keep port assets in a state of good repair to $6.5 million per year.

Potential Funding Mechanisms

FEMA Public Assistance Grants, USDOT, CDBG-BR, private sector, private insurance. Funding sources could include:

- FEMA programs (Public Assistance and CDBG-DR)
- FTA funding for ferry terminals
- government of Puerto Rico assistance (through the PRPA)
- shared tax or user fees imposed on port owners, shippers, other MTS users
- lease arrangements with port developers and operators, shipping lines.

Implementation

Mayagüez Ports Commission, Ponce Port Authority, PRPA, Puerto Rico Maritime Transportation Authority, private port operators.

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1 PRPA, 2016.
Potential Pitfalls

Lack of demand, ongoing maintenance needs, and lack of coordination could pose challenges. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

Lack of demand: There is an assumption that there will be sufficient future demand and that the amount of port capacity needed in the past will continue to be the same in the future. If outmigration continues and economic activity declines, there is a danger of overinvestment. Scarce revenues could be spent shoring up all ports when a smaller number of ports might be sufficient to meet the demand for imports. If some services are moved (e.g., there is discussion of moving ferry service from Fajardo to Roosevelt Roads), repairing that infrastructure would not be necessary.

Ongoing maintenance needs: While these capital investments may be sound, repairing major ports without sufficient future funding and attention dedicated to maintenance will result in the eventual loss of functionality (as in the example of the cranes at the Port of Ponce). Any major capital investments should be accompanied by a plan for, and dedicated funding to pay for, routine scheduled and other necessary maintenance.

Lack of coordination: Given the centrality of the port system to an island economy, repairs should be prioritized such that the most important ports receive attention first. It is probably unrealistic to carry out all repairs at the same time given finite amounts of skilled labor, parts, and funding, so a prioritization exercise based on costs and benefits should be undertaken.

Likely Precursors

No precursors have been identified.
Reassess the Marine Transportation System Recovery Plan

Issue/Problem Being Solved

Contingency planning for the Port of San Juan is not fully coordinated with all critical stakeholders. Comprehensive coordination and documentation of multijurisdictional activities have not been accomplished. There is a lack of both coordination and documentation of multijurisdictional activities that have been identified as significant for effective emergency management. During meetings and discussions with port operators (particularly in areas other than San Juan), it became apparent that there were no formal plans in place to address recovery of the port in the event of a disaster.

Description

This COA will reevaluate the Marine Transportation System Recovery Plan to assign key roles to partners to identify reserve capacities and pre-positioned response assets, establish an integrated operations center, develop a communications protocol for first responders during a disaster, and implement prestorm protection measures in an integrated fashion to protect critical resources.

The Marine Transportation System Recovery Plan was developed by maritime partners and stakeholders in the Captain of the Port Zone and includes lessons learned from real-world operations and exercises. The plan was updated in 2015, but the 2017 hurricane season provides an opportunity to address lessons learned that will be useful during both contingency planning and postincident activities following a significant MTS disruption. The 2006 Maritime Recovery and Restoration Task Force Report following Hurricane Katrina established the USCG as the leader for recovery during any incident that significantly impacts maritime transportation. It also recognized that USCG captains of the port serving as Federal Maritime Security Coordinators and Federal on Scene Coordinators are uniquely positioned to coordinate short-term MTS recovery activities. As such, the USCG should lead the reassessment of the Marine Transportation System Recovery Plan through the Area Maritime Security Committee as outlined in the Maritime Transportation Security Act to facilitate system stabilization and short-term recovery during the response phase of incident management (notionally less than 90 days), assist in the transition from short-term recovery to long-term recovery efforts performed by others, support long-term recovery through steady-state activities, and maintain domestic maritime commerce and global supply chain security. The USCG’s Navigation and Vessel Inspection Circular No. 9-02,
Change 4 and Commandant Instruction 16000.28B provide detailed guidance and a template for the Marine Transportation System Recovery Plan.¹

In addition to reassessing the plan, stakeholders should identify physical resources that will enhance recovery that may not be required or necessary in other ports due to Puerto Rico being an island dependent on the MTS for arrival of goods. These physical resources should include equipment to repair critical infrastructure in the port, pre-positioned response assets, and identification of prestorm protection measures to protect these resources. This portion of the plan should also identify an integrated operations center to support recovery operations, including assessing whether a mobile command center should be purchased in the event of the loss of the primary building.

Potential Benefits

An updated Marine Transportation System Recovery Plan would take advantage of lessons learned during Hurricanes Irma and Maria to further develop a precoordinated disaster recovery plan for the various ports in Puerto Rico. An updated plan will ensure that Puerto Rico can recover quickly in the event a future disaster disables or disrupts port activity with cascading effects to the health, safety, and security of the population.

Moreover, the identification of an integrated operations center, along with primary and secondary communications, will be critical to facilitate communications between decisionmakers following an incident or disaster. Establishing pre-positioned assets, materials, and equipment will be necessary to quickly recover from a disaster and reopen a port or divert ship arrivals to an alternate port.

Potential Spillover Impacts to Other Sectors

This COA could have a positive impact on all sectors since maritime trade either directly or tangentially influences every aspect of life on an island. A more robust recovery plan will ensure that maritime trade and port operations are resilient and responsive to disasters.

Potential Costs

Potential up-front costs: $100,000–$300,000 in estimated up-front costs.
Potential recurring costs: $200,000 in estimated recurring costs (11 years).
Potential total costs: $300,000–$500,000 in total estimated costs.

Our up-front estimate ranges from $100,000 to $300,000, with $20,000 annually in ongoing costs for in-person training or exercises to cover personnel travel, the facility, and any communication requirements (webcast, etc.). This is similar to the estimate for AEPs (TXN 6), whose costs were estimated by the PRPA. Reassessing the Marine Transportation System Recovery Plan will incur minimal costs, as the plan is required to be reviewed regularly by the Area Maritime Security Committee in accordance with the Maritime Transportation Security Act. Implementing portions of the plan, including pre-positioned assets and the establishment of an integrated operations center, may cost up to $250,000, but these estimates may vary depending on new regulations that could be imposed, so they are not included.

The most expensive component of this COA will be the establishment of an integrated operations center, which might include communications (landline and internet connections) and leasing arrangements for physical buildings. The General Services Administration gives an example of costs for command center vehicles.²

Potential Funding Mechanisms

USCG, FEMA Pre-Disaster Mitigation Grant Program, PRPA.

The Port Security Grant program ($100 million in 2017), administered by the USCG, provides funding to support security measures across U.S. ports. This grant program would substantially offset the initial costs surrounding the establishment of fencing, lighting, buildings, and other infrastructure needed to create a secure port and can be competed for and awarded annually.

FEMA’s Pre-Disaster Mitigation Grant Program is designed to assist states, U.S. territories, federally recognized tribes, and local communities in implementing a sustained predisaster natural hazard mitigation program. The goal is to reduce overall risk to the population and structures from future hazard events while also reducing reliance on federal funding in future disasters. This program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strikes.³

Implementation

PRPA, USCG, maritime stakeholders.

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³ FEMA, 2018b.
Potential Pitfalls

Establishing consensus among partners on final approval of the plan could be challenging. There may be disagreement about funding priority levels and establishing responsibilities for maritime port partners within the *Marine Transportation System Recovery Plan*. If any agency is unwilling or unable to support components of the plan, this will lead to weaknesses in execution.

Likely Precursors

No precursors have been identified.
Long-Term Planning to Develop Port of Ponce as a Regional Transshipment Hub

Issue/Problem Being Solved

Puerto Rico is well situated geographically to serve as a major transshipment port, but does not currently function in that role. Investment in the Port of Ponce could help the port keep pace with forecast changes in worldwide shipping, both increasing resiliency and allowing the port to eventually serve as a major Caribbean transshipment hub, while providing regional feeder services to the eastern and southern Caribbean.

Description

This COA will invest in the Port of Ponce and provide an economic incentive, such as reduced taxes or government subsidy, for shipping agencies to use the Port of Ponce as a primary transshipment point for North and South America on a proposed circumequatorial distribution network.

Puerto Rico lies on the shortest route between the Panama Canal and major European transshipment ports and could support transshipment for the east coasts of both North and South America. Additionally, it is 1,000 nautical mi shorter to transit through the Panama Canal from Shanghai to Rotterdam than it is to go through the Suez Canal. This COA could address the existing overcapacity of terminal space at Ponce and may make Ponce competitive with ports in Freeport, Bahamas; Cartagena, Colombia; Mariel, Cuba; and Kingston, Jamaica.

Industry experts believe that the expansion of the Panama Canal is opening a new phase for transshipment in the Caribbean. At a global level, only 17% of maritime freight traffic involves direct connections between ports. Transshipment is a fundamental aspect of maritime shipping networks. Hub ports have a transshipment incidence around 50%. While they function as transshipment hubs, they also service their hinterland (the inland area supplying goods to a port), implying a complex and shifting balance between the gateway and transshipment functions. In many cases, the hinterland traffic acts as an anchor to transshipment traffic and enables capturing additional traffic from other ports not directly called by the shipping lines serving the hub port.

Many smaller ports in the Caribbean are feeder ports that can access global shipping networks only through a regional transshipment hub. Further, regional transshipment hubs can also link long-distance shipping services handling transshipment between North America and western Africa. This may be a timely, strategic option for Puerto Rico to expand its footprint in the Caribbean by helping the Port of Ponce become a more attractive port and become better positioned for expansion as a transshipment hub as Post-Panamax ship numbers increase in the coming years.
Unlike bulk shipping, which is usually based on point-to-point services, container shipping networks are established as sequences of port calls along a route often structured to connect 2 main maritime trade regions. Therefore, a set of direct or transshipment connections are required to link all country pairs by ocean shipping services. In addition to network economics, transshipment can be the result of ports that do not generate enough traffic or have insufficient draft and must thus be serviced by smaller ships. This effect accounts for a third of the global transshipment activity, and is common throughout the eastern Caribbean. The main rationale is an attempt to shorten the route and rotation time for the mainline service, which also could reduce the number of ships on the mainline service while maintaining the same frequency of service. Several ports along the Mexican and U.S. Gulf Coast could be serviced by a transshipment hub in the Caribbean. Transshipment ports require large yard areas, since only a few containers are leaving the terminal; most may be stored for several days waiting to be transshipped. The Port of Ponce is a good candidate given current unused capacity.

Transshipment helps link smaller ports to the global maritime shipping system in a more effective fashion. Most transshipment in the Caribbean is geared toward Asia and U.S. East Coast trade, the most important trans–Panama Canal trade. Under such circumstances, 87.7% of the transshipment takes place along a corridor extending from Panama to Freeport, Bahamas, and passing through the Windward Passage. The traditional determinants for locating transshipment hubs are proximity to trade routes, local traffic volume, and port productivity and cost. In the Caribbean, the Panama Canal essentially acts as a funnel for shipping lanes between the Atlantic and Pacific Oceans.

**Potential Benefits**

This COA could lead to long-term sustained economic growth within the MTS, as well as reliable revenue streams in the growing container transshipment market. This COA could make Puerto Rican ports more attractive for investors, shipping lines, and port operators, as well as provide a reliable and sustainable revenue stream with second-order effects over the next decade or more.

Transshipment allows the use of larger and more specialized vessels and takes advantage of economies of scale at the major hub ports. For small countries or territories, even a low volume of transshipment can make up a high proportion of total port cargo traffic. Transshipment is extremely attractive to ports because it adds cargo to the local trade, making otherwise uneconomical operations profitable and expensive infrastructure investment more viable. This in turn leads to direct benefits for local traders and consumers as it increases the number of services that call at the port while lowering unit costs.

Several transshipment activities could move to a more central location, thus creating shorter feeder distances. This location, the Windward Passage, could experience a reemergence of its geographic advantage for hub-and-spoke networks. The Caribbean is the world’s smallest transshipment market, with about 8% of all transshipment, and the only significant such market.
The Caribbean Basin lends itself well to transshipment activities, particularly because of the small economic size of most of its islands and countries. Direct high-volume deep-sea services provided by large ships cannot effectively call at Caribbean ports, and transshipment hubs must be used to switch cargo to smaller short sea services.

With the growth of containerized trade transiting through the Panama Canal and its proximity to shipping lanes, the amount of cargo being transshipped in the Caribbean has increased, and this is forecast to continue. The timing is thus critical for Puerto Rico to make a move to increase its port activity and capitalize on the global shipping trends. In addition to the capacity of Caribbean and U.S. East Coast ports to accommodate the larger containership drafts (50 ft/15.2 m), there must also be sufficient cargo volumes to justify direct port calls. Under such circumstances, several East Coast ports may be facing a “tail cutting” or “bypassing” situation as direct services are eliminated and replaced by feeder services. The expansion of the Panama Canal could indeed trigger this far-reaching global restructuring of the shipping network, also defined as the “fourth revolution,” integrating Asian, European, and South American services into a global grid. This would dramatically increase the amount of transshipment in the Caribbean.

**Potential Spillover Impacts to Other Sectors**

Transshipment would have implications for many other sectors, but most directly for the economic sector. Because Puerto Rico is a Caribbean island nation MTS, many other sectors are either significantly directly or indirectly affected by maritime commerce and efficiencies or inefficiencies therein. The current shipping model favors a just-in-time approach and minimizing stored commodities that run counter to resiliency and recovery strategy, which dictate future contingency planning, redundancy, and the stockpiling of emergency supplies. Virtually all sectors will be directly or indirectly affected by this COA because the entire island and its population are dependent on the movement of supplies, food, resources, and people through the MTS. Any significant change to the flow will have a downstream effect.

**Potential Costs**

Potential up-front costs: $50 million–$300 million in estimated up-front costs (8 years).
Potential recurring costs: $50 million–$200 million in estimated recurring costs (11 years).
Potential total costs: $100 million–$500 million in total estimated costs.
This action was costed at 50% implementation in the *Recovery Plan*.

Estimates of total cost range from $100 million to $500 million, based on previous efforts to position the port as a transshipment hub. Potential cost estimates are both complex and highly variable depending on market forces and the overall marketing strategy utilized by the Ponce Port Authority, strategic partners, and stakeholders.

Costs could include the cost to market a transshipment port to shippers, subsidy cost (if reducing the costs to use the port is a short-term strategy to attract users), and the cost of
upgrading key pieces of infrastructure. Obtaining reliable cost estimates for establishing and/or increasing transshipment would require considerably more market research and obtaining the services of expert consultants in global shipping, which is beyond the scope of this report. In order to realize the potential of a vital transshipment hub port, it is recommended that port authorities consult with global shipping firms that understand the global market forces in the Caribbean, the design steps, and a marketing plan that must accompany any plan to place Ponce on the most advantageous path.

Previous attempts to invest in increasing transshipment at Ponce were made in the past decade. According to press reports, the government of Puerto Rico invested $250 million to $285 million (of a plan that called for $700 million) to upgrade facilities, including rehabilitating Berths 4, 5, and 6, dredging the channel entrance to 50 ft, and constructing Berths 7, 8, and 9 and associated container yards. Without detailed market studies, it is difficult to develop a cost estimate, but this past spending and the $700 million originally envisioned provides the basis for a range of $100 million–$500 million.

International shipping firms, venture capitalists, port developers, and/or other nations may also recognize Puerto Rico’s potential as a viable transshipment hub for the eastern and southern Caribbean and approach Puerto Rico to expand their operations, making up-front costs for the government of Puerto Rico minimal or negligible. Conversely, this COA could require considerable investment in making the port attractive and a marketing/business development plan that could take years to implement in order to establish the right relationships and leverage the international market. Caribbean governments should evaluate the opportunity costs of investing limited capital resources and the use of prime real estate space to construct cruise ship port terminals that do not match the island’s image, culture, and carrying capacity. Economic returns often do not justify the investment outlay, and capital could be better utilized in supporting community-based activities with less demand on the infrastructure.

**Potential Funding Mechanisms**

Private-sector, nongovernmental sources.

Funding sources could include collective investment (cost sharing) across MTS stakeholders, as well as international investors such as port developers and shipping lines.

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Implementation

Ponce Port Authority, PRPA.

Potential Pitfalls

Degradation to any of the key drivers to transshipment will negatively influence the prospect of a Caribbean hub port. Avoiding such degradation will require active management and investment. The key drivers of transshipment include being located at the crossroads of principal maritime trade routes, productivity of stevedoring operations, a guarantee of berths, control of operations, safety and security, and dedicated feeder services. The complexity of port ownership and Law No. 156 of 2013, which restructures governance over the Port of Ponce, may confound coordination efforts.²

A conducive transshipment environment requires continued demand of the Panama Canal, which is not guaranteed forever but is certainly guaranteed for the near future. The canal is a major gateway for cargo moving from Asia to the U.S. East Coast. Any prospect for increased Caribbean transshipment involvement is integrally tied to the efficiency and competitiveness of the expanded Panama Canal.³

In addition, competition from other Caribbean ports may make it difficult to attract new business. Major competing hubs within the Caribbean may respond to Puerto Rico’s transshipment efforts, which may slow the process or reduce benefits through their own competitive actions. The major competitors are Cartagena, Colombia; Caucedo, Dominican Republic; Freeport, Bahamas; Kingston, Jamaica; Colon, Panama; and Port of Spain, Trinidad and Tobago. Given the poor performance of most container terminals in the Caribbean, it is not surprising that handling charges are 2 or 3 times as high as in similar ports in other regions and that the overall cost of transport and insurance in the Caribbean basin is some 30% higher than the world average.⁴ While there is no doubt that containerization is a necessary condition to increase trade in the Caribbean, its very presence does not guarantee that such development will occur. The Port of Ponce is competitive because of its depth of 50 ft, large container yard, and the potential for further land expansion to accommodate additional containers and cranes. A key competitor, Kingston, Jamaica, has a controlling depth of 40 ft, with future plans for 42.6 ft depth. The current shipping corridor could be altered to include Puerto Rico, potentially eliminating a stop in Kingston and/or Freeport.

As the Post-Panamax ships are built and deployed over the next 5–8 years, the major route could be conceivably altered due to a decrease in the number of both Caribbean and U.S. ports

² Puerto Rico Law 156, Ley de la Autoridad del Puerto de Ponce [Ponce Port Authority Act], December 19, 2013.
³ Pinnock and Ajagunna, 2013.
⁴ Pinnock and Ajagunna, 2012.
that can accommodate their draft and beam, potentially making Ponce more attractive along the circumequatorial route and as a regional transshipment hub. Puerto Rico is geographically located within the Caribbean Transshipment Triangle and along the circumequatorial route to take advantage of forecasted trends in the Post-Panamax era.

Previous attempts to position Ponce as a transshipment hub have not come to fruition, despite major investments. As a 2014 article notes, “The expectation that ocean carriers would take advantage of a new, centrally located Caribbean facility has not panned out” and “so far the port is mostly empty, unable to attract much business from ocean carriers.” The article continues, “Analysts say the primary reasons undermining Ponce’s appeal are the Jones Act and high labor costs for stevedoring, which make the site uncompetitive with ports in Jamaica, the Dominican Republic, Bahamas and Panama, among others.”

**Likely Precursors**

Completing repairs and resilience improvements to the Port of Ponce is a precursor to transshipment capacity development, making the port more viable and attractive for an increase to the current transshipment activity. These costs would be incurred as part of TXN 12 and TXN 22.

The transshipment activity in the era following the expansion of the Panama Canal depends on which configuration prevails, and is therefore subject to wide uncertainty. Accordingly, the expansion could result in more transshipment or more direct services to the largest ports of the U.S. East Coast. Both trends could play out, but in 2 consecutive phases. The first phase of change follows immediately the expansion of the Panama Canal by 2021. In this short time frame it is likely that Post-Panamax ships of 8,000 TEUs will replace most of the existing Panamax ships of 4,500 TEUs in cross-canal shipping services. Although this will induce some transshipment growth in the Caribbean, only limited changes in the service configuration are expected, since these ships can directly call at most of the large U.S. East Coast ports.

The second phase relates to the changes expected to mostly take place within a decade after the canal expansion (2026). At this stage, Neo Panamax ships of 13,500 TEUs are likely to be deployed in Panama Canal services with larger ships of 15,000–18,000 TEUs deployed on Suez Canal services. Under such circumstances the circumequatorial scenario becomes a likely outcome since it integrates transshipment and the setting of efficient round-the-world shipping services. In the era following the expansion of the Panama Canal, these limitations are substantially mitigated, giving shipping companies more options about how to structure their service networks to handle global trade. The second phase could thus see a leveling off of direct services to U.S. East Coast ports and the growth of transshipment in the Caribbean.

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**TXN 15**

**Consolidate Port Ownership**

**Issue/Problem Being Solved**

Maritime subject-matter experts and recent port assessments unanimously cite the current ownership structure of Puerto Rico’s ports as a significant detriment to port improvement plans, collaborative efforts, and overall MTS resiliency.

**Description**

This COA will consolidate port ownership and oversight across Puerto Rico’s main ports to better manage the MTS as a whole. The 3 major ports are the Port of San Juan, owned by the PRPA; the Port of Ponce (Rafael Cordero Santiago Port of the Americas), owned by the municipality of Ponce and run by the Ponce Port Authority; and the Port of Mayagüez, owned by the Mayagüez Port Commission and PRIDCO. The PRPA, a public corporation of the government of Puerto Rico, also has authority over additional smaller ports, including Fajardo, Yabucoa, Guayama, Aguirre, Peñuelas, Guayanilla, Guanica, Aguadilla, Arecibo, Vieques, and Culebra. In addition, the PRPA has recently acquired, via a no-cost public benefit conveyance, dock areas at the former Naval Station Roosevelt Roads in Ceiba.¹

Much of the information about Puerto Rico’s port cargo-handling capacity is unknown or not available for consideration in recovery planning efforts. Elements of the MTS include terminals and piers that are privately owned and operated. The Port of San Juan relies on private contractors to evaluate navigable waterway safety and functionality and to maintain the waterway. The *Area Contingency Plan* is missing some essential elements of information that detail the role of the USCG’s Marine Transportation System Recovery Unit and the steps needed to facilitate port recovery or move operations to a secondary port. Most Caribbean ports are managed under the public service port mode. This arrangement is often inefficient due to the lack of internal competition and user or market orientation. This structure also leaves the port vulnerable to government interference due to the dependence on government budgets, as well as to the value of customs to national budgets.

Port management models divide ports into either landlord or public service models. The landlord model remains the dominant model for medium-size ports, and is characterized by its mixed public-private orientation, under which a port authority acts as the regulatory body and as

the landlord, while port operations are carried out by private companies. Examples of landlord ports are those of Antwerp; New York City; Rotterdam; and Singapore. The public service port model is characterized by the port authority offering the complete range of services required for the functioning of the seaport system. The port owns, maintains, and operates every available asset, and cargo handling is executed by labor employed directly by the port authority. The landlord model appears to have benefited those ports that have adopted it—for example, Kingston, Jamaica, which has operated successfully employing this model. Port of Spain, Trinidad and Tobago, has also moved to this model in an attempt to improve port efficiency. Those ports that have not yet adopted this model may benefit from doing so.

According to industry analysis, other trends affecting Caribbean ports that have had a significant influence on the way port operations are planned, developed, executed, positioned, and marketed include joint investment by port operators and private companies in various maritime activities; increasing cooperation among ports to share resources in capacity building; changing the composition of port ownership; and greater involvement of shipping companies in container port development. Table A.5 provides a comparison and potential benefits of these ownership models currently used in the maritime port industry when consolidating MTS port ownership.

Table A.5. Strengths and Weaknesses of the Landlord and Public Service Models

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<th>Landlord Model</th>
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| **Strengths**            | • A single entity executes cargo-handling operations and owns and operates cargo-handling equipment. The terminal operators are more loyal to the port and more likely to make needed investments as a consequence of their long-term contracts.  
                          | • Private terminal-handling companies are generally better able to cope with market requirements. | • Superstructure development and cargo-handling operations are the responsibility of the same organization (unity of command). |
| **Weaknesses**           | • Risk of overcapacity as a result of pressure from various private operators.  
                          | • Risk of misjudging the proper timing of capacity additions.                     | • No role, or only a limited one, for the private sector in cargo-handling operations.  
                          |                                                                             | • Less problem-solving capability and flexibility in the case of labor problems because the port administration is also the major employer of port labor.  
                          |                                                                             | • Lack of internal competition, leading to inefficiency.                          
                          |                                                                             | • Wasteful use of resources, and underinvestment, as a result of government interference and dependence on a government budget.  
                          |                                                                             | • Operations are not user- or market-oriented.                                    
                          |                                                                             | • Lack of innovation.                                                            
                          |                                                                             | • No, or limited, access to public funds for basic infrastructure.               |

Potential Benefits

This COA would lead to more efficient and profitably run ports; greater cohesion between port owners and, thus, greatly simplified coordination; and improved resiliency for response and recovery operations. This COA would make Puerto Rico’s ports more attractive for investors, shipping lines, and port operators, and it could increase Puerto Rico’s port competitiveness as a regional transshipment hub.

Potential Spillover Impacts to Other Sectors

Virtually all sectors will be directly or indirectly affected by this COA because the entire island and its population are dependent on the movement of supplies, food, resources, and people through the MTS. Any significant change to the flow will potentially have upstream and downstream effects. The maritime transportation industry affects and is affected by many other sectors, ranging from construction and engineering to a wide range of services, thereby involving, or having implications for, the livelihood of many people at all levels of society. The converse is also true; the economic potential of maritime transportation can be curtailed by a major policy failure in another, unrelated, area. Maritime transportation also imposes a range of diverse burdens and impacts on the environment and other infrastructure.

Potential Costs

Since this is a policy decision, under the cost methodology we used for these COAs, this would incur no direct financial cost. Implementation of any decisions made could have costs for changes in ownership of port property and assets. Consolidating ownership and/or port operations oversight will most likely require complex incentives and negotiations. Gaining a full understanding of the potential costs will be based on consolidation decisions made that will then require additional research and analysis.

Potential Funding Mechanisms

PRPA, private sector.

Mechanisms to incentivize the private sector could include tax benefits, shared funding models, and government incentive programs in order to make consolidation of ownership more attractive. One would envision a fairly complex funding plan potentially requiring collective investment (cost sharing) across MTS stakeholders, federal and territorial governance bodies, and the private sector.

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and international partners (port developers and shipping lines) in order to create ample incentive
to compel changes in ownership. Legislative support may also be required to ensure that an
appropriate legal and regulatory environment exists—one that is conducive for consolidation.

**Implementation**

PRPA, private sector.

**Potential Pitfalls**

Coordination among current owners and operators could prove challenging. Additionally, the
effects of Law No. 156, as issued on December 19, 2013, to amend Articles 2, 3, 5, and 7 of Law
No. 240 of 2011, which affects the governance structure in the Port of Ponce, is unknown.³

It will be challenging to coordinate with multijurisdictional entities and the
diverse set of owners and operators that are characteristic of the island’s maritime infrastructure.
As the Puerto Rico Climate Change Council has noted, “There are no known capital improvement
plans for maritime transport by the Puerto Rico Ports Authority as the ports have many different
tenants and operations requirements and capital improvement plans would be determined by the
individual companies.”⁴ Ports with the right combination of location and infrastructure are best
positioned to benefit from volume and revenue growth going forward. Ports with modern
infrastructure that are not located in geographically attractive areas could fall behind during these
transitions, perhaps just as much as ports with inadequate water depth and landside
infrastructure. Any port that loses market share as alliances shift cargoes may find it difficult to
recover quickly given the longer-term nature of contracts between ports and shipping lines.
However, smaller and midsize ports play an important role in specialized markets. Ports that
serve local import and export demand or service specialized industrial centers can be less
exposed to competitive pressures.

Some regional ports that serve secondary markets and are unable to process larger vessels
risk losing some services or being skipped completely. The combined impact of the shift to
larger vessels and carrier alliances is giving shippers significant negotiating leverage over ports.
Carriers are seeking economies of scale through higher utilization of each vessel, which can
result in fewer vessel calls overall. Furthermore, larger vessels can limit an individual carrier’s
reliance on any particular port or terminal. This has led to a reduction in the number of ports
called on during each voyage, raising pressure on ports to improve terminal capability and
productivity. Some ports that already have adequate water depth are investing to improve the

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³ Puerto Rico Law 156, Ley de la Autoridad del Puerto de Ponce [Port of Ponce Authority Act], December 19, 2013;
Puerto Rico Act 240, Ley de la Autoridad del Puerto de Ponce [Port of Ponce Authority Act], December 12, 2011.
efficiency of existing terminal facilities, seeking to maintain or improve their positions by increasing their share of first-call services. Trends toward consolidating services could leave smaller regional ports at risk of losing some services or being skipped completely by carriers.

**Likely Precursors**

Before any progress can be made, stakeholders must develop a full understanding of port ownership across all of Puerto Rico’s ports. Significant research must be completed by a third party with access to historical records, lease agreements, titles, local relationships, and an understanding of the island port culture.
Repair Damage to Surface Transportation Network

Issue/Problem Being Solved

Hurricanes Irma and Maria caused extensive damage to Puerto Rico’s surface transportation network. The immediate effect was debris blocking roads, but over 6,000 incidents were reported to DTOP, including landslides and collapsed or weakened bridges. Roadside signs were destroyed, and many traffic signals were physically damaged or rendered nonoperational. Bus and rail service in San Juan was suspended.

Roads and Bridges: A DTOP dashboard on the operational status of island transportation dated March 9, 2018, lists 15 sections of roadway that were still closed. These sections varied in length from 1.7 km to 56.1 km. Of 778 DTOP bridges, 9 were reported to be closed in the March 9 dashboard. These bridges varied in length from 0.17 km to 13.1 km. The dashboard also notes that debris removal, assessment of traffic signals, and installation of temporary traffic control devices was proceeding.

Public Transportation: Service on the Tren Urbano was suspended until December 19, 2017, largely due to the lack of power at key substations and the difficulty of running tests to evaluate operations. Three stations suffered structural damage. As of March 2018 the system was operating normally with the exception of 2 stations that remained closed due to damage (trains pass through the stations but do not service those platforms). A bus bridge has been established to service those stations.

No bus service was provided immediately following the storms, but AMA service on 21 of 23 routes was restored by September 29, 2017. Reports of when other bus and paratransit services around the island were suspended and restarted were not available.

The damage to the surface transit systems was noted in the Hill International report. The assessments offer 3 different estimates for repair costs: repair to functionality, repair to code and

4 DTOP, Emergency Operations Center, 2018b.
standard, and repair with mitigation (meaning that additional “resiliency” upgrades were identified and added to the costs of repairing to code and standard).\textsuperscript{6}

**Description**

This COA will make repairs to roads that remain blocked, including the road that serves the FAA radar tower in El Yunque National Forest, and it will replace bridges that failed or sustained significant damage during the hurricanes. It will also repair transit systems to meet codes.

**Potential Benefits**

Restoring Puerto Rico’s surface transportation network to its prehurricane levels of functionality is vital to ensuring the efficient transportation of people, goods, and services across the island.

Making the road network, bridges, and public transport infrastructure usable again would enable the free flow of people, goods, and services to and from multiple locations in Puerto Rico. This is essential for the recovery effort, and for restoring the functionality of several other sectors.

**Potential Spillover Impacts to Other Sectors**

Ensuring that Puerto Rico’s surface transportation network is restored to its prehurricane functionality would have a range of positive impacts given that roads are needed for economic activity, access to social services, and for maintaining other infrastructure.

While estimates are not available, the extent of damage to the roadway network and public transportation networks affected people’s abilities to reach emergency assistance, medical care, schools, jobs, and social networks. Because Puerto Rico’s interior is mountainous, the considerable damage meant that some communities were not reachable, severely impacting the residents of those communities. Disruptions to the surface transport network meant that emergency supplies were slow to reach people in need.

**Potential Costs**

Potential up-front costs: $800 million in estimated up-front costs (3 years).
Potential recurring costs: $16 million in estimated recurring costs (11 years).
Potential total costs: $820 million in total estimated costs.

There are $800 million in up-front costs, plus $16 million in ongoing surface transit maintenance costs. Table A.6 details these costs.

\textsuperscript{6} Hill International, 2018. Although the report is dated May 9, 2018, most of the field assessments were completed in October and November 2017, and thus reflect conditions at that time. FTA officials provided this report to the HSOAC research team.
### Table A.6. Estimated Costs of Surface Transportation Systems Repair

<table>
<thead>
<tr>
<th>Transportation Mode</th>
<th>Source of Assessment</th>
<th>Estimated Cost to Repair Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads and bridges, FHWA emergency relief construction</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$395.5 million</td>
</tr>
<tr>
<td>Roads and bridges, FHWA emergency relief acquisition</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$32.52 million</td>
</tr>
<tr>
<td>Roads and bridges, FHWA emergency relief design</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$55.5 million</td>
</tr>
<tr>
<td>Roads and bridges, FHWA emergency relief active projects</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$10.96 million</td>
</tr>
<tr>
<td>Roads and bridges, emergency relief construction management and inspection</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$20.32 million</td>
</tr>
<tr>
<td>Roads and bridges, emergency relief material testing</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$8.13 million</td>
</tr>
<tr>
<td>Roads and bridges, FEMA emergency relief permanent construction</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$103.71 million</td>
</tr>
<tr>
<td>Roads and bridges, local emergency relief design management</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$12 million</td>
</tr>
<tr>
<td>Roads and bridges, FEMA local share</td>
<td>PRHTA Revised Fiscal Plan</td>
<td>$8 million</td>
</tr>
<tr>
<td>Tren Urbano O&amp;M facility</td>
<td>Hill International, 2018</td>
<td>$7.6 million</td>
</tr>
<tr>
<td>Tren Urbano stations</td>
<td>Hill International, 2018</td>
<td>$70.5 million</td>
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<tr>
<td>Tren Urbano systems (excluding power)</td>
<td>Hill International, 2018</td>
<td>$16.4 million</td>
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<tr>
<td>Tren Urbano power</td>
<td>Hill International, 2018</td>
<td>$11 million</td>
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<td>AMA buses</td>
<td>Hill International, 2018</td>
<td>$20,000</td>
</tr>
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<td>AMA O&amp;M facility</td>
<td>Hill International, 2018</td>
<td>$8.3 million</td>
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<tr>
<td>AMA bus terminals</td>
<td>Hill International, 2018</td>
<td>$2.8 million</td>
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<td>AMA radio tower</td>
<td>Hill International, 2018</td>
<td>$3.5 million</td>
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<tr>
<td>Municipality facilities</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
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<td><strong>$803.1 million</strong></td>
</tr>
</tbody>
</table>

**NOTE:** In the PRHTA, Revised Fiscal Plan 2018–2023, the total estimate for damage to the roadway network was estimated at $652 million. We subsequently communicated with McKinsey Consulting, who shared revised information and a breakdown of these costs. The costs in this table are based on that revision. McKinsey staff, email communication with Liisa Ecola, June 2018.

Ongoing costs for road maintenance are not included here, as TXN 5 includes future maintenance priorities. However, we do include ongoing maintenance costs of $1.6 million for municipalities and the bus system operated by the AMA. These are based on an estimate provided by a subcontractor of $6.12 per ft² for bus terminals.\(^7\) Based on information provided in

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\(^7\) WSP Global (HSOAC subcontractor), email to Benjamin Miller and David Metz, June 27, 2018. This per-square-foot cost is based on Douglas Abate, Michael Towers, Richard Dotz, Luca Romani, and Peter S. Lufkin, *The Whitestone Facility Maintenance and Repair Cost Reference 2009–2010*, Santa Barbara, Calif.: Whitestone Research, 2009, and is adjusted by an industry-standard escalation of 3 percent annually.
the Hill International report, we determined that the average size of a bus or público terminal was roughly 3,500 ft², and 75 such buildings required repair.

Ongoing costs for the privately operated toll roads and the Tren Urbano are assumed to be paid by those operators and not included here.

**Potential Funding Mechanisms**

USDOT, FEMA, government of Puerto Rico.

USDOT’s FHWA funds could be used for federal-aid roads. FEMA funds could be used for non-federal-aid roads, and the FHWA’s Office of Federal Lands Highway, Eastern Federal Lands Highway Division for roads on federal lands.

**Implementation**

DTOP, PRHTA.

**Potential Pitfalls**

There are few potential pitfalls to repairing the storm damage to Puerto Rico’s surface transportation network. However, a concern is that because of population displacement and permanent migration, some road linkages that would be repaired by this COA may not be used frequently enough to justify repair costs.

**Likely Precursors**

No precursors have been identified.
TXN 17
Provide High-Capacity Transit Service to SJU

Issue/Problem Being Solved

There is currently very limited transit service (only 3 bus routes, with relatively infrequent service) to Puerto Rico’s largest airport, SJU.

Not only is there no high-capacity transit service, but there is limited bus service.\(^1\) Arriving and departing passengers rely on private automobiles, taxis, shuttles, and ride hailing services such as Uber.

Description

This COA will construct a BRT service or a light rail line to SJU. An exact alignment has not been identified. Given the relatively low number of projected riders, heavy rail is not considered a viable option.

The *Puerto Rico 2040 Islandwide Long Range Transportation Plan*, adopted in 2013, discusses previous work on the Tranvia de Carolina (Carolina Tramway) that would reach the airport, and possible alignments:

This corridor was studied in 2006–2008 as an LRT [light rail transit] project. Several alignments were reviewed and a final route was recommended. Total cost was estimated at approximately $600 million for a route extending from the traditional town center at PR-3 north and east, past Plaza Carolina to the Isla Verde tourism district. A second route traversing western Carolina was also identified. Ridership was estimated at approximately 13,000 daily riders. While not part of the study concept, a third segment from the airport southeasterly to Hato Rey was also tested and obtained about 12,000 daily riders. While the project was originally proposed as a PPP [i.e., P3] project, this process never advanced.\(^2\)

Figure A.4 shows the general alignment. While this map shows a connection to a broader transit system, the PR-3 East Corridor is not built, so the proposed alignment would function as a single line, disconnected from the existing Tren Urbano. It also does not connect with tourism or business destinations, such as the Puerto Rico Convention Center or Old San Juan.

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\(^1\) The 2015 bus route reorganization shows 3 routes (D53 and T5 to Old San Juan, and E40 to Hato Rey), that run every 20 to 45 minutes on weekdays, every 30 to 60 minutes on Saturdays, and every 30 minutes (on only 1 route) on Sundays. All routes operate only until 8:00 or 9:00 p.m. See Oficina del Gobernador, La Fortaleza, 2015.

\(^2\) DTOP, 2013b.
Figure A.4. Proposed Future Alignments for Transit Corridors in the San Juan Metropolitan Area

NOTES: Systems that are operational are noted in the figure as "(existing)." The others are at various planning stages. The colors delineate the separate transit lines; they do not reflect any decisions about technology.

Information provided by DTOP indicates that a 2009–2010 study of bus service also concluded that a route linking the Tren Urbano to SJU via the Teodoro Moscoso Bridge could also be feasible.3

There is relatively little difference in capacity between BRT and LRT. According to a 2009 meta-analysis, BRT can carry similar numbers of daily passengers per line as LRT: 9,000 to 30,000 for BRT, as opposed to 12,200–26,900 for LRT. Even regular bus service with articulated buses can serve up to 7,200 riders.4

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3 DTOP, Combined COAs GENERAL REVIEW, unpublished (written comments received from FEMA and DTOP on proposed courses of action), received June 13, 2018.
Potential Benefits

BRT or LRT would provide an alternative means of transportation to Puerto Rico’s busiest airport that could reduce emissions and congestion if car trips are replaced by rail trips.

In addition to passengers, the airport and its on-site vendors employ many people who could ride public transit to commute. Ridership might be improved with faster operating speeds that could be achieved through dedicated lanes or signal priority at intersections.

Potential Spillover Impacts to Other Sectors

Health outcomes and environmental conditions could be improved with reductions in emissions from car traffic. The benefit would depend on the number of trips that switch from driving to transit use. Most U.S. airports with rail service have relatively low mode shares—a 2008 report found that the highest rail mode share was only 13% (meaning that only 13% of passengers arriving at the airport got there by rail), and most were in the single digits. Mode share was higher for buses and shared-ride vans, reaching a high of 16%, with 8 airports enjoying a share of 10% or more.5

Potential Costs

- Potential up-front costs: $400 million in estimated up-front costs (8 years).
- Potential recurring costs: $170 million in estimated recurring costs (11 years).
- Potential total costs: $570 million in total estimated costs.

This action was costed at 50% implementation in the Recovery Plan.

The estimate for providing LRT is $800 million, based on a preliminary environmental study of this corridor. The estimate for annual operating costs for LRT is $38 million, based on similar light rail systems. The estimate for up-front costs for BRT is $185 million, with annual operating costs of $12 million.

The estimated costs of the 2 modes are shown in Table A.7. The Islandwide Long Range Transportation Plan puts the cost at $600 million for the Tranvia de Carolina. Other cost estimates showed $675 million for a first alternative and $644 million for a second alternative.6 The preliminary environmental review document mentions $800 million.7

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6 Tranvia de Carolina Appendix B-E, Conceptual Cost Estimates.
Table A.7. Estimated Costs of Light Rail Transit Versus Bus Rapid Transit to SJU

<table>
<thead>
<tr>
<th></th>
<th>LRT</th>
<th>BRT</th>
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</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Best”</td>
<td>$800 million</td>
<td>$185 million</td>
</tr>
<tr>
<td>Low</td>
<td>$535 million</td>
<td>$62 million</td>
</tr>
<tr>
<td>High</td>
<td>$2.5 billion</td>
<td>$500 million</td>
</tr>
<tr>
<td>Annual costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Best”</td>
<td>$38 million</td>
<td>$12 million</td>
</tr>
<tr>
<td>Low</td>
<td>$13 million</td>
<td>$3 million</td>
</tr>
<tr>
<td>High</td>
<td>$85 million</td>
<td>$34 million</td>
</tr>
</tbody>
</table>

One transit cost fact sheet puts light rail costs at $20 million–$60 million per mile, which would put a 20-km (12.4-mi) system at between $250 million and $750 million. For 3 recently built light rail projects of similar size, construction costs ranged from $43.1 million per mile to $67.3 million per mile. These would suggest low and high estimates of $535 million to $835 million. Other projects have exceeded these figures; a 7.3-mi light rail extension in Portland cost $1.49 billion, or more than $200 million per mile. For a 12.4-mi system, that would mean a total cost of $2.5 billion. A number of factors—including density of local development, right-of-way acquisition costs, labor costs, and geotechnical concerns—drive differences in the per-mile costs of these systems, so costs will depend on the details of the alignment selected and other locally determined costs.

Light rail operating costs are generally measured in the cost to operate 1 vehicle for an hour (“cost per vehicle revenue hour”). According to the FTA’s National Transit Database, the average cost per hour to operate light rail systems is $293, and the average light rail system provides 320,000 hours of vehicle revenue service per year, for an average total operating cost of $91 million. Of all U.S. light rail systems, the lowest total operating cost was $13 million per

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8 Reconnecting America, Transit Technologies Worksheet, Oakland, Calif.: Reconnecting America, undated.
10 FTA, undated a.
year (in Cleveland) and the highest is $318 million (in Los Angeles). However, many of these systems are far longer than the proposed 12.4-mi system for Puerto Rico. Looking at 3 systems of similar total mileage (in Charlotte, Cleveland, and Seattle), their average operating cost is $37.7 million. The highest of these 3 similar systems is Seattle, at $85 million.

BRT is considerably cheaper to build than light rail service: the transit fact sheet cites figures of $4 million–$40 million per mile.\textsuperscript{11} A 2001 GAO report found an average of $13.5 million for BRT and $37.8 million for LRT (in 2000 dollars).\textsuperscript{12} Austin, Texas, recently completed over 30 mi of BRT corridors for $1.1 million per mile, far less than recent LRT projects.\textsuperscript{13} Assuming an average of $15 million for BRT (an adjustment upward from the GAO figures), this corridor would cost about $185 million. A low per-mile cost of $5 million would mean $62 million to build BRT, while a high cost of $40 million per mile would mean almost $500 million.

National Transit Database figures find an average operating cost of $183 per hour for BRT.\textsuperscript{14} If we look at BRT systems with 10–35 vehicles in service, operating costs range from $3.1 million to $34.4 million, with an average of $12.4 million.\textsuperscript{15}

These are the same calculations used for TXN 18, regarding transit service between Caguas and San Juan, which is projected to be slightly greater in length (15.1 mi versus 12.4 mi). However, operating costs are generally measured in hourly costs to operate 1 vehicle, which is a closer proxy for the amount of service provided. Given that transit to SJU would likely run more frequently—since we expect demand to and from an airport to be more evenly spread throughout the day than for what is primarily a commuter service—and the Caguas–San Juan line is probably more likely to run less frequently in off-peak hours, we believe it is reasonable that the amount of service provided in terms of vehicle revenue hours might be similar.

### Potential Funding Mechanisms

USDOT, P3s, DTOP.

The FTA funds transit systems of this size through its New Starts program, provided that grantees meet certain requirements. Local applicants generally match 20% of the costs. The FTA’s Section 5309 program funds fixed guideway capital investments. An LRT project similar

\textsuperscript{11} Reconnecting America, undated.
\textsuperscript{15} FTA, undated a. Average ridership on these systems is 12,700 riders, similar in size to projected ridership on this corridor.
to the 1 proposed would need to apply for a New Starts grant, which funds new projects with anticipated costs exceeding $300 million.\textsuperscript{16}

The new USDOT BUILD program (which replaces the previous Transportation Investment Generating Economic Recovery grants program) allocates federal money on a competitive basis to applicants who submit specific projects. Grants are limited to $25 million, and transit projects are eligible.

Transit projects are also generally eligible for many USDOT “innovative finance” programs, such as Transportation Infrastructure Finance and Innovation Act credit assistance and grant anticipation revenue vehicles.\textsuperscript{17}

A few U.S. transit projects have been built as P3s—most prominently, the Eagle Project for commuter rail in Denver. Additional funding from other sources was still required, and the transit agency will make availability payments to the operator (i.e., fares will not cover operating costs).\textsuperscript{18}

Operating expenses are covered by passenger fares and locally generated revenues, often sales taxes or other dedicated taxes.

**Implementation**

PRP3A, PRHTA.

**Potential Pitfalls**

Building new transit systems may entail construction cost overruns and lower-than-anticipated ridership leading to lower revenues and benefits. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

**Construction cost risk:** Large public transportation (and other) construction projects often incur greater-than-anticipated costs. The Tren Urbano, Puerto Rico’s only passenger rail line, was initially costed at $1.25 billion in 1996, whereas actual costs were $2.25 billion by the time the system opened for full revenue service in 2005. This represents an 80\% cost increase from inception to completion. According to an FTA study, reasons for the cost overrun include higher-than-anticipated construction bids, system design changes, and contractor requests for additional

\textsuperscript{16} FTA, Fact Sheet: Fixed Guideway Capital Investment Grants, Chapter 53 Section 5309, Washington, D.C.: FTA, undated h.

\textsuperscript{17} Additional research would be needed to determine the eligibility of projects in Puerto Rico given current constraints under the Financial Oversight and Management Board for Puerto Rico. General information on innovative finance is available at FHWA, Center for Innovative Finance Support, “Tools and Programs,” webpage, undated c.

\textsuperscript{18} FHWA, Center for Innovative Finance Support, “Project Profile: Eagle Project,” webpage, undated a.
funds due to weather (including 3 hurricanes), project complexity, and coordination issues.\textsuperscript{19} Other recent light rail projects have also experienced cost overruns; the 3 most recently completed FTA reports of light rail systems found cost overruns of 22\% (for Dallas) and 62\% (for Norfolk, Virginia).\textsuperscript{20} A Salt Lake City system accurately predicted its costs.\textsuperscript{21}

\textbf{Lower-than-anticipated ridership risk:} Many transit systems have substantially overestimated their ridership. The Tren Urbano’s original ridership forecast was 114,500 daily riders for 2010, whereas actual ridership in its second year was 26,900, only 23\% of the predicted forecast. The report attributed this to several factors, including an overestimation of the preference for rail over car and bus, an assumption that fares would be lower than they actually were, an assumption of faster end-to-end travel times than were actually the case, an overprediction of riders arriving by bus, and an anticipation of population growth instead of decline.\textsuperscript{22}

Of the 3 recently built light rail projects, ridership on the Dallas line was only 82\% of projected ridership (approximately 32,000 daily riders when 40,000 were predicted). The other 2 systems exceeded projections (at 117\% for Salt Lake City and 159\% for Norfolk, Virginia), but both of these systems predicted fewer than 7,000 daily riders.\textsuperscript{23}

Lower-than-predicted ridership means higher operating subsidies are required, thus increasing the cost to the operator. The Tren Urbano currently has a farebox recovery ratio (the proportion of operating costs covered by passenger fare revenue) of 16\%, the second lowest in the country. The average of all U.S. heavy rail systems is 41\%. Lower-than-predicted ridership also implies that benefits are not as great as had been anticipated, because fewer car trips were replaced by light rail trips.

\textbf{Likely Precursors}

It would be helpful to conduct a study regarding how new mobility options, expanded bus and fixed-route service, and the Tren Urbano can be better integrated, including assessments of demand for new transit services.

\textsuperscript{20} This is the authors’ calculation of the Dallas cost overrun, based on FTA, 2015a. Norfolk figure from, FTA, 2015b.
\textsuperscript{21} FTA, 2016.
\textsuperscript{22} FTA, 2007.
\textsuperscript{23} FTA, 2016 and 2015b.
TXN 18
Provide High-Capacity Transit Service Between San Juan and Caguas

Issue/Problem Being Solved

There is currently no scheduled transit service between San Juan and Caguas (an adjoining municipality of approximately 130,000 people).

Description

This COA will construct a high-capacity transit service (BRT or LRT) between San Juan and Caguas along the route of PR-52. Given the relatively low number of projected riders, heavy rail is not considered a viable option.

The Islandwide Long Range Transportation Plan, adopted in 2013, discusses previous work on the Caguas-San Juan Commuter Rail Corridor and possible alignments:

This proposed 24.33-km. [15.1-mile] corridor is presently proposed as a commuter transit service named the Novotren, and extends from the Cupey and/or Centro Medico Tren Urbano stations south along PR-52 to terminal stations with park-and-ride lots at Plaza Catalinas on PR-52 and Plaza Centro on PR-30. Originally planned as LRT, it was later proposed as BRT and as magnetic levitation (maglev) modes. As the project advances, the transit technologies are not limited to a specific mode, but are open to alternatives that are technically and economically feasible. The proponents of the project include the municipality of Caguas, and DTOP and PRHTA. An alignment analysis and environmental report were prepared a few years ago as an LRT project; an extension of the environmental study was requested and was granted in July 2013. Cost figures have varied, the most recent being an estimate of $400 million. Ridership estimates have ranged up to 14,000 daily passengers for rail service. This project has been proposed as a public/private Design/Build/Operate/Maintain (DBOM) procurement process.¹

According to press reports, this project was close to being bid as a P3 in 2013, but was ultimately not pursued.² Accrod to information received from DTOP, the project has received $175 million in funding for an option with a dynamic toll lane and BRT.³

Figure A.4, in TXN 17, shows the general alignment.

¹ DTOP, 2013, p. 5-27.
³ DTOP, Combined COAs GENERAL REVIEW, unpublished (written comments received from FEMA and DTOP on proposed courses of action), received June 13, 2018.
Potential Benefits

BRT or LRT would provide an alternative means of transportation between San Juan and Caguas that could reduce emissions and congestion if car trips are replaced by transit trips. Ridership might be improved with faster operating speeds that could be achieved through dedicated lanes or signal priority at intersections.

Potential Spillover Impacts to Other Sectors

Health outcomes and environmental conditions could be improved with reductions in emissions from car traffic; the benefit would depend on the extent of the number of trips that switch from driving to public transit use. While this new line would have the benefit of connecting to the only existing rail line, the Tren Urbano, ridership on that line is currently less than 30,000 riders per day.\(^4\) PR-52, which links San Juan and Caguas, carries over 20,000 vehicles per day and is currently at level of service E, indicating a high level of congestion.\(^5\) This was projected to worsen to level of service F by 2040 according to modeling performed for the *Puerto Rico 2040 Islandwide Long Range Transportation Plan*.\(^6\) However, that model was calibrated to assume population increases, while the current modeling accounts for recent population decline.\(^7\)

Potential Costs

Potential up-front costs: $200 million in estimated up-front costs (3 years).
Potential recurring costs: $170 million in estimated recurring costs (11 years).
Potential total costs: $370 million in total estimated costs.
This action was costed at 50% implementation in the *Recovery Plan*.

The estimate for LRT between San Juan and Caguas is $400 million, based on the *Puerto Rico 2040 Islandwide Long Range Transportation Plan* adopted in 2013.\(^8\) The estimate for annual operating costs is $38 million.

The estimate for up-front costs for BRT is $225 million, with annual operating costs of $12 million.

The estimated costs of the 2 modes for this corridor are shown in Table A.8.

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\(^5\) This is the highest level indicated in the figure. Press reports state that 120,000 vehicles use the road daily. “Listos para poner los rieles” [“Ready to Lay the Rails”], *El Nuevo Dia*, March 20, 2013.
\(^6\) DTOP, 2013b, Figures 5.7, 5.9, and 5.10.
\(^7\) PRHTA, 2018d.
\(^8\) DTOP, 2013b.
Table A.8. Estimated Costs of Light Rail Transit Versus Bus Rapid Transit for San Juan–Caguas Corridor

<table>
<thead>
<tr>
<th></th>
<th>LRT</th>
<th>BRT</th>
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<tbody>
<tr>
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<td>$225 million</td>
</tr>
<tr>
<td>Low</td>
<td>$300 million</td>
<td>$75 million</td>
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<tr>
<td>High</td>
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<td>$38 million</td>
<td>$12 million</td>
</tr>
<tr>
<td>Low</td>
<td>$13 million</td>
<td>$3 million</td>
</tr>
<tr>
<td>High</td>
<td>$85 million</td>
<td>$34 million</td>
</tr>
</tbody>
</table>

The only other cost information we located on this project was a presentation by the Puerto Rican Planning Society. This suggests that light rail along this corridor would cost $600 million–$700 million, while BRT would cost $490 million.

For comparison, a transit cost fact sheet puts light rail costs at $20 million–$60 million per mile, which would put a 15.1-mi system at between about $300 million and $900 million. However, all proposed alignments use existing highway right-of-way, either PR-1 or PR-52, which should be less expensive than laying tracks along arterials that have numerous intersections.

The same presentation states that a light rail system would have operating costs of $561 million over 35 years, while BRT would have operating costs of $833 million over that same period. This suggests annual costs of $16 million for light rail and $23.8 million for BRT. It would be unusual for BRT to have higher operating costs than LRT; of 12 agencies with various configurations of BRT in the 2016 National Transit Database, the average is $16 million, and 9 are under $10 million.

Light rail operating costs are generally measured in the cost to operate 1 vehicle for an hour ("cost per vehicle revenue hour"). According to FTA’s National Transit Database, the average cost per hour to operate light rail systems is $293, and the average light rail system provides

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9 Sociedad Puertorriqueña de Planificación (Puerto Rican Planning Society), La Transformación del Transporte Regional (Transforming Regional Transportation), PowerPoint presentation, March 11, 2015.
10 See, for example, Reconnecting America, undated.
11 These estimates did not provide any details of how they were calculated; presumably, costs would increase over time with inflation.
13 FTA, undated a.
320,000 hours of vehicle revenue service per year, for an average total operating cost of $91 million. Of all U.S. light rail systems, the lowest total operating cost was $13 million per year (in Cleveland), and the highest is $318 million (in Los Angeles). However, many of these systems are far longer than the proposed 12.4-mi system. Looking at 3 systems of similar total mileage (in Charlotte, Cleveland, and Seattle), their average operating cost is $37.7 million. The highest of these 3 similar systems is Seattle, at $85 million.

BRT is considerably cheaper to build than light rail service—the transit fact sheet cites figures of $4 million–$40 million per mile.\(^{14}\) A 2001 GAO report found an average of $13.5 million for BRT and $37.8 million for LRT (in 2000 dollars).\(^{15}\) Austin, Texas, recently completed over 30 mi of BRT corridors for $1.1 million per mile, far less than recent LRT projects.\(^{16}\) Assuming an average of $15 million for BRT (an adjustment upward from the GAO figures), this corridor would cost about $225 million. A low per-mile cost of $5 million would mean $75 million to build BRT, while a high cost of $40 million per mile would be around $600 million.

National Transit Database figures find an average operating cost of $183 per hour for BRT.\(^{17}\) If we look at BRT systems with 10–35 vehicles in service, operating costs range from $3.1 million to $34.4 million, with an average of $12.4 million.\(^{18}\)

These are the same calculations used for TXN 17, regarding transit service to SJU, which is projected to be slightly shorter in length (12.5 mi versus 15.1 mi). However, operating costs are generally measured in hourly costs to operate 1 vehicle, which is a closer proxy for the amount of service provided. Given that transit to SJU would likely run more frequently, that demand is probably higher throughout the day, and the Caguas–San Juan line is probably more likely to run less frequently in off-peak hours, we believe it is reasonable that the amount of service provided in terms of vehicle revenue hours might be similar.

### Potential Funding Mechanisms

USDOT, P3s, DTOP.

The FTA funds transit systems of this size through its New Starts program, provided that grantees meet certain requirements. Local applicants generally match 20% of the costs. The

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\(^{14}\) Reconnecting America, undated.

\(^{15}\) GAO, 2001.

\(^{16}\) FTA, 2018b.

\(^{17}\) FTA, Office of Budget and Policy, 2017.

\(^{18}\) FTA, undated. Average ridership on these systems is 12,700 riders, similar in size to projected ridership on this corridor.
FTA’s Section 5309 program funds fixed guideway capital investments. An LRT project similar to the 1 proposed would need to apply for a New Starts grant, which funds new projects with anticipated costs exceeding $300 million.\(^{19}\)

The new USDOT BUILD program (which replaces the previous Transportation Investment Generating Economic Recovery grants program) allocates federal money on a competitive basis to applicants who submit specific projects. Grants are limited to $25 million, and transit projects are eligible.

 Transit projects are also generally eligible for many USDOT “innovative finance” programs, such as Transportation Infrastructure Finance and Innovation Act credit assistance and grant anticipation revenue vehicles.\(^{20}\)

 A few U.S. transit projects have been built as P3s—most prominently, the Eagle Project for commuter rail in Denver. Additional funding from other sources was still required, and the transit agency will make availability payments to the operator (i.e., fares will not cover operating costs).\(^{21}\)

 Operating expenses are covered by passenger fares and locally generated revenues, often sales taxes or other dedicated taxes.

**Implementation**

PRHTA, PRP3A.

**Potential Pitfalls**

Building new transit systems may entail construction cost overruns and lower-than-anticipated ridership leading to lower revenues and benefits. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

**Construction cost risk:** Large public transportation (and other) construction projects often incur greater-than-anticipated costs. The Tren Urbano, Puerto Rico’s only passenger rail line, was initially costed at $1.25 billion in 1996, whereas actual costs were $2.25 billion by the time the system opened for full revenue service in 2005. This represents an 80% cost increase from inception to completion. According to an FTA study, reasons for the cost overrun include higher-than-anticipated construction bids, system design changes, and contractor requests for additional

\(^{19}\) FTA, undated b.

\(^{20}\) Additional research would be needed to determine the eligibility of projects in Puerto Rico given current constraints under the Financial Oversight and Management Board for Puerto Rico. General information on innovative finance is available at FHWA, Center for Innovative Finance Support, undated c.

\(^{21}\) FHWA, Center for Innovative Finance Support, undated a.
funds due to weather (including 3 hurricanes), project complexity, and coordination issues.\textsuperscript{22} Other recent light rail projects have also experienced cost overruns; the 3 most recently completed FTA reports of light rail systems found cost overruns of 22\% (Dallas) and 62\% (Norfolk, Virginia).\textsuperscript{23} The Salt Lake City system accurately predicted its costs.\textsuperscript{24}

**Lower-than-anticipated ridership risk:** Many transit systems have substantially overestimated their ridership. The Tren Urbano’s original ridership forecast was 114,500 daily riders for 2010, whereas actual ridership in its second year was 26,900, only 23\% of the predicted forecast. The report attributed this to several factors, including an overestimation of the preference for rail over car and bus, an assumption that fares would be lower than they actually were, an assumption of faster end-to-end travel times than were actually the case, an overprediction of riders arriving by bus, and an anticipation of population growth instead of decline.\textsuperscript{25}

Of the 3 recently built light rail projects, ridership on the Dallas line was only 82\% of projected ridership. The other 2 systems exceeded projections (at 117\% for Salt Lake City and 159\% for Norfolk, Virginia), but both of these systems predicted fewer than 7,000 daily riders.\textsuperscript{26}

Lower-than-predicted ridership means higher operating subsidies are required, thus increasing the cost to the operator. The Tren Urbano currently has a farebox recovery ratio (the proportion of operating costs covered by passenger fare revenue) of 16\%, the second lowest in the country. The average of all U.S. heavy rail systems is 41\%. Lower-than-predicted ridership also implies that benefits are not as great as had been anticipated, because fewer car trips were replaced by light rail trips.

**Likely Precursors**

It would be helpful to conduct a study regarding how new mobility options, expanded bus and fixed-route service, and the Tren Urbano can be better integrated, including assessments of demand for new transit services.

\textsuperscript{22} FTA, 2007.
\textsuperscript{23} This is the authors’ calculation of the Dallas cost overrun based on information in FTA, 2015a. Norfolk figure from FTA, 2015b.
\textsuperscript{24} FTA, 2016.
\textsuperscript{25} FTA, 2007.
\textsuperscript{26} FTA, 2016 and 2015b.
**TXN 19**

**Extend PR-5**

**Issue/Problem Being Solved**

There is no limited access highway through Bayamón, a major population center in the San Juan metropolitan area. Existing roadways are heavily congested.

**Description**

This COA will extend PR-5 in Bayamón, between PR-167 and PR-199, ensuring that environmental risks are mitigated and a resilient design is used. PR-5 is a small 2.5-mi toll road that connects the San Juan metropolitan area to Bayamón. The toll road was leased through a P3 concession agreement and is currently being operated by a private firm, Autopistas Metropolitanas de Puerto Rico, LLC, better known as Metropistas. This toll road currently generates about $4 million annually in toll revenues.¹ The extension of PR-5 would fill in a gap in the road that presently exists in Bayamón between PR-167 and PR-199.

**Potential Benefits**

This COA would improve mobility options in this part of Puerto Rico. As the Build Back Better request for funding notes, this COA would “allow efficient transportation from the Metropolitan Area to mountain municipalities allowing logistics flow during critical climate events.”² Currently, in order to drive through Bayamón, drivers have to exit PR-5 and use PR-167 and PR-199. These principal access routes that connect the municipalities have high traffic volumes, traffic lights, and no access controls.³ The hope is that extending PR-5 would alleviate congestion by providing drivers with a faster route to and from San Juan.

**Potential Spillover Impacts to Other Sectors**

This COA would improve economic opportunities for those people around Bayamón. It would spur additional development in the area, affecting the economics, energy, housing, and water sectors.

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² Governor of Puerto Rico, 2017.

Potential Costs

Potential up-front costs: $220 million in estimated up-front costs (10 years).
Potential recurring costs: $0.
Potential total costs: $220 million in total estimated costs.

The governor’s Build Back Better request for funding includes a request for $165 million for the PR-5 extension, noting that the “Project can be shovel ready within 6 months” and that there is the “Potential for [a] Design Build approach.” The Statewide Transportation Improvement Program for fiscal years 2017–2020 also mentions this project and shows a total estimated project cost of $215 million. Annual toll revenue for this extension is estimated to be between $5 million (2014) and $8 million (2039).

Once built, keeping this section of PR-5 well maintained could cost 50 cents to 70 cents per square yard per year. At 4 lanes, PR-5 would be 16 yds wide (assuming 4 yds per lane). At roughly 3 mi (or roughly 5,000 yds) of road length, the total square yardage of roadway that needs to be maintained is equal to 80,000. Thus, maintenance costs would be roughly $50,000 per year. However, this road is currently operated by a private firm that is responsible for O&M costs that are funded in part by toll collection. Assuming that this arrangement continues, no additional public funds are required for O&M.

Potential Funding Mechanisms

USDOT, P3s, DTOP.

The use of a P3 would enable the use of private funds at the cost of future tolls on road users.

Implementation

PRHTA, PRP3A.

Potential Pitfalls

Design and construction of this road extension will be challenging due to existing development in the area. Congestion mitigation impacts may not be sustained in the long run. Contractor

4 Governor of Puerto Rico, 2017.
capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

Although the tollway extension could alleviate congestion in the short term, evidence on the impacts of highway construction on congestion suggests that these impacts are likely to be temporary, at best.\footnote{Gilles Duranton and Matthew A. Turner, “The Fundamental Law of Road Congestion: Evidence from US Cities,” \textit{American Economic Review}, No. 101, October 2011, pp. 2616–2652.}

\textbf{Likely Precursors}

No precursors have been identified.
### TXN 20

#### Extend PR-22

**Issue/Problem Being Solved**

There is no limited access highway through the northwestern region of the island. Existing roadways are congested, and travel times are slow.

**Description**

PR-22 currently goes from San Juan to Arecibo in the north of Puerto Rico. PR-22 and PR-2, to the west, connect San Juan to the western half of the island. This COA will extend PR-22 for roughly 40 km in the area currently served by PR-2, ensuring that environmental risks are mitigated and a resilient design is used.

According to the *Islandwide Long Range Transportation Plan*, “The PR-2/PR-22 corridor is the essential link for trucking freight between San Juan and much of the western half of the Island.”¹ PR-22 is an expressway built to relatively high design standards and is in good condition. PR-22 was leased through a P3 concession agreement and is currently being operated by a private firm, Autopistas Metropolitanas de Puerto Rico, LLC, better known as Metropistas. This toll road currently generates about $85 million annually in toll revenues.²

PR-2 is a smaller road; it runs through relatively built-up areas, making it difficult to widen without affecting adjacent properties. It would make sense to extend PR-22, to build an expressway from the point where PR-22 currently ends to destinations farther west. Such an extension would likely terminate in Aguadilla, a major center in northwest Puerto Rico. This will be a challenging engineering project. As the *Islandwide Long Range Transportation Plan* notes, “A 40-km segment between Aguadilla and the current terminus of the PR-22 toll road near Hatillo presents a substantial challenge to the completion of the circumferential corridor.”³

**Potential Benefits**

A new road built to high design standards in this area would reduce travel times and travel time variance, while improving safety, along a heavily traveled corridor. As the *Islandwide Long-Range Transportation Plan* notes,

> Because the circumferential corridor remains the only east-west link on the north coast between the eastern and western halves of the island, improvements to

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¹ DTOP, 2013b.
² Kantrow-Vázquez, 2011a.
³ DTOP, 2013b.
capacity and safety in this corridor are essential to the future quality of life and economic growth of Puerto Rico.⁴

The Long Range Transportation Plan adds,

An improved PR-2/22 corridor is also essential to the revitalization and growth of Rafael Hernández International Airport and its planned related economic development as well as to the success of the Porta Del Sol tourism plan for the west coast.⁵

An extended PR-22 would also increase resilience in the face of future natural disasters. According to the Build Back Better request for funding, a major benefit would be to increase access to the western region of the island and to “to provide access to emergency vehicles during times of disasters.”⁶

**Potential Spillover Impacts to Other Sectors**

This project would improve economic opportunities for those people living in the northwest region of Puerto Rico. It would spur additional development in the area, impacting the economic, energy, housing, and water sectors.

**Potential Costs**

Potential up-front costs: $1 billion in estimated up-front costs (10 years).
Potential recurring costs: $0.
Potential total costs: $1 billion in total estimated costs.

As noted earlier, the relevant corridor is “heavily traveled and lined with roadside development . . . making it expensive to upgrade to expressway standards.”⁷

A 2010 study from the PRP3A quotes a cost of $825 million for this project.⁸ The study notes that “there are multiple ways to complete this Project. The first option would be to extend PR-22 from Hatillo to Aguadilla. The second alternative would be to convert the current route, PR-2, to an expressway, adding additional lanes and widening the road. The final option would be a mix

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⁴ DTOP, 2013b.
⁵ DTOP, 2013b.
⁶ Governor of Puerto Rico, 2017.
⁷ DTOP, 2013b.
of the two.” The governor’s Build Back Better request for funding mentions this project and estimates its cost at $1 billion.\textsuperscript{9}

Once built, keeping these sections of PR-22 well maintained could cost 50 cents to 70 cents per square yard per year.\textsuperscript{10} At 4 lanes, PR-22 would be 16 yds wide (assuming 4 yds per lane). At 40 km (or roughly 44,000 yds) of road length, the total square yardage of roadway that needs to be maintained is equal to roughly 700,000. Thus, maintenance costs would be on the order of $420,000 per year. However, this road is currently operated by a private firm that is responsible for O&M costs that are funded in part by toll collection. Assuming that this arrangement continues, no additional public funds would be required for O&M.

**Potential Funding Mechanisms**

USDOT, P3s, DTOP.

As noted above, Metropistas currently operates tolls on the existing PR-22 route. One approach to financing the extension of PR-22 would be to create a new concession agreement, where the road extension is leased to Metropistas (or another contractor), who retains the rights to operate and toll the extended road.

According to information provided by DTOP, there is a budget gap resulting from lower-than-expected toll revenues.\textsuperscript{11} This gap has been estimated at over $150 million for the segment between Camuy and Hatillo. The gap for the total project is closer to $800 million.

**Implementation**

PRHTA, PRP3A.

**Potential Pitfalls**

There are two possible alignments for this road segment, the existing PR-2 or a new route farther south, and both present significant challenges. As the Long Range Transportation Plan notes, “New alignment alternatives for an extension of PR-22 to Aguadilla would, however, likely run mainly south of PR-2, passing through environmentally sensitive limestone karst areas as well as agriculturally important lands.” The plan also notes that local topography also presents a challenge in several spots.\textsuperscript{12} It will be a challenging engineering task to develop an optimal

\begin{itemize}
  \item \textsuperscript{9} Governor of Puerto Rico, 2017.
  \item \textsuperscript{10} Ford, 2013.
  \item \textsuperscript{11} DTOP, correspondence provided to the HSOAC following presentation on COAs, June 5, 2018.
  \item \textsuperscript{12} DTOP, 2013b.
\end{itemize}
geometric design for this roadway. Failure could result in unnecessary environmental or economic damage or suboptimal future road conditions.

As a result of these challenges, transportation planners have considered an alternative option, which is rebuilding the existing PR-2 to expressway standards instead of building a new PR-22 extension. Such an upgrade would involve constructing interchanges at major intersections, reducing access to the road, and creating frontage roads. Upgrading PR-2 would involve displacing development that is currently along the roadside, which could be challenging politically. In particular, equity concerns would be important. Moreover, the topography (particularly around the area of Quebradillas) presents challenges that would constrain upgrades to PR-2. As a result, some combination of extending PR-22 and upgrading PR-2 might be a possible solution.\textsuperscript{13}

Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

**Likely Precursors**

No precursors have been identified. However, to proceed with extending PR-22, the National Environmental Policy Act process needs to be completed, and it requires an investment of over $500,000, which is pending approval by the PRP3A. The ongoing process has not adequately considered resiliency and the benefits of an alternative route to PR-2. Doing so may require a higher initial investment.

\textsuperscript{13} DTOP, 2013b.
Issue/Problem Being Solved

The only major north-south road in the western half of Puerto Rico is hazardous, and travel times are slow.

Description

This COA will fill in a gap in the strategic highway network of Puerto Rico. PR-10 is an important route in the network, and 1 of the few north-south routes on the island. It is particularly important for connecting settlements in the western interior to the rest of the island. This COA will complete this route while also ensuring that environmental risks are mitigated and a resilient design is used.

PR-10 is one of the island’s principal cross-island corridors, connecting the city of Ponce on the south coast to Arecibo in the north. Although construction on the highway is nearly complete, a 6.2-mi stretch of the highway between Adjuntas and Utuado remains unfinished. Drivers on PR-10 are diverted to the old route, PR-123, and the road narrows from a 3- or a 4-lane highway to only 2 lanes. Navigating this section of PR-123 is slow and tedious, as the road was engineered to follow the contours of the mountains, and driving conditions can be hazardous, especially for trucks.

Potential Benefits

This COA would improve mobility options in a part of Puerto Rico. As the Islandwide Long Range Transportation Plan notes, “The remaining missing segments between Utuado and Adjuntas . . . when completed will provide quality connectivity between the interior regions and both the north and south coasts.” There would be local economic benefits. In addition, this project would likely improve resilience and road safety.

Completing PR-10 would increase road speeds along the corridor, which would enhance mobility and improve freight outcomes. A straighter road alignment could also increase safety.

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1 The old route that PR-10 parallels, PR-123, was built in the late nineteenth century by the Spanish colonial government to connect Adjuntas, formerly a coffee growing area, to the port city of Ponce.

2 DTOP, 2013b, p. 5-16.
Potential Spillover Impacts to Other Sectors

This COA would improve economic opportunities for those people living in western Puerto Rico. It would spur additional development in the area, impacting the economic, energy, housing, and water sectors.

Potential Costs

Potential up-front costs: $370 million in estimated up-front costs (10 years).
Potential recurring costs: $510,000 in estimated recurring costs over an 11-year period.
Potential total costs: $370 million in total estimated costs.

Correspondence with DTOP states that the project’s 4 segments have a total construction cost of $350 million. However, this could be larger, with additional soft costs of $35 million, and the costs of completing design and land acquisition could be an additional $10 million. This brings us to a total of $395 million. Taking the average of $350 million and the high estimate of $395 million gives us an estimated cost of $372.5 million.

Once built, keeping these sections of PR-10 well maintained could cost 50 cents to 70 cents per square yard per year. At 4 lanes, PR-10 would be 12 yds wide (assuming 3 yds or 12 ft per lane). At 6.2 mi (or 10,912 yds) of road length, the total square yardage of roadway that needs to be maintained is equal to 130,944. Thus, maintenance costs range from $65,472 to $91,660.

Potential Funding Mechanisms

DTOP, P3s.

A P3 would enable the use of private funds at the cost of future tolls on road users.

Implementation

PRHTA.

Additionally, implementation could come from the PRP3A if a P3 arrangement is pursued.

Potential Pitfalls

Design and construction of this road extension will be challenging due to local terrain. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

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3 DTOP, June 2018.
4 Ford, 2013.
As the Islandwide Long Range Transportation Plan notes, “This connection has encountered frequent major engineering challenges throughout its many years of development, because of the difficult topography and ground conditions.”

**Likely Precursors**

No precursors have been identified.

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5 DTOP, 2013b, p. 5-15.
Issue/Problem Being Solved

The resilience of Puerto Rico’s port facilities is limited. Restoring the MTS to its prehurricane condition will not assure any of the additional resiliency that is recommended in anticipation of forecast storms of increasing intensity and frequency over the next decade or more. Existing infrastructure could be enhanced or upgraded for increased redundancy across multiple port complexes, hardening against the effects of storm surge, high winds, and the anticipated rise in sea level, as well as for maintaining ports that are poised to capitalize on global shipping trends (to include the increased size, capacity, and drafts of Post-Panamax ships).

Recent comprehensive port damage assessments have revealed substandard material conditions within Puerto Rico’s major ports. The concrete substrate within many of the ports should be demolished and rebuilt to current marine code for commercial ships of increasing capacity, tonnage, and draft. In addition to the material condition of the piers, electrical conduit and service are in need of upgrades. Supporting pier buildings and drainage systems are also in need of upgrades to become more resilient to hurricane damage. Fendering and mooring systems were also cited in several of the port assessments as badly needing improvement or replacement in order to safely accommodate larger commercial ships.

Description

This COA will improve and rehabilitate piers fendering systems, rip-rap, and associated port buildings across Puerto Rico to increase the MTS’s overall resilience to future storms and sea level rise. The majority of recommended port rehabilitation activities fall into 6 categories: (1) repair, replacement, and upgrading concrete substrate and entire pier structures; (2) raising or increasing pier height; (3) hardening of supporting building infrastructure to better withstand high winds and rain; (4) upgrades to electrical and power systems; (5) water drainage systems; and (6) fendering and mooring systems. The inspections, which were conducted at the request of MARAD, included aboveground and underwater inspection of all port structures and associated systems. All inspection techniques were executed in accordance with the standards set forth in

the American Society of Civil Engineers’ *Waterfront Facility Inspection and Assessment* manual and *Underwater Investigations Standard Practice Manual.*

**Potential Benefits**

This COA would help to ensure continuity of operations at the piers and increase the overall structural integrity of port infrastructure into the future. An increase to overall port capacity, reliability, and capability will make Puerto Rico more competitive as a potential transshipment hub and more attractive to regional and foreign investment. Rehabilitation of Puerto Rico’s MTS will also support improvements to humanitarian assistance and disaster relief operations and overall MTS resiliency.

Any upgrades to MTS capacity, capability, and ability to recovery from both man-made and natural disasters will inherently make Puerto Rican ports more resilient and more attractive for outside investment, as well as making Puerto Rico overall more competitive regionally for commercial shipping, tourism, and recreation maritime activities.

**Potential Spillover Impacts to Other Sectors**

Port consolidation would have implications for many other sectors, but it would most directly impact the economic sector. However, virtually all sectors would be directly or indirectly affected by this COA because the entire island and its population are dependent on the movement of supplies, food, resources, and people through the MTS. Increasing port resilience makes it less likely that future disruptions will occur, or that they will be shorter or less significant.

**Potential Costs**

Potential up-front costs: $360 million–$540 million in estimated up-front costs (10 years).

Potential recurring costs: $0.

Potential total costs: $360 million–$540 million in total estimated costs.

This action was costed at 50% implementation in the *Recovery Plan.*

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The *Recovery Plan* provided an estimate of $360 million–$540 million based on several assumptions:

- the COA would cover only seaports, not ferry terminals
- the seaport estimate of $896 million could be low or high by a factor of 20%, hence a total range of approximately $720 million–$1.1 billion
- the COA would be implemented at 50% (i.e., only half of the repairs would be made).

The current estimate is $998 million, based on FTA- and MARAD-contracted damage assessment reports, as shown in Chapter 3, Tables 3.6 and 3.7 (in the columns titled “Additional Resilience Measures,” which also describe the recommended resilience investment). The estimate for cargo and cruise ship ports is $896 million, and the estimate for passenger ferry terminals is $102.5 million. Recurring costs were assumed to be 0 over this period because the upgrades would require 10 years.

**Potential Funding Mechanisms**

FEMA Hazard Mitigation Grant Program, CDBG-BR, U.S. Department of Commerce Economic Development Administration.

**Implementation**

Mayagüez Ports Commission, Ponce Port Authority, PRPA.

**Potential Pitfalls**

After rehabilitation or repair of the ports and their support systems is complete, there must be adequate O&M recurring funding to sustain the ports and the infrastructure. This will require not only regular maintenance but also regular inspection and corrective action to address any reduction in port capability or capacity (e.g., ports whose material condition does not meet industry standards). Construction and repair costs could be high. Contractor capacity could also be an issue, particularly if numerous other civil engineering projects are undertaken at the same time.

**Likely Precursors**

Precursors might include assessment of relative benefits of resilience upgrades, cost-benefit analysis, and a requirement to provide life cycle cost estimates for all new systems prior to acquisition, as some projects will likely have more benefit than others.
Appendix B. Agencies Consulted

These are the entities with which the HSOAC transportation team consulted during the development of the *Long-Range Recovery Plan*:

- Aerostar Airport Holdings
- American Association of State Highway and Transportation Officials
- Argonne National Laboratory
- ATM
- Berk Consulting
- Colorado DOT
- Committee on Marine Transportation Systems
- COR3
- CSA Group, Inc.
- DHS Office of Infrastructure Protection
- DTOP
- Dynamis, Inc.
- FEMA
- Florida Atlantic University
- Gvelop
- Here
- INRIX
- Institute for Ocean and Systems Engineering
- Local Redevelopment Authority for Roosevelt Roads
- McConnell Valdés LLC
- McKinsey & Company
- Metropistas
- National Association of Development Organizations
- Ponce Port Authority
- Port of Long Beach, California
- Portek International Pte. Ltd.
- PRHTA
- PRIDCO
- PRP3A
- PRPA
- Puerto Rico Department of Economic Development and Commerce
- Puerto Rico Infrastructure Financing Authority
- Puerto Rico Tourism Company
- Shared-Use Mobility Center
- Steer Davies Gleave Ltd.
- University of Puerto Rico—Mayagüez
- USACE
- USCG
- USDOT, including
  - FAA
  - Federal Motor Carrier Safety Administration
  - FHWA
  - FTA
  - MARAD
  - Response and Recovery Office
- World Bank.
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Hurricanes Irma and Maria devastated Puerto Rico in September 2017. The Federal Emergency Management Agency asked the Homeland Security Operational Analysis Center to develop a long-range recovery plan for the damages to Puerto Rico, incorporating all of the sectors indicated in the National Disaster Recovery Framework. This report provides a comprehensive evaluation of the transportation sector. It includes a detailed description of prestorm conditions across surface, maritime, and air transportation; descriptions of the damages caused by the hurricanes, including physical damages and estimated costs to repair them; and a list of proposed courses of action selected by the government of Puerto Rico. Before the hurricanes, transportation in Puerto Rico was marked by roads and bridges in fair condition, a public transportation system with low service provision and declining ridership, a high reliance on one seaport and one airport, declining cargo movements, and significant fiscal solvency concerns. The hurricanes produced widespread damage to the transportation sector, totaling an estimated $1.8 billion in repair costs and another $1.1 billion in recommended resilience upgrades.

The recovery plan proposes 22 courses of action across all transportation modes, divided between repair and maintenance (such as new design standards for roads and bridges, and a “fix it first” policy); upgrades (such as an upgraded airport in the western half of the island and enhancements to increase port resilience); new capacity (three highway projects and two transit corridors); and planning, policy, and management (such as intelligent transportation systems and consolidation of port ownership).